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Certified by

Andres Ibanez

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

UTILITY PATENT APPLICATION TRANSMITTAL <i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;"><i>Attorney Docket No.</i></td> <td style="padding: 2px;">160-125</td> </tr> <tr> <td style="padding: 2px;"><i>First Inventor</i></td> <td style="padding: 2px;">Floyd Backes</td> </tr> <tr> <td style="padding: 2px;"><i>Title</i></td> <td style="padding: 2px;">Program for Adjusting Channel Interference between Access Points in a Wireless Network</td> </tr> <tr> <td style="padding: 2px;"><i>Express Mail Label No.</i></td> <td style="padding: 2px;">Electronic filing</td> </tr> </table>	<i>Attorney Docket No.</i>	160-125	<i>First Inventor</i>	Floyd Backes	<i>Title</i>	Program for Adjusting Channel Interference between Access Points in a Wireless Network	<i>Express Mail Label No.</i>	Electronic filing
<i>Attorney Docket No.</i>	160-125								
<i>First Inventor</i>	Floyd Backes								
<i>Title</i>	Program for Adjusting Channel Interference between Access Points in a Wireless Network								
<i>Express Mail Label No.</i>	Electronic filing								

APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents. 1. ☐ Fee Transmittal Form (e.g., PTO/SB/17) <i>(Submit an original and a duplicate for fee processing)</i> 2. ☐ Applicant claims small entity status. See 37 CFR 1.27. 3. ☒ Specification [Total Pages <u>95</u>] Both the claims and abstract must start on a new page <i>(For information on the preferred arrangement, see MPEP 608.01(a))</i> 4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets <u>59</u>] 5. Oath or Declaration [Total Sheets <u>3</u>] a. ☐ Newly executed (original or copy) b. ☒ A copy from a prior application (37 CFR 1.63 (d)) <i>(for continuation/divisional with Box 18 completed)</i> i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b). 6. ☐ Application Data Sheet. See 37 CFR 1.76 7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program <i>(Appendix)</i> ☐ Landscape Table on CD 8. Nucleotide and/or Amino Acid Sequence Submission <i>(if applicable, items a. – c. are required)</i> a. Computer Readable Form (CRF) i. ☐ Computer Readable Form (CRF) ii. ☐ Transfer Request (37 CFR 1.821(e)) b. Specification Sequence Listing on: i. ☐ CD-ROM or CD-R (2 copies); or ii. ☐ Paper c. ☐ Statements verifying identity of above copies	ACCOMPANYING APPLICATION PARTS 9. ☐ Assignment Papers (cover sheet & document(s)) Name of Assignee _____ 10. ☒ 37 CFR 3.73(b) Statement ☒ Power of Attorney <i>(when there is an assignee)</i> 11. ☐ English Translation Document <i>(if applicable)</i> 12. ☐ Information Disclosure Statement (PTO/SB/08 or PTO-1449) ☐ Copies of foreign patent documents, publications, & other information 13. ☐ Preliminary Amendment 14. ☐ Return Receipt Postcard (MPEP 503) <i>(Should be specifically itemized)</i> 15. ☐ Certified Copy of Priority Document(s) <i>(if foreign priority is claimed)</i> 16. ☒ Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent. 17. ☐ Other: _____

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:

☒ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: 10/781,137
 Prior application information: Examiner BEAMER, TEMICA M Art Unit: 2617

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Name (Print/type)	Holmes W. Anderson			Registration No. (Attorney/Agent)	37272

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of: Floyd Backes et al.

Serial No.:

Examiner:

Filed: Herewith

Group Art Unit:

Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network

Commissioner for Patents
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**COMBINED POWER OF ATTORNEY FOR
PATENT APPLICATION & STATEMENT UNDER 37 CFR 3.73(b)**

AUTOCELL LABORATORIES, INC., a corporation having principal offices at:

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the owner by assignment of the entire right, title and interest to the invention Program for Adjusting Channel Interference between Access Points in a Wireless Network by Floyd Backes et al. and in and to the application for patent and any Letters Patent, whether domestic or foreign, that may issue thereon, by virtue of the assignment (check as applicable):

☐ Recorded Concurrently Herewith
☒ Recorded on March 8, 2005
☒ Recorded at Reel 015743 Frame 0534
☐ Copy Attached

hereby appoints the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

Attorneys Associated with Customer No. 34845

its attorneys with full power of substitution and revocation, to prosecute all domestic and foreign patent applications, including PCT and EPO filings, relating to said invention and to transact all business connected therewith, including signing of all papers on its behalf and making alterations and amendments.

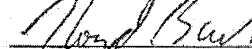
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The undersigned is the representative for the Assignee of the entire right, title, and interest in the patent application identified above, and is authorized to act on behalf of the Assignee.

10-November-2009
Date

AUTOCELL LABORATORIES, INC.



Name: Floyd Backes
Title: Chief Executive Officer

NONPUBLICATION REQUEST UNDER 35 U.S.C. 122(b)(2)(B)(i)	First Named Inventor	Floyd Backes
	Title	Program for Adjusting Channel Interference between Access Points in a Wireless Network
	Atty Docket Number	160-125

I hereby certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral agreement, that requires publication at eighteen months after filing.

I hereby request that the attached application not be published under 35 U.S.C. 122(b).

January 5, 2010
Date

/Holmes W. Anderson/
Signature

Holmes W. Anderson 37,272
Typed or printed name

This request must be signed in compliance with 37 CFR 1.33(b) and submitted with the application **upon filing**.

Applicant may rescind this nonpublication request at any time. If applicant rescinds a request that an application not be published under 35 U.S.C. 122(b), the application will be scheduled for publication at eighteen months from the earliest claimed filing date for which a benefit is claimed.

If applicant subsequently files an application directed to the invention disclosed in the attached application in another country, or under a multilateral international agreement, that requires publication of applications eighteen months after filing, the applicant **must** notify the United States Patent and Trademark Office of such filing within forty-five (45) days after the date of the filing of such foreign or international application. **Failure to do so will result in abandonment of this application (35 U.S.C. 122(b)(2)(B)(iii)).**

Burden Hour Statement: This collection of information is required by 37 CFR 1.213(a). The information is used by the public to request that an application not be published under 35 U.S.C. 122(b) (and the PTO to process that request). Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This form is estimated to take 6 minutes to complete. This time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Comm for Patents, Alexandria, VA

**DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION FILED
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**PROGRAM FOR ADJUSTING CHANNEL INTERFERENCE BETWEEN ACCESS
POINTS IN A WIRELESS NETWORK**

The application of which: (Check applicable choice)

- A. ☒ Is attached hereto.
B. ☐ Was filed on _____ as U.S. Application No. _____
C. ☐ was filed as PCT International Application No. PCT/_____ on _____
and (if applicable to U.S. or PCT application) was amended on _____.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. §1.56.

Except as noted below, I hereby claim foreign priority benefits under 35 U.S.C. §1.119(a-d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International Application which designated at least one other country than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International Application, filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority is claimed, before the filing date of this application.

PRIOR FOREIGN APPLICATION(S)

<u>Number</u>	<u>Country</u>	<u>Day/Month/Year Filed</u>	<u>Date first laid</u> <u>Open or published</u>	<u>Date Patented</u> <u>or Granted</u>	<u>Priority NOT claimed</u>

Except as noted below, I hereby claim domestic priority benefit under 35 U.S.C. §119(e) or 120 and/or 365(c) of the indicated United States applications listed below and PCT International applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed in this application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of each such prior application and the national or PCT International filing date of this application:

PRIOR US PROVISIONAL, NON-PROVISIONAL AND/OR PCT APPLICATIONS(S)

<u>Application No.</u>	<u>Day/Month/Year Filed</u>	<u>Status</u> <u>(pending, abandoned patented)</u>	<u>Priority</u> <u>NOT claimed</u>
60/449,602	2/24/2003	pending	
60/466,448	4/29/2003	pending	
60/472,320	5/21/2003	pending	
60/472,239	5/21/2003	pending	

POWER OF ATTORNEY OR AUTHORIZATION OF AN AGENT

And I hereby appoint the practitioners listed below as my/our attorney(s) or agents to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon;

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR UNITED STATES PATENT

FOR

**PROGRAM FOR ADJUSTING CHANNEL INTERFERENCE BETWEEN
ACCESS POINTS IN A WIRELESS NETWORK**

INVENTORS:

Floyd J. Backes
Gary Vacon
Paul Callahan
William Hawe
Roger Durand

Attorney Docket No.: 160-125

RELATED APPLICATIONS

This application is a continuation of application Serial No. 10/781,137 entitled “Program for Adjusting Channel Interference between Access Points in a Wireless Network”, filed February 18, 2004 which claims priority to provisional patent application serial numbers 60/449,602 filed on February 4, 2003; 60/466,448 filed on April 29, 2003; 60/472,320 filed on May 21, 2003 and 60/472,239 filed on May 21, 2003.

FIELD OF THE INVENTION

The invention relates generally to wireless networks, and more particularly to wireless network configuration and power level adjustment for network performance optimization.

BACKGROUND OF THE INVENTION

The proliferation of laptop and hand-held portable computers has produced a concomitant need for robust, reliable, and high performance wireless networks to maximize the mobility advantages of these devices and increase the ease of construction and management of these wireless networks. Current wireless networks, such as IEEE 802.11b, 802.11a, 802.11g, (etc) networks, are subject to certain limitations that can limit a mobile user's network performance and reliability. For instance, only a very limited number of radio channels are available. In the current state of the art, wireless access

points cannot effectively share the same channel in the same area because of radio and control protocol interference. So, bandwidth over a given area is limited by the number of non-overlapping channels available. Also, current wireless networks require manual site engineering to control the placement of access points and channel distribution between access points, raising the cost and complexity of the wireless network installation process. Furthermore, user roaming between wireless access points is inconsistent. Once associated with an access point, a user will tend to remain associated with that access point even if another access point is capable of providing higher performance for the user. It would be desirable to provide wireless networking solutions which overcome the above described inadequacies and shortcomings of current wireless networks.

SUMMARY OF THE INVENTION

In accordance with the principles of the invention, various apparatus, methods, and computer program products are provided to improve the performance and ease of management of wireless communications environments. For example, a mechanism is provided to enable access points (APs) to perform automatic channel selection. A wireless network can therefore include multiple APs, each of which will automatically choose a channel such that channel usage is optimized. Furthermore, APs can perform automatic power adjustment so that multiple APs can operate on the same channel while minimizing interference with each other. Further aspects of the invention are used to cause load balancing of stations across APs so that user bandwidth is optimized. Novel

movement detection schemes provide seamless roaming of stations between APs. These and further aspects of the invention enable the provision of automatically configurable, high performance wireless communications environments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a wireless communications environment in which wireless users interact with other networked devices via an access point (AP).

Figure 2 shows a wireless network in which wireless user devices, or stations (STAs), access the wireless network via an access point and share the available network bandwidth.

Figure 3 shows a wireless network wherein the stations access the network via two separate access points.

Figure 4 is a flow diagram representing how an AP builds a channel map for use in an automatic channel selection scheme.

Figure 5 is a flow diagram representing an automatic channel selection method.

Figure 6 is a representation of a table kept by APs for use in an alternate channel selection scheme.

Figure 7 is a flow diagram representing an alternate automatic channel selection scheme.

Figure 8 is a flow diagram representing a preferred embodiment of an automatic channel selection scheme.

Figure 9 is a representation of a Scan Table kept by APs for use in the automatic channel selection scheme of Figure 8.

Figure 10 is a representation of a Channel Map kept by APs for use in the automatic channel selection scheme of Figure 8.

Figure 11 is a representation of a Triplet Channel Map kept by APs for use in the automatic channel selection scheme of Figure 8.

Figure 12 is a representation of a Claim APs table kept by APs for use in the automatic channel selection scheme of Figure 8. Figure 13 is a flow diagram showing how an AP builds an AP KnownAPs table.

Figure 14 is an example of an AP KnownAPs table maintained by an AP, and used for power adjustment.

Figure 15 is a flow diagram representing the process by which an AP builds an AP AssociatedSTA table, for use in load balancing.

Figure 16 is an example of an AP AssociatedSTA table.

Figure 17 is a block diagram representing a general mechanism by which an AP adjusts its transmit power backoff.

Figure 18 is a block diagram representing a preferred embodiment of the transmit power backoff mechanism of Figure 13.

Figure 19 is a table showing expected standard errors related to number of power level samples.

Figure 20 is a flow diagram representing the process by which an AP adjusts its transmit power backoff during STA movement.

Figure 21 is a flow diagram representing an AP auction process, used for load balancing of STAs across APs.

Figure 22 is a flow diagram representing the AP's handling of bids during the auction.

Figure 23 is a flow diagram representing the STA initialization process.

Figure 24 is a flow diagram representing a general mechanism by which a STA in a wireless communications environment canvasses channels.

Figure 25 is a flow diagram representing the preferred embodiment of Figure 20 as implemented in an 802.11 wireless networking environment.

Figure 26 is an example of a STA Known APs table, used by STAs for power adjustment and load balancing.

Figure 27 is a flow diagram representing the process by which the STA Known APs table is built by a STA.

Figure 28 is a flow diagram representing the STA power adjustment process.

Figure 29 is a flow diagram representing the STA Bidding process.

Figure 30 is a flow diagram representing the process by which a STA calculates corrected distances for use in determining whether to bid for an AP.

Figure 31 is an example of a distance_to_rate table for use in an 802.11 wireless networking environment.

Figure 32 is an example of a rate_to_load table for use in an 802.11 wireless networking environment.

Figure 33 is a flow diagram representing the STA Bidding process in more detail.

Figure 34 is a flow diagram representing the process by which a STA detects its own movement.

Figure 35 is a block diagram showing the software architectures of APs and STAs.

Figure 36 is a more detailed block diagram of the software architecture of an AP implementing the invention in an 802.11 wireless networking environment.

Figure 37 is a more detailed block diagram of the software architecture of a STA implementing the invention in an 802.11 wireless networking environment.

Figure 38 represents the encoding of a DRCP (Dynamic Radio Control Protocol) message in an 802.11 beacon frame.

Figure 39 represents the encoding of a DRCP message in an 802.11 data frame.

Figure 40 is a table summarizing the DRCP messages used in the various aspects of the invention.

Figure 41 is a table describing the various fields used in DRCP messages.

Figure 42 is a diagram of the message format of a DRCP Preclaim message.

Figure 43 is a diagram of the message format of a DRCP Claim message.

Figure 44 is a diagram of the message format of a DRCP Announce message.

Figure 45 is a diagram of the message format of a DRCP Bid message.

Figure 46 is a diagram of the message format of a DRCP Accept message.

Figure 47 is a diagram of the message format of a DRCP Registration Request message.

Figure 48 is a diagram of the message format of a DRCP Registration Acknowledge message.

Figure 49 is a graph showing discrete measurements of received power over time from the perspective of a wireless network user.

Figure 50 is a graph showing discrete measurements of received power over time from the perspective of a wireless network user, and showing the estimated average received power for the user within a 99% confidence interval.

Figure 51 is a graph similar to Figure 3 showing two different estimated average received power measurements for small sample sizes and their 99% confidence intervals.

Figure 52 is a graph showing two different estimated average received power measurements and their 99% confidence intervals, one for a large sample size and one for a small sample size.

Figure 53 is a graph showing a long term average measurement and a short term average measurement with 99% confidence interval, the comparison showing that it can be determined that a user has moved.

Figure 54 is a table showing the number of samples that need to be taken in order to cause the long term average confidence interval range to converge toward zero.

Figure 55 is a flow diagram of the general operation of the method of the invention.

Figure 56 is a block diagram of an embodiment of a wireless network in which the invention is deployed, wherein an AP ascertains that a user has moved.

Figure 57 is a block diagram of an alternate embodiment of the invention, wherein a user ascertains that the user has moved.

Figure 58 is a block diagram of one embodiment of the invention employing ring buffers.

Figure 59 is a block diagram of an alternate embodiment of the invention employing batched means.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In accordance with the present invention, a fully automatic control system is provided for wireless communications environments. Referring to Figure 1, a typical wireless communications environment 10 includes access devices 12 (one shown) that interface between a wired communications medium 14 and wireless devices 16 to provide network access to the wireless devices 16. Wireless devices 16 can thus communicate with wired devices 18 and with each other via the access device 12. These access devices 12 are referred to by various names depending upon the wireless architecture employed, and are herein referred to as “access points” or “APs”. The wireless devices 16 also have various architecture dependent names and are herein referred to as “stations” or STAs. A wireless communications capable device may be an AP, or a STA, or both.

Various types of wireless communications environments 10 exist. Wireless communications environments include for example wireless data networks and wireless I/O channels. An example of a wireless data network is described in “IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications—Amendment 1: High-speed Physical Layer in the 5 GHz band”, incorporated herein by reference(hereinafter “802.11”). Furthermore, various different 802.11 “modes” are defined. For example, in IEEE 802.11 compatible wireless networks, wireless devices may be arranged in an “infrastructure mode”, whereby the network is configured such that STAs 16 communicate with other network devices via an AP 12, as shown in Figure 1. 802.11 compatible devices may also be arranged in “ad-hoc” mode, whereby all the STAs 16 are within transmission range and can communicate directly with each other. Furthermore, wireless “mesh” technologies exist, whereby each wireless device acts as both an AP and a STA. Wireless I/O channels can be used to provide I/O communications, for example, between servers and storage devices via the “Bluetooth” Standard, or between home entertainment audio and video components , or between wireless telephone handsets and base stations. The various aspects of the invention apply to generally to wireless networking architectures, including those used in wide area networks, metropolitan area networks, enterprise networks, and home networks, and wireless I/O channel architectures, as they exist now and as they are developed.

According to aspects of the invention, an arbitrary number of wireless access points (APs) can be placed in arbitrary positions, and all APs and STAs will automatically configure themselves for optimal channel usage, power levels, and STA/AP associations. So, in a wireless networking environment, channel usage is optimized while interference between APs is minimized. Wireless devices such as wireless enabled laptops or hand-held computing devices or Internet protocol telephones, are transparently and seamlessly distributed between APs such that network performance is optimized from the perspective of the user of the wireless device. And, in a wireless I/O channel environment that might be employed for example in a home, audio, video, and other appliances may be moved without performance degradation, and channel usage for each appliance may be optimized so that the appliances do not interfere with each other.

In order to expedite the understanding of the invention, certain examples will be described as they apply to the relatively well known 802.11 wireless LAN architecture, with the understanding that the principles of the invention apply more generally to any wireless communications environment. A preferred implementation of the inventive principles will then be described as embodied in an 802.11 wireless network

The following aspects of the invention contribute to its advantages, and each will be described in detail below.

1. AP Initialization: In many wireless communications environments, multiple frequencies (“channels”) are available for use by APs. For example, in accordance with 802.11b and 802.11g, 3 non-overlapping channels are available.

In accordance with IEEE 802.11a, 13 non-overlapping channels are available. In an environment where multiple APs are employed, it will be seen that it is advantageous for the APs to use different channels to optimize performance and minimize interference. In accordance with the invention, APs perform automatic channel selection. Where multiple APs are distributed in a given area, the APs execute a distributed protocol to pick channels for each AP. APs close to each other use non-overlapping channels.

2. AP Optimization:

- a. Power Adjustment: When the number of APs in a wireless communications environment exceeds the number of non-overlapping channels, APs and STAs adjust their power such that APs and STAs on the same channel can co-exist in an area without interference. For APs using the same channel, APs continually re-adjust their power levels based on environmental factors such as signal strength changes due to movement of doors, people, background noise floor, and the like, so that the users' optimal bandwidth is maintained without undue interference.
- b. Auction: APs keep track of various parameters for STAs that are associated with them, and STAs will roam between APs for load balancing purposes, which can help to maximize performance over a group of STAs.

3. STA initialization: STAs associate with an initial AP. Invention enabled STAs turn on functions that allow them to receive messages from invention enabled APs.

4. STA optimization:

- a. Channel Canvassing: In order to further optimize performance, STAs periodically canvass the other channels in the band in which the STA is operating to see if a “better” AP is present. To ascertain whether another AP is “better”, various parameters are considered, such as signal strength and load factors, to be further described.
- b. Bidding: If a better AP is found, a STA enters a bidding process to try to cause the STA to roam to the better AP. Load balancing is thereby achieved. In addition, the bidding process accommodates STA movement by causing the STA to associate to a better AP after it has moved closer to the better AP.
- c. Power Adjustment: STAs perform power adjustment such that they can maintain throughput to and from their currently associated AP while minimizing the interference with nearby wireless devices that may be using the same channel.
- d. Movement Detection: STAs perform movement detection so that the bidding process can be turned off while a STA is moving, and then turned back on when the STA has stopped moving. When turned back on, a “better” AP may turn up and thus the STA will bid for it.

5. Software Architecture

- a. The above functionality is advantageously implemented in APs and STAs in a modular manner for ease of transfer between platforms.

- b. The above functionality is described in detail as it is implemented in a preferred 802.11 network embodiment.
- 6. Movement Detection statistical analysis: A novel scheme for highly accurate and computationally efficient detection of a change in an attribute subject to high noise variation is described, and applied to detection of the movement of wireless STAs.

Since exemplary examples will refer to the 802.11 networking environment, the following information provides relevant context, while understandably not limiting the invention to 802.11 environments.

In an 802.11 network, APs periodically send frames called “Beacons”. STAs listen for Beacons. When an unassociated STA (i.e. a STA that is not yet able to communicate on the wireless network) hears Beacons at what it deems to be a reasonable power level, it can attempt to authenticate with the AP sending the Beacons, and then associate with that AP. Once authenticated and associated, the STA is able to send data frames to other STAs on the wireless network via the AP.

More particularly, APs and STAs send and respond to three different types of frames, known as Class 1 Frames, Class 2 Frames, and Class 3 Frames. Class 1 Frames include control frames and management frames, and can be sent regardless of whether a STA is authenticated and associated with an AP. A Beacon is a type of Class 1 frame. Class 2 Frames are sent only once a STA is authenticated, and include for example

association request / response messages. Class 3 Frames can be sent only if associated, and include data frames.

In order to maximize user bandwidth and throughput, the invention automatically optimizes the operation of multiple APs for a given wireless communications environment. In accordance with the exemplary IEEE 802.11a networking standard, 13 non-overlapping frequencies are available for use by the APs. Each AP is capable of transmitting and receiving data at a maximum rate of 54 Mbps. The actual rate at which data is transmitted and received between an AP and a STA depends upon many factors, including the distance between the AP and the STA, the structures located between the AP and the STA, and the environmental interference occurring on the particular frequency. One skilled in the art will realize that the invention is not limited by the maximum data rates of current wireless technology, nor is it limited by currently understood radio frequency attenuation factors. The principles of the invention will continue to be applicable as wireless technology evolves.

Consider an area such as the wireless network shown in Figure 2, wherein 8 users (shown as STAs 16), which may be mobile laptops, PDAs, and the like, share a space including a single AP 12 operating on one of the 13 available 802.11a frequencies, denoted "f1". The 8 users 16 share the bandwidth provided by the AP 12. If all 8 users 16 are located close enough to the AP such that the AP provides a 54Mb bit maximum data rate, then all 8 users 16 share the AP's bandwidth such that each user maintains 6.75Mb throughput on average. (The invention contemplates the fact that data traffic is bursty and that a user in the present example may attain 54Mb throughput for a short

interval, but for purposes of simplicity, the average throughput over time for a given user is discussed.)

Now, referring to Figure 3, a second AP 12 has been added in the area. The second AP 12 operates on a different one of the 13 frequencies, denoted “f2”, such that the two APs 12 do not interfere, nor do their associated STAs 16. As shown, 4 of the 8 users have roamed to the second AP 12. Now each user maintains 13.5Mb throughput on average. Addition of further APs on different frequencies further increases user average throughput.

In accordance with the invention, a Dynamic Radio Control Protocol (DRCP) provides a mechanism for an arbitrary collection of STAs and APs to automatically control the frequency and power of their radios in order to extend the properties exemplified in Figure 2 to maximize overall system performance. DRCP messages are passed between APs and APs, as well as between APs and STAs to implement this functionality. Eight types of messages are used: DRCP Preclaim, DRCP Claim, DRCP Announce, DRCP Bid, DRCP Accept, DRCP Registration Request, and DRCP Registration Acknowledge.

DRCP Preclaim and Claim messages are exchanged between APs during AP initialization, and are used to aid automatic channel selection in accordance with the invention. DRCP Announce messages are sent by APs and received by STAs during STA optimization. These Announce messages inform invention-enabled STAs of available invention-enabled APs to which they may choose to associate, and provide information about APs that STAs can use to aid a decision as to whether to request to

roam to another AP. DRCP Bid messages are sent by STAs to APs during STA optimization. These messages inform invention-enabled APs of invention-enabled STAs that are requesting association to the APs. DRCP Accept messages are sent by APs to STAs in response to DRCP Bid messages. These messages inform a STA that it may associate with the AP it is requesting to associate with. DRCP registration request and acknowledge messages are exchanged by invention-enabled APs and STAs to indicate to each that the other is DRCP capable.

The DRCP protocol employing these messages will first be described as used in a generic wireless communications environment. The detailed implementation of each of these messages will then be further described in terms of a preferred embodiment in an 802.11 environment.

The aspects of the invention are now described as they apply to AP initialization and optimization, and then as they apply to STA initialization and optimization. It is noted that, though many of the inventive aspects described herein with regard to STAs and APs are advantageous when implemented, they are not required to be implemented in a wireless communications environment. Performance advantages are achieved when only the APs, or only the STAs, or both implement one or more of the various aspects of the invention.

1. AP Initialization

During AP initialization, APs perform automatic channel selection. In accordance with the channel selection aspect of the invention, APs located in the same wireless network automatically select channels for operation such that they do not interfere with nearby APs. The invention contemplates that different bands of frequencies are available, for example based on 802.11 version and the country in which the network is deployed. According to a preferred embodiment, APs attempt to select a channel, in each band in which the AP is equipped to operate, which is least likely to interfere with other APs that are already deployed. APs also quarantine channels in accordance with rules associated with regulatory domains (Europe, etc.) so they don't interfere with other wireless applications (radar, etc.). In the event that one AP selects a free channel, and another AP selects the same free channel at the same time (i.e. a channel selection "Collision"), the APs' media access control (MAC) addresses are used as a tie breaker. If the other AP is a standard AP that does not include the improvements associated with the current invention, then the invention-enabled AP will direct its own radio to the "next best" channel. The AP repeats the channel selection phase for each band of frequencies.

More particularly, referring to Figure 4, before a newly added AP 12 starts to "Beacon" (i.e. broadcast management packets to other APs and STAs), the AP 12 first examines a list of RF bands supported by the AP 12, and the list of channels supported and not quarantined by the radio which implements the Physical Layer (PHY) for each RF band. The AP 12 then selects a channel in each band according to the following algorithm:

For each band:

Scan Intervals occur periodically. During a Scan Interval (step 20), the AP 12 passively scans all channels which the AP supports within the band (step 22). The AP 12 gathers a list of active APs 12, the channels on which they are operating, and the power at which the beacons from each AP 12 was heard. This information is used to build a table called a channel map 24 (step 26), which contains a list of all APs 12 heard from, the channel on which they were heard, and the signal strength at which they were heard. There is a separate channel map 24 for each band. The AP 12 sorts the channel map to produce a list of APs 12 in ascending order of power level (step 28).

Referring to Figure 5, a channel is now selected by the AP 12 as follows. First, the AP 12 peruses the channel map (step 30), and if there is a channel on which no AP 12 is operating (i.e. signal strength = 0) (step 32), then the AP 12 selects that channel (step 34). Otherwise, the AP 12 peruses the list for the channel transmitting the weakest signal (step 36). The AP 12 now enters a time interval referred to as the “claiming period” (step 38).

If the AP 12 selected a channel having the weakest signal strength, the AP 12 notes the channel-ID of the channel that it has selected, the received power level on the channel, and the AP-ID of the AP that generated that power level (step 40). It will use the power level value as a baseline against which to detect increases in received power on its selected channel. If the AP 12 selected an empty channel, the baseline power level will be the AP’s noise floor.

The AP 12 then advertises its intention to use the selected channel by periodically transmitting DRCP Claim messages during the claiming period (step 42). Claim

messages are transmitted at full power. During this claiming period, the AP 12 receives all Beacons, DRCP Claim messages, and DRCP Announce messages transmitted on the currently chosen channel (step 44) and uses the information contained therein to build an “Other APs” table 46 (Fig. 6, Fig. 5 step 48). For each Beacon it receives, the AP 12 notes the AP-ID and the received power level in the Other APs table 46. For each Claim or Announce message it receives, the AP 12 notes the AP-ID of the AP that sent the message, the received power level, and the transmit power backoff (TP backoff) in the Other APs table 46. The TP Backoff value indicates how far from maximum power the sending AP’s radio has been turned down, and will be explained in more detail in the AP Power Adjustment section. The AP 12 also marks the entry for that AP-ID as being DRCP capable. A normalized received power value is calculated by adding the TP Backoff value to the received power value. The normalized received power value equalizes the AP power levels for comparison purposes. When the AP 12 receives a Beacon or DRCP message from an AP for which it already has an entry, it updates the entry and stores the received power and TP_backoff values as a list.

If another AP 12 starts to radiate significant energy on the selected channel, one of two events must have occurred. The new AP 12 is either not running DRCP, or a conflict has occurred with another DRCP-active AP, where a race condition has caused the other DRCP-active AP to select the same channel at the same time. This is called a Channel Selection Collision (CSC).

At the end of the claim period (step 50), the AP 12 stops sending Claim messages and evaluates the information it has collected, its CSC data, to determine if a CSC has

occurred. It looks to see if the received power in any entry is greater than the baseline power level it recorded for the channel (step 52). If so, it looks to see if the received power is exceeded in at least half of the power level values for the entry (step 54). If so, the AP 12 checks to see whether the AP in the entry is DRCP capable (step 56).

If the other AP is not DRCP active, the AP 12 defers to the non-DRCP-active AP and starts the entire channel selection process over again.

If the other AP is DRCP-active, then a CSC is assumed to have occurred. When a CSC has occurred, the MAC address of the other AP is compared to the MAC Address of this AP 12. If the MAC address of this AP 12 is numerically higher than the observed MAC address (step 58), this AP 12 starts the channel selection process over again.

If at the end of the claiming period, the AP has succeeded in claiming the selected channel, it begins running on the channel. The AP starts beaconing, begins sending DRCP Announce messages, and prepares to enter the Optimization stage in order to run its Auction and Power Adjustment functions (step 60).

A variation on the channel selection process of Figure 5 can be employed to improve channel selection coverage when several APs 12 are powered on all at once. Referring to Figure 7, each AP, upon power-up, sends a claim message on a first channel chosen from the channel map – for purposes of example designated channel 1 (steps 62, 64). All APs scan all channels. All APs scanning on channel 1 will hear each other's claim messages. During the claiming period, an AP will ascertain whether channel 1 is in fact available for use by it. Accordingly, the AP listens for other DRCP Claim messages on the same channel, which would indicate that another invention-enabled AP is trying to

use the same channel (step 66). The AP 12 keeps track of the number of different APs it hears (based on AP IDs the claim messages received) and the average signal strength of claim messages from each AP. The AP 12 builds an adjacency vector (adjacency count, adjacency power total) (step 68). Adjacency count represents the number of APs heard on the channel. Adjacency power total represents the sum of the average power levels for each AP heard. Each AP sends its adjacency vector to all the other APs in its claim messages step 70. If a DRCP claim message is received (step 72), in this case on channel 1, the AP 12 first compares its adjacency count with the adjacency count received in the claim message (step 74). If the AP 12's adjacency count is higher than that received in the claim message, this probably indicates that the AP 12 is closer to the center of the network. The AP 12 therefore continues to claim the channel during the claim period. If the AP's adjacency count is the same as the adjacency count received in the claim message (step 76), the AP 12 then compares its own adjacency total power to the adjacency total power value received in the claim message. If the AP 12's own adjacency total power is higher than that received in the claim message (step 78), this may also indicate that the AP 12 is closer to the center of the network, and therefore the AP 12 continues to send claim messages on the channel. If the AP 12's own adjacency total power is the same as that received (step 80), then the AP 12 performs the previously described MAC address test step 82). If the AP 12 finds that its own adjacency count or adjacency power are lower than any received in claim messages, or that in the event of a tie on these values that its MAC address is higher, it ceases to send claim messages on the channel and returns to peruse the channel map (step 84). Otherwise, the AP 12 continues

to send claim messages including its adjacency vector (step 70). If, at the end of the claiming period (step 86), the AP 12's adjacencies are greater than other AP's adjacencies, the AP 12 has won the channel and proceeds to the AP optimization phase (step 88). According to this method, the APs closest to the center of a multi-AP network obtain the first channel assignments and subsequent channels are assigned to the other APs.

Referring to Figure 8, a preferred embodiment of the automatic channel selection algorithm is shown. For each band:

Scan Intervals occur periodically. During a Scan Interval (step 100), the AP 12 scans all channels which the AP supports within the band, receiving Beacons and Announce messages (step 102). The information received in the Beacon and Announce messages is used to build a table called the "Scan table" (step 104). An example of a Scan table 106 is shown in Figure 9. The Scan table 106 includes an entry for each AP 12 from which a Beacon or Announce message has been received. For each entry, there is stored the AP-ID and the channel on which that AP 12 was heard. Also stored is a "rxPowerRunningTotal" value that represents the sum of the signal strengths of each message received from that AP 12. Also stored is a "rxPowerSampleCount" value that represents the number of messages received from the AP 12. A DRCP flag is set if an Announce message has been received from the AP 12. The entryAge entry is incremented every time the channel is scanned. The "rxPowerAvg" is calculated during a Preclaim interval as will be further described.

As the scan progresses, the rxPowerSampleCount values in the Scan table 106 are monitored, and if any one of them exceeds a threshold, herein labeled “threshold1” (step 108), the AP 12 proceeds to step 110 to build a channel map. In addition, if any entryAge value in the table exceeds a certain threshold “threshold2” (step 112), the AP 12 will proceed to step 110. Also, if the number of scans completed exceeds a certain threshold “threshold3” (step 114), the AP 12 will proceed to step 110. Otherwise the AP 12 continues scanning and updating the Scan table 106.

An example of a preferred channel map 116 is shown in Figure 10. The channel map 116 contains an entry for each channel ID. To build the channel map, the AP 12 peruses the Scan table 106 and calculates the “rxPowerAvg” value for each entry, as:

$$\text{RxPowerAvg}[I] = \text{Scan table}[i].\text{rxPowerRunningTotal} / \text{Scan table}[i].\text{rxPowerSamplecount};$$

For each channel, the AP-ID with the highest rxPowerAvg value is entered in the channel map 116. The AP’s rxPowerAvg value is entered into the channel map 116 as the highestPwrlevel parameter.

In certain network implementations, it is undesirable to locate two operating APs 12 within a certain distance of each other, because doing so does not increase network performance and may reduce it. So, according to a preferred option, once the channel map has been assembled, the AP 12 checks the channel map to see if any of the highestPwrlevel values in the map exceed a certain threshold power level (step 118). The threshold power level is chosen to indicate that the AP 12 is located too close to another AP. If any highestPwrlevel exceeds the threshold power level, the AP 12 is placed in “Standby mode” (step 120). The AP 12 in Standby mode waits for a period of time

herein referred to as “Standby Interval” before returning to start another scan interval (step 122).

If no highestPwrlevel values are found to exceed the threshold power level, the AP proceeds to assemble a triplet channel map 124 (step 126). As shown in Figure 11, the AP 12 sorts a channel map into triplets, for example, channels 1, 2 and 3, channels 2, 3 and 4, channels 3, 4 and 5, etc.. The power heard on each channel in the triplet is averaged into a triplet average. The list of triplets is sorted in ascending order, with the triplet with the lowest average power at the top of the list. The AP 12 starts at the top of the list and looks for the first triplet in which the power heard on the center channel of the triplet is less than or equal to the power heard on the two adjacent channels, and selects this channel (step 128). If no such triplet is available, the AP selects the channel with the lowest triplet average. In the example shown in Figure 11, AP 12 chooses channel 3. This process advantageously minimizes interference between channels by selecting channels that do not tend to have high power adjacent channel usage.

The AP 12 then records the baseline power for the selected channel as the highestPwrlevel value for the channel, and records the AP-ID of the AP at that power level (step 130). A Preclaim Interval is now entered (step 132). During the Preclaim interval, the AP transmits Preclaim messages on the selected channel (step 134). The AP 12 also receives Beacon, Announce, and Preclaim messages on the channel (step 136). The AP 12 uses the received messages to update the Scan table (step 138). The AP 12 continues to update the Scan table until one of two Preclaim intervals expires. During the min Preclaim interval (step 140), the rxPowerSampleCount value for each AP-ID on

the selected channel is checked to see if a minimum sample size threshold has been exceeded. If so, the Preclaiming interval ends and the AP proceeds to check to see whether too many APs are operating on the selected channel (step 142). Otherwise, the Preclaiming period extends until the end of the max Preclaim interval (step 144).

In some network environments, and in particular environments of limited area, the operation of too many APs on the same channel does not increase network performance and may cause a performance reduction. So, according to a preferred option, the AP checks to see if there are too many APs operating on the network (step 142). The number of different AP-IDs present in the Preclaim APs table is used to make this determination. If there are too many APs operating on the selected channel at a power level greater than a defined threshold, the AP 12 enters Standby mode

If there are not too many APs operating on the selected channel, the AP 12 calculates an “adjacency vector sum” (step 146). The adjacency vector sum is calculated over all APs on all channels as:

Adjacency vector sum = $\text{sum}(\text{Preclaim APs}[i].\text{ReceivedPowerTotal} / \text{Preclaim APs}[i].\text{count})$

The adjacency vector sum is used as a tiebreaker if necessary during the Claiming interval, to be further described.

The AP 12 now enters the Claiming interval (step 148). During the Claiming interval, the AP 12 transmits Claim messages on the selected channel (step 150). Claim messages include the adjacency vector sum. The AP 12 also receives all Beacon, Announce, and Claim messages on the selected channel (step 152). The AP 12 uses the information contained in the received messages to build a “Claim APs table” 154 (step

156). An example of the Claim APs table is shown in Figure 12. The Claim APs table 154 contains an entry for each AP-ID. The received power level of each message received from a given AP is stored in the Claim APs table 154 as a list of values (shown as column “ReceivedPowerlevel”). Furthermore, for each Announce or Claim message received, a DRCP flag is set. The AP continues to update the Claim APs table until the end of the Claiming interval (step 158).

The AP 12 then evaluates the Claim APs table 154 (step 160) to ascertain whether any other APs were heard from. If no entries exist in the Claim APs table 154 (step 162), the AP 12 has “won” the selected channel. The AP 12 can then begin Beaconsing and sending Announce messages on the channel (step 164). If the Claim APs table 154 includes one or more entries, then if the selected channel was empty at the beginning of the Claiming Interval (step 166), the AP 12 concedes the channel and returns to re-scan (step 100). Otherwise, if the channel was not empty, then if the ReceivedPowerlevel values for all entries in the table are less than the baseline level recorded during Preclaiming plus a threshold level (e.g. 2db) (step 168), then the AP has won the channel (step 164). However, if the AP does find a ReceivedPowerlevel value that exceeds the baseline power level plus the threshold level, and that entry is associated with an AP-ID that was not the one recorded on the channel during the Preclaiming Interval, then the AP checks the entry’s DRCP flag (step 170). If the DRCP flag indicates that the AP-ID associated with the entry is not DRCP capable, then the AP returns back to the scan interval to re-start the channel selection process. If the DRCP flag indicates that the AP-ID associated with the entry is DRCP capable, then the AP compares its adjacency vector

with the adjacency vector received in the other AP's claim messages (step 172). If the AP's adjacency vector is less than the other AP's adjacency vector, the AP concedes the channel and returns to re-scan. If the AP's adjacency vector is not less than the other AP's adjacency vector, then the AP checks to see if the adjacency vectors are equal (step 174). If they are, the MAC addresses of the two APs are compared (step 176). If the AP's MAC address is greater than the other AP's MAC address, the AP has "won" the channel (step 164). Otherwise, the AP concedes the channel and returns to re-scan (step 100). One skilled in the art will realize that the MAC address comparison decision is arbitrary and can be made in the opposite manner.

2. AP Optimization

Once an AP is running on a channel, it continuously performs the following functions to optimize its configuration in the wireless LAN:

- Radio Power Adjustment. Each DRCP-enabled AP adjusts its power as appropriate, to accommodate the nearest AP operating on its channel while maintaining its connection to its farthest associated STA. The AP conveys a TP_backoff parameter in its Announce messages. The TP_backoff value provides an indication of how far the sending AP has turned its transmit radio down. This TP_backoff value is used by other APs to determine their own TP_backoff values. A STA that is associated to the AP can then adopt the

communicated TP_backoff value to adjust its radio power, and can track this value as it changes.

- Auction. The AP runs the Auction process to accept new DRCP STAs for association, as appropriate, based on received DRCP Bid messages. These two functions are now described in terms of a preferred embodiment.

2.a. Radio Power Adjustment

2.a.1 AP maintained tables

In order to perform Radio Power Adjustment, the AP 12 maintains a number of tables. The tables include information received from other APs and STAs operating on the selected channel. This information is used to ascertain such things as power levels of other devices on the channel, and distances between devices on the channel, in order to control the AP's power level.

2.a.1.1 AP KnownAPs table

Each AP 12 maintains a number of tables that it consults to perform power adjustment. One such table is the AP KnownAPs Table 200. As shown in Figure 13, once initialized on a channel, an AP 12 receives Beacons and DRCP Announce messages from all other APs 12 operating within the range of its radio, on its channel (steps 202, 204, 206). The AP 12 uses these received messages to build the AP KnownAPs table 200.

For each message it receives, the AP 12 checks to see if it has an entry in the AP knownAPs table for the AP-ID in the message (step 208). If found, the AP 12 updates the entry (step 210), otherwise it creates a new one (step 212), up to a maximum of Max_AP entries (step 214). The value of Max_AP is design dependent.

Referring to Figure 14, the AP 12 stores the following fields in the corresponding AP knownAPs table 200 entries:

- AP-ID
- TP Backoff
- Max Power
- DRCP capable
- Age
- Normalized power
- Sample size
- Corrected power

The AP-ID, TP Backoff, and Max Power fields are extracted from each DRCP Announce and Hello message received. The TP Backoff value is stored as a list of values for each message received from each AP-ID. The sample size is the number of TP Backoff values received for each AP-ID.

Since Announce messages are only sent by DRCP-enabled APs, the AP 12 also marks the entry as DRCP-active. APs sending Beacons which contain no DRCP fields are not marked DRCP-active. For each message received, the AP adds the TP Backoff value to the received power level to determine a normalized received power level, as follows:

$$\text{normalized\_power} = \text{avg}(\text{received\_power} + \text{tp\_backoff});$$

Accounting for the TP backoff in the normalized power level provides a value that is consistent and can be used for comparison with power level measurements from other APs.

Received beacons do not explicitly carry a TP backoff value, however, since beacons are always transmitted at full power they effectively carry a TP backoff value of zero. Thus, the AP 12 can update the AP KnownAPs table 200 based on a received Beacon. In this case the AP 12 stores the TP backoff value as zero, and sets the normalized power and the Max Power to the received power level value.

Additionally, the AP 12 keeps an Age for each entry. The Age is reset to zero, “0”, each time a Beacon or DRCP Announce is received from the AP corresponding to the entry. Entries are aged as part of the AP Power Adjustment process.

2.a.1.2 AP AssociatedSTAs table

APs 12 also continuously maintain a table of the STAs 16 that are associated with it – the AP AssociatedSTA table. Referring to Figure 15, for every associated STA 16, the AP 12 monitors and collects signal strength information for data packets received (step 220). If an entry for the STA already exists in the AP AssociatedSTAs table (step 222), that entry is updated (step 224). Otherwise a new entry is created for the STA (step 226). The collected data is periodically analyzed by the AP for AP power adjustment purposes. In addition, whenever a DRCP-active STA 16 becomes associated with an AP 12, it sends a Registration Request message to the AP 12. Registration Request messages are sent by the STA 16 to the AP 12 periodically until a Registration Acknowledge

message is received by the STA 16. Upon receipt of a Registration Request from an STA 16 (step 228), the AP 12 updates the entry in the AssociatedSTA Table and marks it as a DRCP-active STA (step 230) and sends a Registration Acknowledge message to the STA 16 (step 232).

As shown in Figure 16, the AP 12's AP AssociatedSTA Table 240 maintains the following information about each STA:

- STA-ID – MAC Address of the Station
- Quiet-time – A value representative of the amount of time since data was last received from this STA
- DRCP-Active – defaults to false, set to true upon receipt of a Registration Request
- Distance – Distance (in Banzais, to be further described) to this STA, calculated based on signal strength information and TP Backoff
- Max Power – list of power values
- Power samples – number of power samples received
- Normalized_power
- Corrected_power
- sta_load_factor – The load of this STA on this AP, see section 4.c.

2.a.1.3 AP Power Adjustment

During the channel selection process, the AP 12 transmits at maximum power, that is, it uses a TP backoff value of zero. Once the AP 12 has successfully claimed a channel, it calculates a TP Backoff value and adjust its transmit power for data transmissions down, in accordance with this value to minimize same channel interference and maximize channel coverage. The calculation of the TP Backoff value is now further described.

Generally, with reference to Figure 17, AP power adjustment is accomplished as follows: The AP 12 peruses its AP KnownAPs table (step 260). The AP 12 finds the AP in the table with the highest TP Backoff value. The AP 12 then sets its own Max TP backoff value to the highest TP Backoff value (step 262). This Max TP Backoff value, if used as the AP 12's TP Backoff value, would reduce the AP 12's transmit power to a level just below the range of the nearest AP operating on the same channel.

Once the Max TP backoff is calculated, the AP then scans the AssociatedSTA table to ascertain the distance to the farthest associated STA 16 (step 264). The distance to the farthest associated STA 16 is compared to the distance to the closest AP 12 operating on the same channel (step 266). If the distance to the farthest associated STA 16 is less than the distance to the closest AP 12, the AP's TP Backoff value is left at Max TP Backoff (step 268). If the distance to the farthest associated STA is greater than the distance to the closest AP operating on the same channel (step 266), then the Max TP backoff value is adjusted back down to accommodate this STA (step 270), and the AP's TP backoff is set to this adjusted value (step 272). This power adjustment is periodically

repeated to account for changes in the AP KnownAPs table and the AP AssociatedSTAs tables change (step 274). Power adjustment may be repeated every second, for example, in an 802.11 environment.

In accordance with the preferred embodiment for use in a wireless data networking environment, as shown in Figure 18, APs perform the above described power adjustment as follows. First, the AP 12 checks to see if its Avoid Other WLANs flag is set (step 280). The AvoidOtherWLANs flag is a configuration parameter which can affect Power Adjustment. In many wireless networking architectures, it is possible for several APs to occupy the same channel while serving different physical networks. For example, in the 802.11 architecture, several APs can serve different ESSs. The AvoidOther WLANs flag is false by default. When set to false, the AP 12 will ignore any other APs on the same channel who's physical network is different from this AP 12's physical network (e.g. ESS ID). This option is useful for cases when there are multiple APs in relatively close proximity that are on different networks. In this case, the operator may prefer to run his AP at the maximum power level to provide the best possible signal for all stations on his network.

If the Avoid Other WLANs flag is not set, the AP 12 sets its TP Backoff to 0 (step 282). The AP 12 will therefore transmit at full power as long as the Avoid Other WLANs flag is not set. If the Avoid Other WLANs flag is set, the AP proceeds with the power adjustment process and will not interfere with other APs even if they are operating on a different network.

The AP 12 processes the information in the AP KnownAPs table every Hello Interval (step 284), to perform power adjustment. The Hello Interval is architecturally and design dependent. In an 802.11 environment, the Hello Interval may be for example the 100ms beacon interval. The knownAPs table entries are first aged before other processing is performed. The age of each entry is incremented (step 286), and any entries whose age exceeds Max AP Entry Age are deleted (steps 288, 290). Thus, if an AP hasn't been heard from in a while, it is aged out of the table to prevent it from affecting this AP 12's power adjustment calculations.

As previously described, the normalized power field of an entry, “n”, of the AP KnownAPs table is determined by averaging over several received power measurement samples. The greater the number of samples used to derive the value, the more accurate the measurement. The AP accounts for the inaccuracy in this value by subtracting a standard error, based on the sample size, from the normalized power level, as shown in the following formula. Note, in an 802.11 environment, the normalized power level is expected to be a negative number, ranging in value from –25 to –90 dBm.

$$\text{AP knownAPs}[n].\text{corrected\_power} = \text{AP knownAPs}[n].\text{normalized\_power} - \text{getStandardError}(\text{sample\_size});$$

In this formula, the function “getStandardError” would return the standard error for the sample size of “sample_size” in each entry “n”. For example, table I in Figure 19 shows the standard error values for a number of sample sizes for RF signal

measurements. This formula is applied to each entry “n” in the AP KnownAPs table to calculate the corrected_power values for each entry (step 292).

The AP KnownAPs table is then scanned for the entry corresponding to the AP which was heard at the highest corrected_power level. This corrected_power level is compared to the AP 12’s noise floor (step 294). (The AP’s noise floor is a measure of background power on the channel.) If the AP 12 finds that the highest corrected_power level is less than the AP 12’s noise floor, then the AP 12 may transmit at maximum power without interfering with the other APs on the channel. It therefore leaves its Max TP Backoff value at 0 (step 296). If the AP 12, however, finds that the highest corrected_power level is higher than the AP 12’s noise floor, it needs to set a TP Backoff to avoid interfering with that AP. In this case the AP 12 calculates Max TP Backoff by subtracting its noise floor from the corrected_power associated with that AP (step 298).

Once it has calculated Max TP Backoff, the AP 12 must then determine if there are any associated STAs 16 that are farther away (ie who’s signal strength is weaker than) the highest_power_AP. The AP 12’s AssociatedSTAs table is analyzed to find the STA 16 that is the greatest distance from the AP (step 300). The normalized_power and sample size values for this STA are used to calculate a corrected_power value for this STA as previously described. The lowest power STA’s corrected_power level is compared to the AP 12’s noise floor (step 302). If the corrected_power level is less than the noise floor, then the AP 12 needs to run at full power to cover the STA, so the AP TP Backoff value is set to 0 (step 304). If the corrected_power level is greater than the AP

12's noise floor, then the STA TP Backoff value is set to the corrected power level minus the noise floor (step 306).

Next, Max TP Backoff is compared to STA TP Backoff (step 308). The AP's TP Backoff ("my TP Backoff") is set to the lower of the two backoff values to avoid interference with the closest AP while ensuring coverage for the farthest STA. So, If STA TP Backoff is less than Max TP Backoff, then my TP Backoff is set to the Max TP Backoff value (step 310). If STA TP Backoff is greater than Max TP Backoff, then the my TP Backoff value is set to the STA TP Backoff value (step 312).

The AP 12 then adjusts its transmit power by the value of my TP Backoff (step 314), and uses my TP Backoff as the value of TP Backoff in its Announce messages. According to the preferred embodiment, the AP will transmit data at a power level adjusted by TP Backoff, but will transmit DRCP management messages (e.g. Claim, Announce, Accept) at full power. So, APs can always hear management messages passed between each other.

Furthermore, various different wireless networking architectures may provide a mechanism for clearing the wireless channel, further increasing the probability that the management messages will be received. For example, in the 802.11 architecture, the AP issues a Clear to Send (CTS) message to clear the channel (step 316), and then sends a DRCP Announce message at maximum power (step 318). After sending the Announce message at maximum power level, the AP resumes use of its calculated TP backoff value for data packets to minimize same-channel interference, as described above.

2.a.1.3.i AP Power Adjustment During Station Movement

When a STA 16 is associated with an AP 12, the AP 12 keeps track of the distance between the STA 16 and the AP 12. If the AP 12 is using a non-zero TP Backoff value, and the AP 12 ascertains that the STA 16 is moving out of range of the AP 12 at backed off power, then the AP 12 can adjust its TP Backoff value to accommodate the STA 16's movement.

The distance between an AP 12 and an associated STA 16 is calculated and stored in the AssociatedSTAs table in units of "Banzais". The Banzai is a unit of distance derived from a measurement of received signal strength from an AP 12 operating with a known transmit power backoff. In an 802.11 environment, for example, a received signal strength measurement is generally expected to range in value from -25 dBm to -90 dBm, but depending upon possible antenna gain at the high end or sensitivity at the low end, may range from 0 dBm down to -100 dBm. A transmit power backoff is generally expected to range in value from 0 dB to 65 dB. Given a received signal strength measurement of "received_power" and transmit power backoff of "TP Backoff" from an AP, the distance to that AP in Banzais is calculated as follows:

$$\text{distance\_in\_banzais} = \text{ABS} [\text{MIN} [0, (\text{received\_power} + \text{tpbackoff})]]$$

Algorithms for movement detection are described in more detail later. For purposes of AP power adjustment, as previously described, the AP 12 collects multiple samples of received_power and TP Backoff values for each STA 16 over time, and the

distance between the AP and the STA is calculated over all these samples. The AP 12 detects movement by continuously checking to see if the difference between the distance to each station, derived from a set of long term samples, is sufficiently smaller than the current distance measurement based on the most recently collected samples, to indicate that the STA 16 is moving away from its AP 12.

If the AP 12 detects that the STA 16 is moving away and the STA 16 is within a given Short Term Standard Error Banzais of the current edge of the transmit signal (based on the current TP Backoff), then the AP 12 switches to a TP Backoff of 0 until it no longer has any moving STAs associated with it.

More particularly, referring to Figure 20, to detect STA movement, the AP 12 collects a long term samples of distance values for a STA 16 (step 320), and then continuously collects short term sample size distance values for the STA 16 (step 322). The difference between the long term distance and short term distance values is compared to a Moving Threshold value plus the standard error in the two distance measurements in order to eliminate false movement detection. (See section 6 for more information.) A station is considered to be moving when the short term distance exceeds the long term distance by more than the Moving Threshold plus the sum of the errors in the two measurements. The following pseudo code describes this comparison.

```
IF ((AssociatedSTAs[n].short_term_distance - AssociatedSTAs[n].distance) >
    (movingThreshold + longTermStdError + shortTermStdError)) (step 324)
THEN
    moving = TRUE (step 326)
ELSE moving = FALSE; (step 328)
```

If the AP 12 detects that the STA 16 is moving, the AP 12 sets its TP Backoff to 0 so that it transmits data at maximum power (step 328). The AP 12 remains at maximum power until it detects that the STA 16 is no longer moving, or quiet. If the AP 12 determines that it is no longer moving before the STA 16 loses the association to its AP, the AP 12 resumes normal processing of received signal strength to determine a new appropriate TP Backoff value as previously described (step 334).

Once the AP 12 detects that the STA 16 is moving, it begins using another test to detect when the STA 16 has stopped moving. To detect that the STA 16 has stopped moving, the AP 12 compares the distance to the STA 16, derived using the Long Term Sample Size, to the distance derived from the most recent Short Term Sample Size samples. The AP 12 looks to see when this difference is less than just the standard error in the two measurements to determine that the STA 16 has stopped moving. This test is performed as follows (step 330):

IF ((AssociatedSTAs[n].short_term_distance - AssociatedSTAs[myAP].distance)
< (longTermStdError + shortTermStdError)) THEN
 moving = FALSE; (step 332)

2.b AP Auction

The purpose of the Auction is to accomplish the distribution of STAs 16 across APs 12 in a manner that optimizes wireless communications performance. The goal is to have STAs 16 associate to their nearest AP 12 while taking loading (the sum of the individual loads of the STAs 16 already associated to the AP 12) into account. This

allows the RF footprints of the APs 12 and STAs 16 to be minimized, while ensuring that no AP 12 is overloaded.

STAs 16 learn of available APs 12 through the Announce messages transmitted by the APs 12. As will be further described with regard to STA optimization, a STA 16 calculates a “biased distance” to each AP 12 it hears from, including its own AP, using the received power and loading information from the Announce messages. A STA 16 will send a Bid message to an AP that is “better” than the STA’s current AP, where better means that the AP has a lower biased distance. The Bid message contains the value of the difference between the biased distance from the STA 16 to the destination AP 12 and the biased distance to the STA 16’s current AP. This value is called the biased distance delta.

In particular, referring to Figure 21, the AP 12 collects any received Bids over a period of Auction Interval (steps 340,342). If a Bid is received from a STA 16 from which a Bid has already been received (step 344), the new bid information replaces the previous bid information (step 346). Otherwise a new entry is created for the STA 16 (step 348). In either case the bid entry’s age is reset (step 350).

At the end of Auction Interval (step 352), the AP 12 processes the received bid information. (The Auction Interval in an exemplary 802.11 environment may be on the order of, for example, 7.5 seconds.) The age of all bid entries is incremented by one (step 354) and then any bid entry whose age is greater than Max Bid Age is deleted (step 356). The list is then sorted by biased_distance_delta value (step 358).

The AP 12 selects the bid entries with the highest biased distance delta values, up to acceptsPerAuction entries, and sends a DRCP Accept message to each of the STAs 16

corresponding to those entries (step 360). The IDs of each STA 16 being sent an Accept is put in a list of outstanding accepts (step 362), and a count of accepted STAs who have not yet associated and registered is noted as numAcceptsOut (step 364). At this point the next auction period begins.

In addition to receiving DRCP Bids, the AP 12 also receives an indication any time a STA 16 associates to the AP 12. Referring to Figure 22, on receipt of the indication (step 366), the AP checks to see if it has bid information from the newly associated STA 16 (step 368). Any bid information found for the newly associated STA 16 is deleted (step 370). The AP 12 also checks to see if the STA 16 is in the list of outstanding accepts (step 372), and if the STA 16 is in the accepts outstanding list that entry is deleted (step 374) and the numAcceptsOut count is decremented (step 376). At the end of the Auction Interval, any outstanding accepts from the previous auction cycle are considered to have timed out, hence the list of outstanding accepts is emptied and numAcceptsOut is reset. These processes continue as long as the AP 12 is active on a given channel.

3. STA Initialization:

The purpose of the STA initialization phase is to find and associate to a suitable AP 12 to provide the STA 16 with access to the wireless LAN, and to prepare for the operation of the DRCP protocol and algorithms.

Referring to Figure 23, when started, the STA 16 produces a list of channels supported by the STA 16 (step 380). In multi-PHY-variant STAs (e.g., STAs supporting

multiple bands such as 802.11a/b/g), the channel list will include all of the channels that are supported across the various supported bands.

First, the STA 16 scans for beacons on all channels across all supported bands (e.g., STAs supporting multiple bands such as 802.11a/b/g will scan all channels in each of the a, b, and g bands.) (step 382) The AP 12 that is received at the greatest signal strength is selected (step 384).

Preferably, where multiple bands are supported, the selection of an AP 12 also takes into account a preference for the higher bandwidth bands so that, for example as implemented in an 802.11 environment, an AP 12 on an 802.11a or 802.11g channel is given some preference to one operating on an 802.11b channel.

Once an AP 12 is chosen, the STA 16 authenticates and associates to that AP (step 386). Any security policies that control association are executed at this point.

During initialization, the STA 16 also enables the DRCP protocol so that the STA 16 will receive DRCP Announce messages (step 388). The STA 16 then proceeds to the STA optimization phase (step 390).

4. STA Optimization

Once it has made its initial association and has access to the wireless LAN, the STA continuously performs the following functions to optimize its configuration:

- Canvassing. The STA periodically tunes its radio to listen on other channels, while retaining its association to its AP on its operating channel. This canvassing of other

channels is done to allow the STA to receive DRCP Announce messages from APs operating on other channels.

- Bidding. The STA receives and processes DRCP Announcements from all APs that are operating within its range on any of its supported channels. It evaluates the received power and loading information from the Announce messages and if it finds an AP to which it would be more optimally associated than its current AP, the STA makes a bid to move to that AP.
- Radio Power Adjustment. The STA adopts the TP Backoff value communicated in Announce messages from its AP, tracking this value as it changes.
- Movement Detection. The STA continuously checks to see if it is moving away from the AP to which it is currently associated. If it detects that it is moving, it stops participating in the DRCP bidding process and adopts a process of next AP selection that is invoked when the association to its AP degrades.

These functions are described more particularly as follows:

4.a STA Canvassing

The process by which the STA 16 canvasses the other channels to determine whether to send a DRCP Bid message is now described in further detail. In order to monitor DRCP Announce messages, a STA 16 periodically tunes its radio to the channels other than the one to which it is currently associated. However, the STA 16 must remain associated to its current AP 12 so that it does not lose data packets. So, packets must be

buffered during the time that the STA 16 is canvassing. Various wireless communications architectures may provide different means for packet buffering.

Generally, referring to Figure 24, during a periodic scan interval (step 400), the STA 16 causes the AP 12 to which it is currently associated to temporarily buffer the packets destined for the STA 16 (step 402). Packet buffering can be initiated in a variety of ways. For example, the STA 16 may send a DRCP message to the AP 12 to cause the buffering, or the AP 12 may periodically turn on buffering and notify the STA 16 that it has done so. While the STA 16's packets are being buffered, the STA 16 tunes its radio to another channel and listens for Beacons and DRCP Announce messages on that channel (step 404). This information is used by the AP 12 to determine whether to bid for another AP. When the scan interval is complete, packet buffering is turned off and the STA 16 receives its buffered packets from the AP 12 (step 406).

Figure 25 sets forth a STA canvassing mechanism for use in an 802.11 wireless networking environment. The 802.11 architecture conveniently provides a power save mode that, in accordance with the principles of the invention, can be used for this purpose.

The 802.11 power save mode is intended for use by STAs 16 so that they can turn off their radios for periods of time in order to save power. STAs 16 can indicate to APs 12 that they are entering this power save mode. In response, APs 12 buffer the STAs' packets while the STAs 16 are "sleeping". APs 12 periodically send special Beacon messages to the STAs 16. STAs 16 wake up in response to these special Beacon

messages. These Beacon messages include information as to whether any data is buffered for the STA 16. The STA 16 “wakes up” if data is buffered for it.

STAs 16 operating in an 802.11 environment in accordance with the preferred embodiment of the invention use the 802.11 power save mode to go off-channel and canvass other channels for DRCP Announce messages. After the channel canvass is complete, the STA 16 reverts to normal power save mode. Stations that have not been set to Power Save Mode by management are caused by the STA 16 to act as if they’ve been set to the Power Save Mode. STAs 16 that have already been set to Power Save Mode by management will have even more time to canvass.

In particular, referring to Figure 25, at the start of a scan interval (step 410), the STA 16 inquires about the current state of its power save mode. The power save mode that was set by management (active, power save) is remembered (step 412). The power save mode is set to power save, and the listen time (time the STA 16 stays asleep), if any, is increased by a period of time herein referred to as scan time (step 414). At the beginning of the power save cycle, the STA 16 actually stays awake temporarily, instead of dozing as it told the AP it was going to do. It is during this time that other channels are canvassed for beacons and DRCP Announce messages (step 416). After the canvass is done the STA 16 resumes its power save cycle (step 418). This process repeats every scan interval. Whenever the STA 16 is not canvassing, it restores the remembered management set power save mode. The scan interval may be for example twice per Beacon interval.

Stations that have not been set to Power Save Mode by management are caused by the STA 16 to act as if they've been set to Power Save Mode, with listen interval set to the minimum value (i.e., every Beacon). STAs 16 that have already been set to Power Save Mode by management will have the most amount of time to canvass.

During the canvass time the STA 16 tunes its radio to a different channel in order to passively listen for beacons and DRCP Announce messages. The STA 16 keeps track of which channels have been canvassed, stepping through all of the channels until all supported channels have been canvassed. The STA 16 keeps track of all DRCP Announce messages, and the power level at which they were received.

4.a.1 STA KnownAPs Table

The STA 16 receives beacons and DRCP Announce messages from all APs 12 within the range of its radio. These are processed to build a table of all known APs 12, the "STA knownAPs" table 430, as shown in Figure 26. The STA knownAPs table includes the following parameters for each entry:

- AP-ID
- age
- Channel ID
- Load factor
- TP Backoff
- Max Power
- Distance_samples
- Distance
- My_load_factor
- Biased_distance

The STA Known APs table 430 is built as shown in Figure 27. For each Beacon or Announce message received (steps 432, 434), the STA 16 checks to see if it has an entry in the STA KnownAPs table 430 for the AP-ID in the message (step 436). If found, the STA updates the entry (step 438), otherwise it creates a new one (step 340), up to a previously set maximum herein referred to as Max APs entries (step 442).

The STA 16 stores the following fields from received beacons in the STA knownAPs table entries:

- AP-ID
- Channel ID
- Max Power

The STA 16 stores the following fields from received Announce messages in the corresponding STA knownAPs table entry:

- AP-ID
- Channel ID
- Received Power
- Load Factor
- TP Backoff

The STA 16 also notes the received power level that accompanied the beacons and Announce messages and uses these values along with the TP backoff values to calculate the distance to the APs in Banzais, as previously described. (Again, since non-

DRCF APs will always send beacons at full-power, the TP Backoff value for these is set to 0.)

The Received Power and TP Backoff entries are lists, where each entry in each list corresponds to a Beacon or Announce message received for the corresponding AP-ID. The received power level value and correspondingly, the distance in Banzais, are subject to variability in the RF channel. The STA 16 saves a number of these distance measurements for each entry in the knownAPs table, so that it can use averaging to compensate for this variance, to be further described. For its own AP (i.e. the AP to which the STA is currently associated), the STA 16 averages over a relatively large number of distance values, herein referred to as “Long Term Sample Size” distance values. For all other entries, the STA uses fewer, “Bid Sample Size”, distance values.

Additionally, the STA keeps an Age for each entry. The Age is reset to zero, “0”, each time an Announce message is received from the AP corresponding to the entry. Entries are aged as part of the STA Bidding process, described below.

4.b STA Power Adjustment

Referring to Figure 28, an associated and registered STA 16 receives all Announce messages from the AP 12 to which it is associated. Upon receipt of an Announce message (step 556), the STA notes the TP Backoff value in the Announce message and adopts that value as the STA’s own TP Backoff (step 558).

4.c STA Bidding

Each time the STA Canvassing function completes a canvass of all channels, the STA 16 analyzes the information in the STA knownAPs table to see if there is a potential “better” AP 12 with which to associate. The notion of what constitutes a better AP takes into account the distance to the AP in Banzais, the available data rate, and the loading (number of associated STAs) on the AP, if known.

Referring to Figure 29, the STA Bidding process operates generally as follows. When the canvass is complete and a sufficient number of samples have been collected on each channel (step 450), the STA knownAPs table 330 entries are aged before other processing is performed (step 452). The age of each entry is incremented, and any entries whose age exceeds Max AP Entry Age are deleted (step 454). Since the age field is cleared each time an Announce message or Beacon is received, this aging process will eliminate APs from whom nothing has been heard for “Max AP Entry Age” bidding cycles.

As mentioned, the STA 16 uses averaging to compensate for variance in its distance measurements. It requires Long Term Sample Size distance values for the STA knownAPs entry corresponding to its AP, before it performs further processing of the table (step 456). Once the STA 16 has Long Term Sample Size distance values for its own AP, it then waits until it has Bid Sample Size distance values for all entries in the

knownAPs list at that time before it begins looking for a better AP (step 458). This is to avoid making a decision to move to a new AP before it has sufficient information about the other APs in the network. However, to avoid the potential for waiting indefinitely, it will not delay processing the knownAPs list for any new APs that were added after it has Long Term Sample Size distance values for its own AP.

Working with the entries for which there are sufficient distance measurement samples, the STA 16 looks for a potential better AP. In summary, a biased distance is calculated for each entry, which takes into account the available data rate as well as the loads on the APs (step 460). The data rate is deduced based on the received signal strength and the technology being used (i.e., in an 802.11 environment, the 802.11 mode of operation (a,b,g)). After calculating the biased distances for all of the entries in the STA knownAP table, the AP with the lowest biased distance is considered to be the best candidate and, if it appears better than its current AP (step 462), a Bid is sent (step 464).

More particularly, referring to Figure 30, for each entry “n” in the STA knownAPs table (denoted KnownAPs[n]), the following processing is performed on entry knownAPs[n]. An index of “myAP” corresponds to the entry for the AP to which the STA is currently associated, i.e., knownAPs[myAP] is the entry for the STA 16’s current AP.

As previously described, the distance field in the STA knownAPs table 430, knownAPs[n].distance per entry, is the distance in Banzais, to the corresponding AP, averaged over a number, Bid Sample Size, of measurement samples. As previously noted, this value is subject to variance in the RF channel. The bid selection process

should preferably yield the choice of a “better” AP only when the new AP actually would provide better performance for the STA, and not when the new AP simply appears to be better due to this variance. The variance in the new AP’s distance measurement is represented by a “Bid Sample Std Error” value related to the bid sample size, and the variance in the current AP’s distance measurement is represented by a “Long Term Std Error” value related to the long term distance sample size. It is advantageous to minimize the error in the distance measurement for a given entry n, in comparison to the STA’s current AP. This is done by using a corrected distance that is set to the distance to the STA’s current AP, if the entry falls within the sum of the standard errors on the two distance measurements. The corrected distance, “corrected_distance”, is determined as follows:

```

IF ( ABS [knownAPs[n].distance – knownAPs[myAP].distance] ≤
      (Bid Sample Std Error + Long Term Std Error) ) (step 470) THEN
      corrected_distance = knownAPs[myAP].distance (step 472)
ELSE corrected_distance = knownAPs[n].distance; (step 474)

```

4.c.1 Distance to Load Factor Conversion

The corrected distance to each AP 12 is recorded in the STA knownAPs list. This distance is then used in conjunction with data related to the particular wireless environment in which the AP 12 is operating to derive an estimate on the expected load factor for the STA. For example, in an 802.11 environment, the distance and 802.11

mode (a,b,g) are used to retrieve the expected data rate for the STA 16 from the distance_to_rate table:

```
knownAPs[n].data_rate = distance_to_rate [knownAPs[n].mode ]  
                                [ knownAPs[n].corrected_distance ] ;  
                                (step 376)
```

An example of distance to rate calculations for 802.11 modes is shown in Table II in Figure 31.

Then, the expected load for this datarate is retrieved from the rate_to_load table:

```
knownAPs[n].my_load_factor = rate_to_load[ knownAPs[n].data_rate ]; (step  
478)
```

An example of a rate_to_load table for 802.11 networks is shown in Table III in Figure 32. One skilled in the art will realize how to implement distance-to-rate and rate-to-load tables from specifications for other wireless environments. The corrected_distance and my_load_factor parameters are determined in this manner for each entry n in the STA Known APs table 430.

Any entries in the knownAPs list that represent non-DRCP APs need to be given default values for their load_factors so that they can be considered by the Stations for associations as well. These default load_factors are derived from a default number of STAs per AP value that should be consistent across the network and a default “average data rate” per technology. That is:

```
if (knownAPs[n].DRCP_Enabled == FALSE) then  
    knownAPs[n].load_factor = STAs_per_AP *
```


rate_to_load [default_rate [knownAPs[n].mode]];

When determining the load of the STA 16's current AP (myAP), when myAP is a non-DRCP AP, then its default load_factor value is preferably incremented by the STA's load on that AP. This helps to support a consistent view of the load of that AP both before and after a STA associates with it – that is, since the STA adds its own load to the default load of its prospective (non-DRCP) AP before it makes a decision to associate with it, it must also add its load to the default load for this AP after it has associated with it.

4.c.2 Biased distance calculation

Using the my_load_factor to the AP 12, the load_factor currently on the AP 12 (received from Announce messages) and the corrected distance to the AP 12, the STA 16 calculates a biased_distance value to account for the loading on the prospective AP 12 in comparison to the loading on the STA 16's current AP, as shown in Figure 29. The biased distance is calculated as described by the following formula:

$$\text{knownAPs}[n].\text{biased\_distance} = \frac{\text{knownAPs}[n].\text{corrected\_distance} * (\text{knownAPs}[n].\text{load\_factor} + \text{knownAPs}[n].\text{my\_load\_factor})}{\text{knownAPs}[\text{myAP}].\text{load\_factor}} \quad (\text{step 490})$$

Next, a biased distance to the STA 16's current AP 12 is calculated to account for the loading on the current AP 12 relative to the loading on the prospective AP. This calculation is made as follows:

```

knownAPs[n].my_ap_rel_biased_distance =
    knownAPs[myAP].distance *
    knownAPs[myAP].load_factor /
    (knownAPs[n].load_factor + knownAPs[n].my_load_factor) (step 492)

```

Finally, the difference between the biased distance to the prospective AP and the relative, biased distance to the STA 16's current AP is determined, as follows:

```

knownAPs[n].biased_distance_delta =
    knownAPs[n].my_ap_rel_biased_distance - knownAPs[n].biased_distance
(step 494)

```

After calculating the biased_distances and biased_distance_deltas for all of the APs in the knownAPs list, the STA 16 checks to see if any of the biased_distance_delta values are positive (step 496). If not, then the STA 16's current AP is still the best AP, so the STA 16 remains associated with its current AP (step 498). Of any positive biased_distance_delta values, the best AP is the one with the highest positive biased_distance_delta value (step 500). If the best AP is not DRCP enabled (step 502), then the STA 16 associates with that AP (step 504). If the best AP is a DRCP AP (step 502), then a Bid is sent (step 506) and the STA 16 resumes normal operation until it either receives a DRCP Accept or it completes another Canvass Sample Number passes of all channels. If there is more than one AP with the same highest biased_distance_delta values (step 508), the STA 16 checks to see if any of them is the last AP to which it Bid (step 510) and if so, it selects that one again (step 512).

If a DRCP Accept is received with the AP-ID matching the selected APs AP-ID (step 514), the STA sets its TP backoff value to zero (step 516) and associates with the

AP from which the Accept was received (step 518). The STA 16 now sends a DRCP Registration Request to the AP (step 520) and starts a timer (step 522) to go off every Registration Timeout Interval. When the timer expires (step 524), the STA 16 sends out another DRCP Registration Request and resets the timer. Upon receipt of a DRCP Registration Acknowledge (step 526), the timer is disabled (step 528).

If no DRCP Accept is received (step 414) in response to the STA's Bid message after a certain period of time (step 530), the STA remains associated with its current AP.

After the STA 16 has associated with a new AP, the STA 16 waits until it has collected a large number, Long Term Sample Size, of distance measurements to its new AP before it resumes this process of evaluating the knownAPs table for bidding.

4.d STA Movement Detection

When a STA 16 is associated with an AP 12, the STA 16 receives DRCP Announce messages from all APs 12 within the range of its radio. Referring to Figure 34, once the STA 16 has collected Long Term Sample Size of distance measurements from Announce messages received from its AP 12 (step 540), it can begin the movement detection process.

The STA 16 continuously collects Short Term Sample Size distance values to the current AP (step 542). To detect movement, the STA 16 compares the distance to its AP 12, derived from averaging over the long term using Long Term Sample Size, to the short term distance, derived from averaging the most recent Short Term Sample Size samples.

This difference is compared to a Moving Threshold value plus the standard error in these two measurements in order to eliminate false movement detection. A station is considered to be moving when the short term distance exceeds the long term distance by more than the Moving Threshold plus the sum of the errors in the two measurements. The following pseudo code describes this comparison.

```
IF ((knownAPs[myAP].short_term_distance - knownAPs[myAP].distance) >
    (movingThreshold + longTermStdError + shortTermStdError)) (step
544) THEN
    moving = TRUE      (step 546)
ELSE moving = FALSE;  (step 547)
```

Once the STA 16 detects that it is moving (step 446), and as long as the STA 16 does not detect that it has stopped moving, the STA 16 refrains from participating in the bidding process (step 548), seeking a new AP only if warranted by the deterioration of its current association. If the STA 16 determines that it is no longer moving before the STA 16 loses the association to its AP, the STA 16 resumes normal operation including participation in the bidding process.

As in movement detection, to detect that the STA 16 has stopped moving, the STA 16 compares the distance to its AP 12, derived using the Long Term Sample Size, to the distance derived from the most recent Short Term Sample Size samples. The STA 16 looks to see when this difference is less than just the standard error in the two measurements to determine that the STA 16 has stopped moving. The following pseudo code describes this test.

IF ((knownAPs[myAP].short_term_distance - knownAPs[myAP].distance) <
(longTermStdError + shortTermStdError)) (step 550) THEN
moving = FALSE (step 552)

If the STA 16 determines that it has stopped moving, the bidding process is restarted (step 554).

5. Software Architecture

In accordance with the preferred embodiment, the previously described functionality is implemented in software in APs 12 and STAs 16 respectively. Referring to Figure 35, the software is implemented in accordance with a layered architecture, such that it contains a platform dependent module that interacts with a platform independent module. This architecture is advantageous for porting the inventive functionality between different wireless architecture platforms. As shown each AP 12 includes a platform independent module 560 that interacts via an AP API 562 with an AP platform dependent module 564. Likewise, each STA 16 (one shown) includes a STA platform independent module 566 that interacts via a STA API 568 with a STA platform dependent module 570. In environments where the APs 12 are connected to each other via a wired network 14, DRCP messages may be passed directly between the APs 12 via the wired network 14. In environments where the APs are interconnected via only the wireless network 15, APs 12 interact with each other and with STAs 16 by passing DRCP messages to the respective platform dependent layer, which causes wireless platform

specific protocol messages to be passed between the APs 12 and STAs 16 to implement the DRCP protocol.

Referring to Figure 36, there is shown a representation of the AP architecture of Figure 35 as it applies to in an 802.11 networking environment. The AP Radio Management Agent (ARMA) 580 is the platform independent layer of the software. The AP Radio Manager (ARM) 582 is the platform dependent layer of the software. The ARM software is actually implemented within several different 802.11 platform specific elements of the AP. More information on these elements can be found in the incorporated 802.11 specification.

Referring to Figure 37, the Station Radio Manager (SRM) 584 is the platform dependent portion of the STA software. As shown, the SRM communicates with various 802.11 platform specific elements. The Station Radio Management Agent (SRMA) 586 is the platform independent portion of the STA software. Likewise, the AP radio manager is the platform dependent portion of the AP software, communicating with 802.11 platform specific elements. SRMAs communicate with ARMAs through the use of DRCP messages as previously described.

These DRCP messages are now described in further detail. Generally, DRCP messages could be encoded as standard LLC data frames, and the invention does not preclude such an implementation. But, according to the preferred embodiment as implemented in an 802.11 networking environment, DRCP management messages are encoded as new types in existing Class 1 Frames. DRCP messages are addressed either to a Group MAC Address, or to an individual MAC address, and are distinguished by the

presence of the DRCP Protocol Identifier in the Protocol Identification Field of a SNAP PDU.

The DRCP messages are now described in detail as they operate on an IP WLAN. Some DRCP messages are transmitted as IEEE 802.11 MAC management frames of subtype Beacon on the wireless LAN only, while others are transmitted as data frames encoded as LLC 1 Unnumbered SNAP PDUs on the wireless LAN or the wired/wireless network between APs.

Figure 38 shows the encoding of a DRCP message in an IEEE 802.11 Beacon frame. The DA field is set to a specific DRCP group MAC address as appropriate to the message type, and the BSS ID is a DRCP specific BSS-ID. The fixed portion of the Beacon frame is as defined in the 802.11 standard, and the variable portion of the frame is replaced by the information element created to carry a DRCP protocol message. In accordance with a preferred embodiment, it is desirable for DRCP enabled APs to perform automatic channel selection and load balancing by exchanging DRCP Claim, Preclaim, and Announce messages in management frames of subtype Beacon, while preventing STAs from attempting to associate with an AP in response to receipt of one of these messages. Several steps are therefore taken in addition to the DRCP protocol specific address fields already mentioned. First of all, the “Element ID” field includes an OUI specific to the DRCP protocol, which alerts DRCP enabled APs and STAs that the frame holds a DRCP message. Furthermore, standard (non-DRCP) 802.11 Beacons include in the body of the frame field certain fields such as “Supported Rates”, “FH Parameter Set”, “DS Parameter Set”, “CF Parameter Set”, etc. (Refer to the incorporated

802.11 standard document for more information.) Management frames of type Beacon encoding 802.11 Claim, Preclaim, and Announce messages either do not include these fields, or set them to a null value. Non-DRCP STAs that might otherwise attempt to use the DRCP Beacon type frames for association cannot do so due to the lack of this information.

Figure 39 shows the encoding of a DRCP message within an 802.11 MAC Data frame, of subtype Data. DRCP messages are addressed either to an individual MAC address or to one of the DRCP Group MAC addresses, and are distinguished by the presence of the DRCP Protocol Identifier in the Protocol Identification Field of a SNAP PDU. DRCP messages that are transmitted over the DS may be formatted as shown, or may be similarly encoded in another MAC data frame depending upon the DS media.

In accordance with the preferred embodiment, the SRMAs and ARMAs interact with the SRMs and ARMs to generate and/or collect information needed to produce or interpret DRCP protocol messages. It is noted that the DRCP protocol could be implemented over non-802-11 primitives without departing from the principles of the invention. The following describes the primitives used in an 802.11 environment.

5.a Enhancements to Standard 802.11 MAC Service Interface

The ARMAs and SRMAs transmit and receive DRCP messages over a standard 802 MAC Service Interface, with some enhancement. The receive interface is enhanced in both the STA and the AP to allow the SRM and the ARM to indicate to the SRMA and ARMA respectively, the power at which DRCP messages are received. In particular, the

semantics of the 802.11 **MA-UNITDATA.indication** service primitive are modified as shown by the underlined text, to add a received power parameter as follows:

MA-UNITDATA.indication (
source address,
destination address,
routing information,
data,
reception status,
priority,
service class,
received power
)

The received power parameter specifies the signal strength, expressed in dBm, at which the MSDU was received. The received power value indicates the current level at which the sending device is heard, but does not provide an indication of whether or not the sending device is transmitting at full power. The potential power level at which a device might be heard can be determined when the transmit power backoff (i.e., the amount, in dB, by which the radio is turned down) in use by the device is also known.

5.b Enhancements to the Standard 802.11 Management Interface

BSS Description

The BSSDescription Parameter contains a list of elements that describe the BSS.

An additional element is added to this list:

Name	Type	Valid Range	Description
Received Power	Integer	-1 to -99	Indicates the power (in dBm) at which the Beacon from this BSS was received.

Send DRCP

This mechanism is provided to allow the ARMA to send DRCP Messages encoded in 802.11 Management frames of type Beacon.

MLME-SENDDRCP.request

This primitive is used by the ARMA to request that the ARM send a DRCP Message over the wireless media, encoded in an 802.11 Management frame of type Beacon. As shown in Figure 34, this is a special type of Beacon frame wherein the fixed portion of the Beacon frame is as defined as in the 802.11 standard, and the variable portion of the frame is replaced by a single information element that carries the DRCP message.

The primitive parameters are as follows:

MLME-SENDDRCP.request (Destination Address
 Message Length
 DRCP Message
 Quiet Channel
 CTS Duration
)

Name	Type	Valid Range	Description
Destination Address	MAC Address	N/A	A specific DRCP group MAC address as appropriate to the message type.
Message Length	Unsigned Integer	0..2312	Indicates the number of octets in the DRCP Message field.
DRCP Message	DRCP Message	N/A	DRCP Message

Name	Type	Valid Range	Description
Quiet Channel	Boolean	FALSE (0), TRUE (1)	Indicates whether the STAs associated to the AP should be quieted for the Beacon transfer by the transmission of a Clear To Send (CTS) frame immediately prior to the Beacon transfer.
CTS Duration	unsigned integer	16..255 μ sec	Indicates the value to be placed in the duration field of the CTS frame. The value represents the time, in microseconds, required to transmit the pending Beacon frame, plus one short interframe space (SIFS) interval. This parameter is only used when the quiet channel parameter is true.

This primitive is generated by an ARMA to request that a DRCP Message be sent on the wireless media encoded in an 802.11 Management frame of type Beacon. DRCP Claim and Hello messages are sent in this manner. As previously described, the ARMA may optionally quiet the channel before sending a DRCP Hello message by first by sending a CTS frame. In particular, if the Quiet Channel parameter is TRUE, the ARM transmits a Clear To Send (CTS) frame immediately prior to the Beacon transfer. The DRCP Hello CTS Destination MAC Address is placed in the Receiver Address (RA) of the CTS frame. The duration field of the CTS is set to the value of the CTS Duration parameter.

The fixed portion of the Beacon frame is as defined in the 802.11 standard. The DA is set to the Destination Address parameter value, the SA is the AP's MAC address, and the BSS ID is the DRCP Default BSS-ID.. The variable portion of the frame is

replaced by a single information element with an Element ID of DRCP Protocol, with a Length field value of the Message Length parameter and the Information field containing the DRCP Message.

This primitive confirms the transmission of a DRCP message to the ARMA. The primitive parameters are as follows:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-SENDDRCP.request

Power Management Fib

indicate to the AP that it is in power save mode, without actually going into power save mode.

MLME-POWERMGTFIB.request

This primitive requests the SME to use the power save mode interaction with the AP to allow time to canvass other channels. The primitive parameters are as follows:

MLME-POWERMGTFIB.request ()

Name	Type	Valid Range	Description
Null	N/A	N/A	No parameters

This primitive is generated by an SRMA to cause the MLME to borrow part of the doze time (if the STA is in power save mode) or all of the doze time (if the STA is in active mode) in order to canvass other channels.

This request causes the SRM to:

1. save the current power management mode settings
2. set:
 - a. power management = Power_Save
 - b. WakeUp = FALSE
 - c. ReceiveDTIMs = FALSE
3. signal the AP that it is using power management mode.

This request prepares the SRM to:

1. at the start of the power save cycle, signal the SRMA by sending an **MLME-PSSTART.indication** while actually keeping the power on.
2. catch any user or net manager power mode management operations and cause them to use the saved settings, not the active settings.

MLME-POWERMGTFIB.confirm

This primitive confirms the change in power management mode to the SRMA.

The primitive parameters are as follows:

MLME-POWERMGTFIB.confirm (
 ResultCode
)

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-POWERMGMTFIB.request

This primitive is generated by the MLME as a result of an **MLME-POWERMGTFIB.request** to mimic power save mode. The SRMA is thus notified of the change of power mode indicated.

Power Save Start

This mechanism notifies the SRMA that it can begin to canvass.

MLME-PSSTART.indication

This primitive indicates to the SRMA the start of the power save cycle. The STA does not actually power off its radio and enter the sleep state at this point, but preferably, it should not transmit outgoing frames after sending this indication until it receives an **MLME-PWRMGMTFIBCONTINUE.request**. The primitive parameters are as follows:

MLME-PSSTART.indication ()

Name	Type	Valid Range	Description
Null	N/A	N/A	No parameters

This primitive is generated by an SME to indicate the start of power save cycle. The SRMA is thereby notified of the start of the power save cycle.

Power Management Restore

This mechanism further supports a STA's ability to indicate to the AP that it is in power save mode, without actually going into power save mode.

MLME-PWRMGMTRESTORE.request

This primitive tells the MLME that it should restore the user-configured power save mode. This primitive allows the SRMA to tell the MLME that it no longer needs to lie to the AP about power save (that control over power save is passed back to the MLME). The primitive parameters are as follows:

MLME-PWRMGMTRESTORE.request (
)
)

Name	Type	Valid Range	Description
Null	N/A	N/A	No parameters

This primitive is generated when the canvass mechanism is taken out of service. The receipt of this primitive causes the SRM to restore the saved power management mode settings and:

1. if saved power mode was ACTIVE, immediately force the awake state;
2. if saved power mode was POWER_SAVE, continue normal power save mode operation.

MLME-PWRMGMTRESTORE.confirm

This primitive confirms the change in power management mode to the SRMA.

The primitive parameters are as follows:

MLME-PWRMGMTRESTORE.confirm (
 ResultCode
)

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME.PWRMGMTRESTORE.request

This primitive is generated by the MLME to confirm that the SME has executed an **MLME-PWRMGMTRESTORE.request**. It is not generated until the change has been indicated. Upon receipt of this primitive, the SRMA is notified of the change of power mode indicated.

Power Management Fib Continue

Once canvassing is complete, this mechanism informs the SRMA that it “has control” of the radio and communicates power save state (awake or doze).

MLME-PWRMGMTFIBCONTINUE.request

This primitive tells the MLME that it’s safe to enter the awake state and transmit frames if desired. The primitive parameters are as follows:

MLME-PWRMGMTFIBCONTINUE.request ()

Name	Type	Valid Range	Description
Null	N/A	N/A	No parameters

This primitive is generated when the SRMA is has completed canvassing. Upon receipt, the MLME enables transmission of user data frames, if necessary.

MLME-PWRMGMTFIBCONTINUE.confirm

This primitive confirms the change in allowed power management state. The primitive parameters are as follows:

```
MLME-PWRMGMTFIBCONTINUE.confirm (
                                     ResultCode
                                   )
```

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME.PWRMGMTFIBCONTINUE.request

This primitive is generated by the MLME to confirm that the SME has executed an **MLME-PWRMGMTFIBCONTINUE.request**. It is not generated until the change has been indicated. Receipt by the SRMA serves as notification of the change of the allowed power save mode.

Channel Out

This mechanism supports the ability to indicate to an ARMA that a channel has gone out of service.

MLME-CHANNELOUT.indication

This primitive reports to the ARMA that a channel that was previously available has become unavailable. The primitive parameters are as follows:

MLME-CHANNELOUT.indication (
 Channel
)

Name	Type	Valid Range	Description
Channel	Integer	0 - 255	Channel identifier

This primitive is generated by the MLME when a channel becomes unavailable. Receipt of this primitive causes the ARMA to remove the channel from its channel map.

Channel In

This mechanism provides the ability to indicate to an ARMA that a channel has gone into service.

MLME-CHANNELIN.indication

This primitive reports to the ARMA that a channel that was previously unavailable has become available. The primitive parameters are as follows:

MLME-CHANNELIN.indication (
 Channel
)

Name	Type	Valid Range	Description
Channel	Integer	0 - 255	Channel identifier

This primitive is generated by the MLME when a channel becomes available. Receipt of this primitive causes the ARMA to add the channel to its channel map.

Beacon Notify

This mechanism supports the ability to detect any other APs using the same channel.

MLME-BEACONNOTIFY.request

This primitive requests the MLME to notify the ARMA whenever a beacon is received. There is one indication for each Beacon received. An indication is generated any time a Beacon is received on the current channel. The primitive parameters are as follows:

MLME-BEACONNOTIFY.request (
 Notify Enable
)

Name	Type	Valid Range	Description
Notify Enable	Boolean	True or False	When True, indicates that the PIOTE is to be notified of any Beacons received. When False, this mechanism is to be disabled.

This primitive is generated by an ARMA when it wants to be notified of any beacons received on its own channel. Receipt of this primitive by an MLME causes the MLME to enable a mode whereby the ARMA will be notified if any Beacon is received.

MLME-BEACONNOTIFY.confirm

This primitive confirms the change in the beacon notification mechanism. The primitive parameters are as follows:

MLME-BEACONNOTIFY.confirm (
 ResultCode
)

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-BEACONNOTIFY.request

This primitive is generated by the MLME as a result of an **MLME-BEACONNOTIFY.request**. Receipt of this primitive by the ARMA serves as notification of the change of Beacon Notify as indicated.

MLME-BEACONNOTIFY.indication

This primitive reports to the ARMA that a Beacon was received on the data channel. The primitive parameters are as follows:

MLME-BEACONNOTIFY.indication (
 BSSDescription
)

Name	Type	Valid Range	Description
BSSDescription	BSSDescription	N/A	The BSS Description (including any additional Description Elements defined in 0) pertaining to an individual Beacon that was received.

This primitive is generated by the MLME if a beacon is received on the data channel. Note that a separate **MLME-BEACONNOTIFY.indication** is generated for each beacon received, so the primitive parameter will only ever contain a single BSSDescription. Upon receipt of this primitive, The ARMA is notified of the Beacon and the signal strength at which it was received.

5.c DRCP Messages Preferred Implementation

The following describes the manner in which the above described primitives are used to implement DRCP messages in an 802.11 environment. Figure 40 shows a summary of the DRCP messages that are used to implement the previously described functionality. Figure 41 shows field definitions used in DRCP messages, as follows:

DRCP Preclaim

Fig. 42 shows the format of the DRCP Preclaim message. A DRCP Preclaim message is encoded in an 802.11 Management frame of type Beacon. The ARMA sends a DRCP Preclaim message using the MLME-SENDDRCP.request management primitive with the following parameters:

Destination Address - DRCP All ARMAs Group MAC Address
Message Length - 12
DRCP Message - Preclaim Message
Quiet Channel - FALSE (0)
CTS Duration - 0

DRCP Claim

Fig. 43 shows the format of the DRCP Claim message. A DRCP Claim message is encoded in an 802.11 Management frame of type Beacon. The ARMA sends a DRCP Claim message using the MLME-SENDDRCP.request management primitive with the following parameters:

Destination Address - DRCP All ARMAs Group MAC Address
Message Length - 16
DRCP Message - Claim Message
Quiet Channel - FALSE (0)
CTS Duration - 0

DRCP Announce

Figure 44 shows the format of the DRCP Announce message. A DRCP Announce message is encoded in an 802.11 Management frame of type Beacon. The ARMA sends a DRCP Announce message using the MLME-SENDDRCP.request management primitive with the following parameters:

Destination Address - DRCP All Agents Group MAC Address
Message Length - 16
DRCP Message - Announce Message
Quiet Channel - FALSE (0)
CTS Duration - 0

DRCP Bid

Figure 45 shows the format of the DRCP Bid message. A DRCP Bid message is encoded as an LLC 1 Unnumbered SNAP PDU in a data frame. The message is addressed to the Individual MAC Address of the AP in which the target ARMA is instantiated. The SRMA sends a DRCP Bid message over the standard MAC Service Interface.

DRCP Accept

Figure 46 shows the format of the DRCP Accept message. A DRCP Accept message is encoded as an LLC 1 Unnumbered SNAP PDU in a data frame. The message is addressed to the Individual MAC Address of the STA in which the target SRMA is instantiated. The ARMA sends a DRCP Accept message over the standard MAC Service Interface for relay to the DS.

DRCP Registration Request

Figure 47 shows the format of the DRCP Registration Request message. A DRCP Registration Request message is encoded as an LLC 1 Unnumbered SNAP PDU in a data frame. The message is addressed to the Individual MAC Address of the AP in which the target ARMA is instantiated. The SRMA sends a DRCP Registration Request message over the standard MAC Service Interface for relay to the DS.

DRCP Registration Acknowledge

Figure 48 shows the format of the DRCP Registration Acknowledge message. A DRCP Registration Acknowledge message is encoded as an LLC 1 Unnumbered SNAP PDU in a data frame. The message is addressed to the Individual MAC Address of the AP in which the target SRMA is instantiated. The ARMA sends a DRCP Registration Request message over the standard MAC Service Interface for relay to the DS.

6. Movement detection

As previously described, APs and STAs ascertain movement based upon evaluation of short and long term averages of parameters, along with expected error measurements. In accordance with an aspect of the invention, movement detection is achieved through application of a broader inventive concept that provides a way to ascertain the dynamic attributes of a system based upon short and long term averages of discrete data measurements. The principles of this invention apply to any system in which a discretely measured variable may change widely. For purposes of clarity, however, the invention is now described in terms of its particular application to wireless networks.

In a wireless network such as the one shown in Figure 1, a wireless networking user (heretofore also referred to as “STA”) is associated with an access point (AP). The AP provides associated users with network connectivity via radio frequency (RF) signals. Various APs are used to provide seamless RF coverage, so that when the user moves away from one AP toward another AP, the user will associate with the closer AP (or the

AP that is more lightly loaded) and seamless network functionality is thereby maintained. It is therefore important to be able to ascertain the location of a user relative to an AP so that a determination can be made as to whether the user is currently moving. This allows the system to assure that the user rapidly becomes associated with the closest AP so the overall system performance is maximized. As a user moves toward or away from an AP, the received power level (i.e. the power of the RF signal received by the user from the AP) goes up or down respectively. Thus, one way to ascertain user movement is by monitoring received power levels.

However, received power levels can appear to vary greatly even when a user is not moving. For example, the opening or closing of a doorway can cause either a gain or attenuation in the user's received power level. A person waving their hand near the user's antenna can even cause a gain or attenuation in received power level.

Environmental interference can also cause changes in received power levels. These various changes in power level can cause a user to appear to be moving when in fact he or she is not. This can cause the user to roam needlessly between APs, particularly in environments where APs are close together and their transmit power levels are lower than maximum power. Alternatively, variations in signal power due to these effects can mask the fact that the user is indeed moving. In this case, the system could fail to detect the motion and fail to associate the user with the appropriate AP. Figure 49 shows an example graph of discrete measurements of received power vs. time for a user who is not moving. As can be seen, the inaccuracies in data sampling prevent any assumption of movement in one direction or the other.

As a more particular example, consider an 802.11a wireless network. APs in such a network provide a maximum bandwidth of 54Mbps. Bandwidth drops with distance from the AP. Assume that adjacent APs have their transmit power adjusted so that each provides a 54 Mbps cell on the order of about 10 feet in diameter. A walking user might be able to transition through such a cell in 2 seconds. On the other hand, a user sitting at his desk (near the center of the cell, right next to the AP) who gets up and leaves travels only 5 ft, not 10 ft to the edge of the cell – so, it may take the user only just over a second to be in the aisle and out of the cell. These examples provide a motivation for why rapid power estimates based on discrete measurements must be made. Increasing sampling rates increases accuracy, but this also causes more overhead in terms of wireless channel bandwidth, interrupt activity and processing overhead on the user device. Some user devices could be simple appliances such as phones, digital assistants, etc. and have very limited processing power. So a trade-off must be made between sample rate and overhead.

According to one possible implementation, power levels are measured at intervals over a window of time and a roaming decision is made. In an 802.11a network, when a user is about 1ft from an AP whose power is set so that it has a 54 Mbps cell which is about 10 ft in diameter, the user's true mean power level should be about -38dbm. Assume a 99% confidence interval around the true mean (i.e. the power level to be estimated) is desired. Yet, there is a variability to the measurements because of environmental effects (hand waving, etc.) as well as inherent inaccuracy in the implementation measurement itself. Assume these inaccuracies and statistical variability

in the data result in distribution of the data with a standard deviation, $\sigma = 15$ dbm.

Referring to Figure 50, if only 8 samples are taken in such a statistical distribution, then the 99% confidence interval around this (true) mean is -23.4 dbm to -52.6 dbm.

The 99% confidence interval has a range of $|52.6 - 23.4| = 29.2$ dbm, or about 30dbm. This is about ± 15 dbm. So, because of the variability in the signal, if only 8 samples are taken, all that can be known is that the “true power” lies somewhere between -23.4dbm and -52.6dbm and that such conclusion can be drawn with 99% assurance.

If less accuracy can be tolerated, for example 95% or even 90% confidence, the resultant range would be narrower. But, lower confidence intervals increase the likelihood of “false positives”. A false positive occurs when a user is ascertained to be moving when in fact he or she is not, causing the user to needlessly roam to another AP. It is desirable to minimize such false positives as they needlessly consume valuable bandwidth.

When a user doubles his or her distance from an AP, the user’s received power decreases by 6db. So, when a user moves from 1 foot away to 2 feet to 4 feet away from the AP (almost to the edge of the cell), the (true) average received power has decreased from -38dbm to -44dbm to -50dbm respectively. But, as seen in Figure 51, when trying to estimate the average received power from eight samples taken during this motion with a 99% confidence interval in the data, it cannot be ascertained that the user has moved. This is because the true mean is really unknown. All that is known is that it lies somewhere between -23.4dbm and -52.6dbm. So, when only these few samples are

taken, it cannot be ascertained whether the user is moving away from the AP, getting closer to the AP, or not moving at all.

Of course increasing the number of samples taken decreases the range of error. If 20 power samples are taken, then the 99% confidence interval is -29.1dbm to -46.9dbm. But, taking lots and lots of samples will take too long unless channel overhead is increased.

Now consider taking n samples to produce an estimate, and then taking n more to produce a second estimate. The two estimates are then compared to see if a conclusion can be drawn as to whether the user is moving. If the confidence intervals around each estimator are large, e.g. 99%, then there exists a spectrum of outcomes and again it cannot be ascertained as to whether the user is moving toward or away from the AP, or not moving at all. In Figure 51, to tell that the user is moving away from the AP with 99% assurance, the upper edge of the right confidence interval must be positioned below the lower edge of the left confidence interval.

Consider two basic scenarios regarding motion in wireless networks:

- (1) The user stays in one place for a reasonable time and then moves to a new place. The user requires communication while moving, but, the user tends to move and then stop and stay somewhere for a while. Or similarly, the user may move very slowly within one confined area, and then move more rapidly to another area.
- (2) The user is constantly in motion.

In the instance of scenario #1, which describes the very large majority of user activity in wireless networks, the accuracy of the power estimate can be greatly

improved. In accordance with the principles of the invention, two averages of the received signal strength are maintained as above. But, one is the most recent N_1 samples taken over a sliding window, and the other is a long term average, using N_2 samples. So both a long term average and a short term average are maintained. Referring to Figure 52, the confidence interval around the long term average is very small. The error in the estimate is almost completely removed. Therefore, the potential uncertain outcomes in the decision are reduced.

In Figure 53, when the user is moving away from the AP, the upper edge of the right confidence interval will fall below the long term average (which has essentially a confidence interval of close to $\pm 0\text{db}$.)

For a given application, one needs to ascertain how many samples (N_2) must be taken such that the long term average estimate has essentially 0 error. Also, it is desirable to ascertain how few samples (N_1) are needed in the short term average to be able to make a decision with 99% accuracy.

Assume a user starts at a position 1 foot away from the AP and moves towards the edge of the 10 ft cell. The goal is to find out how few samples are required to ascertain that the user is moving with 99% accuracy, in order to produce the most robust implementation from an overall performance perspective. If it were possible to “perfectly” measure power, a -6 db drop would be observed each time the user doubles his distance from the AP. Referring to Figure 54, if the power level is -38 dbm when the user is at 1 foot, it is -44 dbm at 2 feet and -50 dbm at 4 feet which is almost at the edge of the cell. As can be seen in the Figure, when the short term average is -50 dbm and the

upper edge of the 99% confidence interval is just below -38 dbm, then the confidence interval has a width of ± 12 db. To achieve such a confidence interval, 14 samples (N_1) are required in the short term, given the previously assumed standard deviation of the data, $\sigma = 15$ db. With these 14 samples, the 99% confidence interval is $-60.7\text{dbm} < -50 < -39.2\text{dbm}$.

In this wireless network example, it has been assumed that a user can walk from the center of the cell to the edge of the cell in 1.5 seconds. So, samples need be taken every $1.5 \div 14 \approx 100$ milliseconds. As a further improvement, it would be desirable to use 16 samples so that division can be done by a processor via a shift operation. This increases computational efficiency on the user's machine. This increases the sample rate a negligible amount.

Regarding the long term average, it may be reasonable to tolerate a ± 1 db confidence interval around the long term estimate. The tighter this interval needs to be, the longer the user has to stay near the AP, or stay relatively stationary within a certain area, to cause the average to converge. It is desirable to calculate how little time the user needs to stay in place to achieve an accuracy of ± 1 db with 99% confidence. Assume, reasonably, that signal strength samples are taken based on messages received from the AP every 50 milliseconds. Referring to the table shown in Figure 54, it is seen that if the user stays near the AP (1 ft) for about 1.5 minutes, and samples occur every 50 milliseconds, the accuracy of the power estimate becomes less than ± 1 db.

The preferred implementation for the current wireless network example thus utilizes: (a) a short term average over $N_1 = 16$ samples, (b) a long term average over 2048

samples, and (c) “ N_2 ” which is the number of samples taken so far in computing the long term average. The process is as follows:

- (1) continually calculate the long term average. The long term average is not “stable” until at least 2000 samples have been taken. This takes 1.5 minutes at 50 milliseconds per sample. An implementation preferably accumulates 2048 samples to make the division a shift operation.
- (2) calculate a short term average with the most recent $N_1 = 16$ samples. (16 is used instead of 14 so that the division is accomplished via a shift.)
- (3) When the difference between the short term and long term averages is greater than 12db then it is known with 99% accuracy that the user is moving.
- (4) When the user roams to a new AP, the counter used to calculate the long term average samples is reset to 0. Then the long term average is not stable again for another 2048 samples.

In an environment where users tend to remain in a cell for less than 1 second, the long term estimate could be used based on fewer samples. However, this will result in an increased risk of false positives. Several alternatives can be considered to mitigate the occurrence of false positives:

- (1) if the user has just arrived in a new cell (i.e. $N_2 \leq 32$) then require at least 32 samples before allowing a power-based roaming decision. This puts some hysteresis into the

system. There will be some false positives though. If the user roams to a new AP and then back to the old one, false positives may be occurring. It may then help to require that $N_2 \leq 64$ for example. This helps the confidence interval making it - $42.8\text{dbm} < -38 < -33.1\text{dbm}$.

- (2) Take into account the signaling rate. For example, the long term average accumulates while the number of samples (N_2) grows. But, if the user's data rate has dropped, then the user has moved outside the 54 Mbps inner circle by definition. Roaming should be initiated at this point.
- (3) Once a user has roamed to a new cell, the user should become "sticky" and try to stay there until the user is near the edge of the cell. Here it may be useful to require that $N_2 \geq 128$, for example, plus see the data rate drop.

To generalize, in a system wherein particular dynamic attributes are to be ascertained (e.g. "is the wireless network user in motion"), short term and long term averages of a system variable (e.g. signal strength) are calculated. An acceptable difference between the short and long term averages is calculated which positively identifies the system characteristic (e.g. the user has moved.)

Referring to Figure 55, the steps are generally as follows:

1. Define a system dynamic attribute to be ascertained (step 600). For example, in the wireless network example, the dynamic attribute to be ascertained is whether a user is moving. In the network usage example, the dynamic attribute to be ascertained is whether bandwidth for a user should be increased.

2. Define a system variable to be monitored to ascertain the dynamic attribute (step 602). For example, in the wireless network example, the variable is received signal strength. In the network usage example, the variable could be number of packets injected onto the network by the user.
3. Ascertain the statistical characteristics of the system variable measurements (step 604) . This will include specification and analysis of individual system and environmental factors that contribute to statistical variations in the system variable(s). In the wireless network example, the standard deviation of the signal strength measurement is affected by environmental noise, implementation imprecision, spatial events and motion. In the network usage example the standard deviation is affected by the degree of burstiness in the traffic generated by the user, the speed of the user's computer, contention and interleaving effects with other network traffic, and higher layer network protocol parameters.
4. Choose the range of the true mean for the system variable that would indicate that the dynamic system attribute has been identified (step 606). For example, in the wireless network example, when the true mean of the signal strength has changed by 12db, the system attribute– the user has moved – has been positively identified. In the network usage example, one may decide that when the true mean for number of packets injected into the network by a user has exceeded a threshold, the user's bandwidth should be increased.
5. Pick a confidence interval based on the accuracy of decisions to be made regarding the dynamic system attribute (step 608). The rate of "false positive"

decisions and “false negative” decisions is controlled by how accurately the dynamic system attribute is estimated. Calculating that attribute with a higher confidence interval improves that accuracy. In the wireless network example, the confidence interval was 99%.

6. Calculate the number of samples of the variable that must be taken such that the confidence interval around a given metric (such as the average) results in a spread that is minimized to a pre-determined amount based on the decision accuracy desired (step 610). In the wireless network example, this was +/- 1db.
7. Set a long term average based on at least the number of samples obtained in step 6 (step 612). (This average is cumulative as opposed to a moving window.)
8. Given the range chosen in step 4, calculate the number of samples of the variable that must be taken such that the confidence interval around a given metric (such as the average) results in a spread that is less than the range (step 613). This calculation depends upon the standard deviation in a known manner. This calculation is well known in the field of statistics as “sample size estimation”. Statistical studies which use a subset (N) of members of a population need to be designed so that inferences taken from the sample set are statistically significant and representative of the entire population. Specific knowledge, or implicit assumptions, regarding the statistical characteristics of the dynamic system variables obtained in Step 3 are used to compute the sample set size. For more information on known statistical methods for sample size computation, reference is made to "Statistical Analysis", Sam Kash Kachigan, Radius Press, NY 1986

(ISBN: 0-942154-99-1), and in particular to Section 8-11, pg 157, "Parameter Estimation, Sample Size Selection for Limiting Error", and Section 9-10, pg 189, "Sample Size Selection for Desired Power"

9. Set a short term average moving window based on the number of samples obtained in step 8 (step 614).
10. Calculate the absolute difference between the long term average and the short term average (step 516). If the difference is greater than the range chosen in step 4, then the dynamic system attribute has been positively identified (step 618). In the wireless network example, when the difference exceeded the range, it was known with 99% confidence that the user was moving or had moved. In the network usage example, if the difference between short term average packet count and long term average packet count exceeds the chosen range, this indicates that the user should be granted higher bandwidth. If the difference between the long term average and the short term average is greater than the range chosen in step 4, then the dynamic system attribute has not been positively identified (step 620), and N1 moving window samples continue to be collected.

In Figure 56 there is shown a block diagram showing a wireless networking system that implements the invention. A user (STA 16) communicates with an AP 12 over the wireless network. The user sends messages to the AP that indicate the received signal strength from the AP as perceived by the user. These messages are collected by the AP (640). A processor 642 in the AP uses the messages to compute the short and long term

averages according to the process as described in Figure 55. When it is ascertained that the user has moved, an indication 644 is set.

In Figure 57 there is shown a block diagram of a preferred embodiment of a wireless networking system that implements the invention. A user device (STA 16) communicates with an AP over the wireless network. The user message collection mechanism 646 receives messages from the AP and monitors the received signal strength of the messages. A processor or hardware state machine 648 in the user device uses the signal strength of the messages to compute the short and long term averages according to the process as described in Figure 55. When the user device ascertains that it is moving, the user sends an indication or message 650 to the AP requesting to roam.

In Figure 58 there is shown one mechanism that can be used by the processor in the implementations of either Figure 56 or Figure 57 to maintain the short and long term averages needed to perform the process of Figure 55 to ascertain movement. Two ring buffers 652 and 654 are maintained – one for the short term average and one for the long term average. Ring buffers are used so that power sample averaging can be accomplished over a sliding window in time. In a ring buffer, as a new sample is added to the buffer, the oldest sample is removed. In the wireless networking example previously described, the short term average ring buffer stores the most recent 16 samples, and the long term average ring buffer stores on the order of 1024 or 2048 samples. Of course these sample sizes will vary depending on the application. It may also be reasonable to use an accumulator-based average for the long term average, but such an approach could be subject to buffer overflow.

A short term average 656 and long term average 658 are calculated based on the contents of the respective ring buffers 652 and 654. A comparator 660 uses a stored allowed range 662 and the short term average 556 and long term average 658 to produce the movement indication 650 in accordance with the process of Figure 55.

In Figure 59 there is shown an alternate mechanism that can be used by the processor in either Figure 57 or Figure 56 to maintain the short and long term averages needed to perform the process of Figure 55 to ascertain movement. According to this mechanism, a ring buffer accumulates a small number of samples, for example 16, for computation of the short term average. Each short term average computation is saved (656a – 656n). After a certain number of short term averages have been computed and saved, the long term average is computed as the average of all the accumulated short term averages. This approach is known as “batched means”. This approach is advantageous for use in systems containing limited memory resources.

Though the above described aspects of the invention have been exemplified as they apply to wireless networks and, in some particularity, 802.11 networks, it will be clear to the skilled practitioner that the invention can be employed in any wireless communications environment, including wireless data networks, wireless phone networks, and wireless I/O channels. All aspects of the invention may be implemented in either hardware or software. The preferred embodiment has been described as a software architecture because of its advantageous ease of portability between various hardware platforms.

It will be understood that each block of the flowchart illustrations, and combinations of blocks in the flowchart illustrations, can be implemented by computer program instructions. These computer program instructions may be loaded onto a computer, embedded device microprocessor (such as that found in an AP or STA), or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks. These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means which implement the function specified in the flowchart block or blocks. The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart block or blocks.

Those skilled in the art should readily appreciate that programs defining the functions of the present invention can be delivered to a computer in many forms; including, but not limited to: (a) information permanently stored on non-writable storage media (e.g. read only memory devices within a computer such as ROM or CD-ROM disks readable by a computer I/O attachment); (b) information alterably stored on

writable storage media (e.g. floppy disks and hard drives); or (c) information conveyed to a computer through communication media for example using baseband signaling or broadband signaling techniques, including carrier wave signaling techniques, such as over computer or telephone networks via a modem.

While the invention is described through the above exemplary embodiments, it will be understood by those of ordinary skill in the art that modification to and variation of the illustrated embodiments may be made without departing from the inventive concepts herein disclosed. Moreover, while the preferred embodiments are described in connection with various illustrative program command structures, one skilled in the art will recognize that the system may be embodied using a variety of specific command structures. Accordingly, the invention should not be viewed as limited except by the scope and spirit of the appended claims.

We claim:

1. Apparatus for use in a wireless network, comprising:

control circuitry; and

a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, and to transmit a signal with information indicative of a level of attenuation of the communication signals by the variable power transmitter relative to the maximum power level.

2. The apparatus of claim 1 further including a receiver operative to receive, from a second wireless device, a signal with information indicative of level of attenuation of signals by the second wireless device relative to the maximum power level, and wherein the control circuitry is operative to store the information in a memory.

3. The apparatus of claim 2 wherein the control circuitry is further operative to communicate with the second wireless device to select a power level for transmission of wireless signals.

4. A method for operating a device in a wireless network, comprising:

selecting a power level at which to transmit wireless signals;

transmitting communication signals at the selected power level; and

transmitting a signal with information indicative of a level of attenuation of the communication signals relative to a maximum power level.

5. The method of claim 4 including the further step of receiving, from a second wireless device, a signal with information indicative of level of attenuation of signals by the second wireless device relative to the maximum power level, and storing the information in a memory.

6. The method of claim 5 including the further step of communicating with the second wireless device to select a power level for transmission of wireless signals.

ABSTRACT OF THE DISCLOSURE

The performance and ease of management of wireless communications environments is improved by a mechanism that enables access points (APs) to perform automatic channel selection. A wireless network can therefore include multiple APs, each of which will automatically choose a channel such that channel usage is optimized. Furthermore, APs can perform automatic power adjustment so that multiple APs can operate on the same channel while minimizing interference with each other. Wireless stations are load balanced across APs so that user bandwidth is optimized. A movement detection scheme provides seamless roaming of stations between APs.

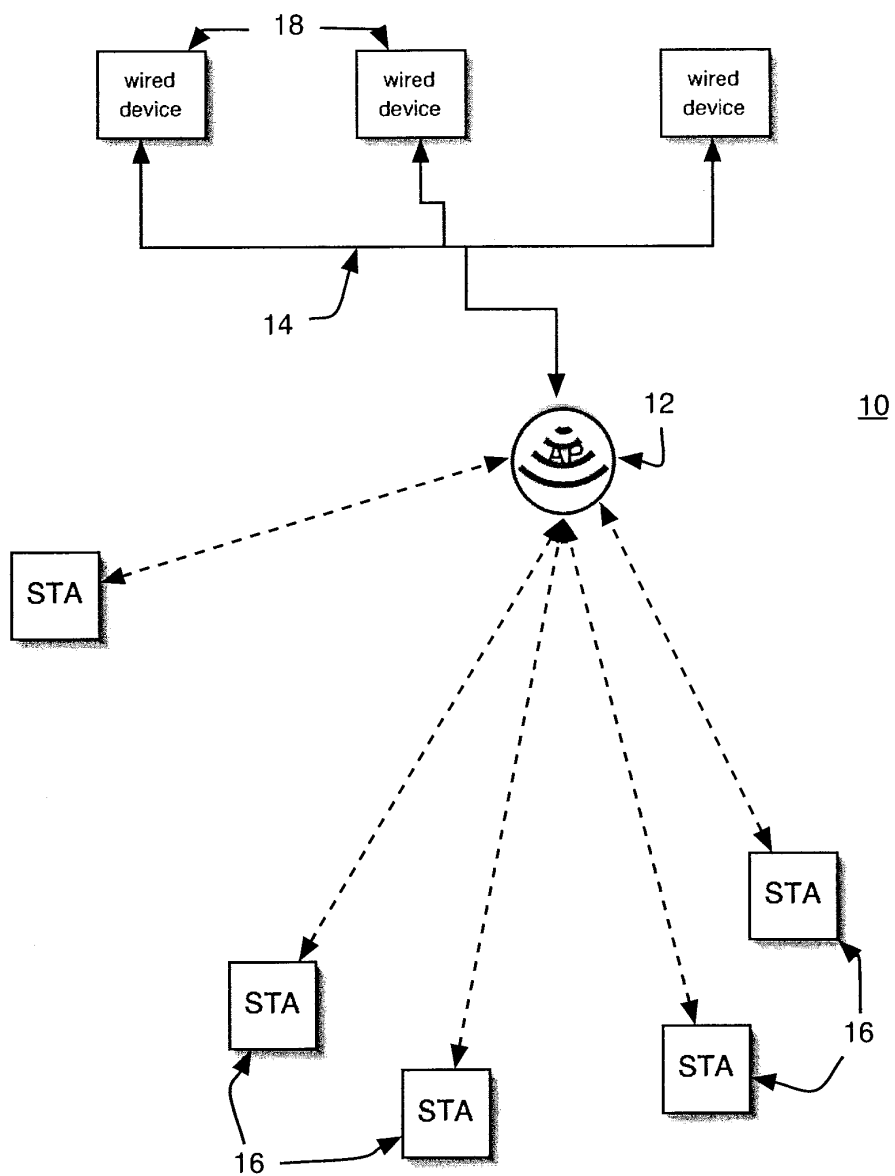


Fig. 1

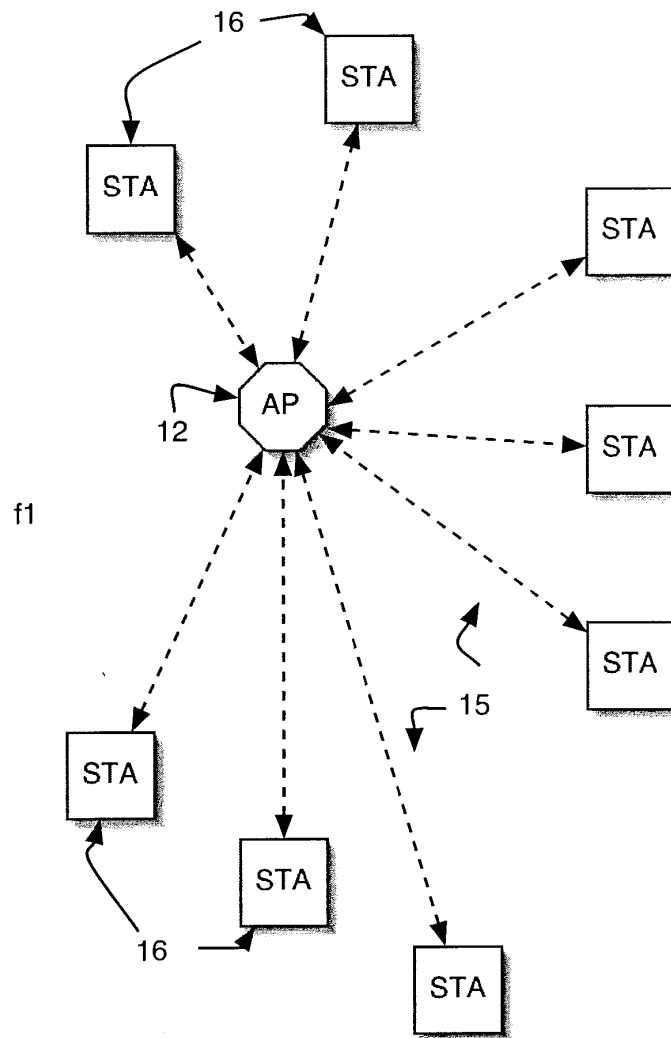


Fig. 2

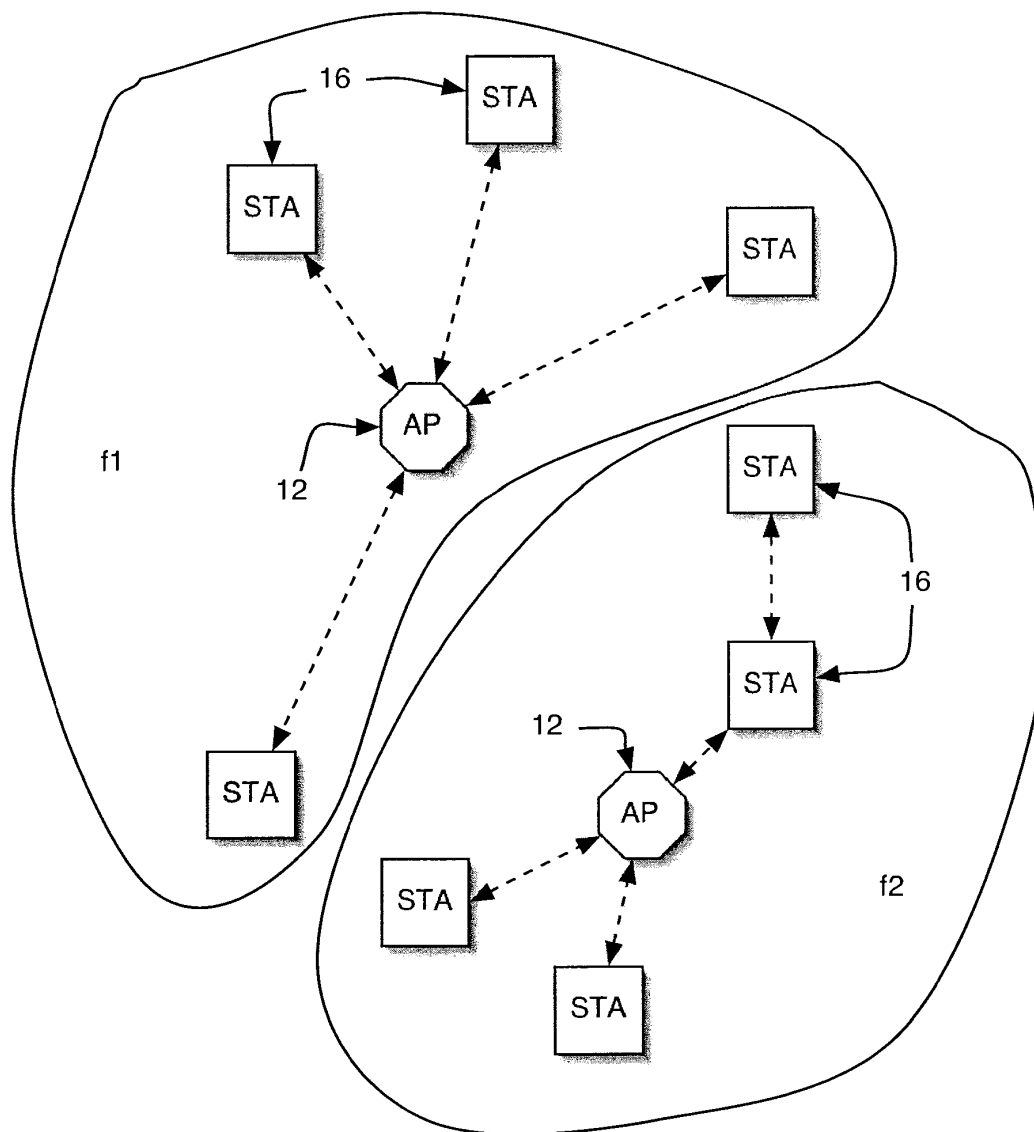


Fig. 3

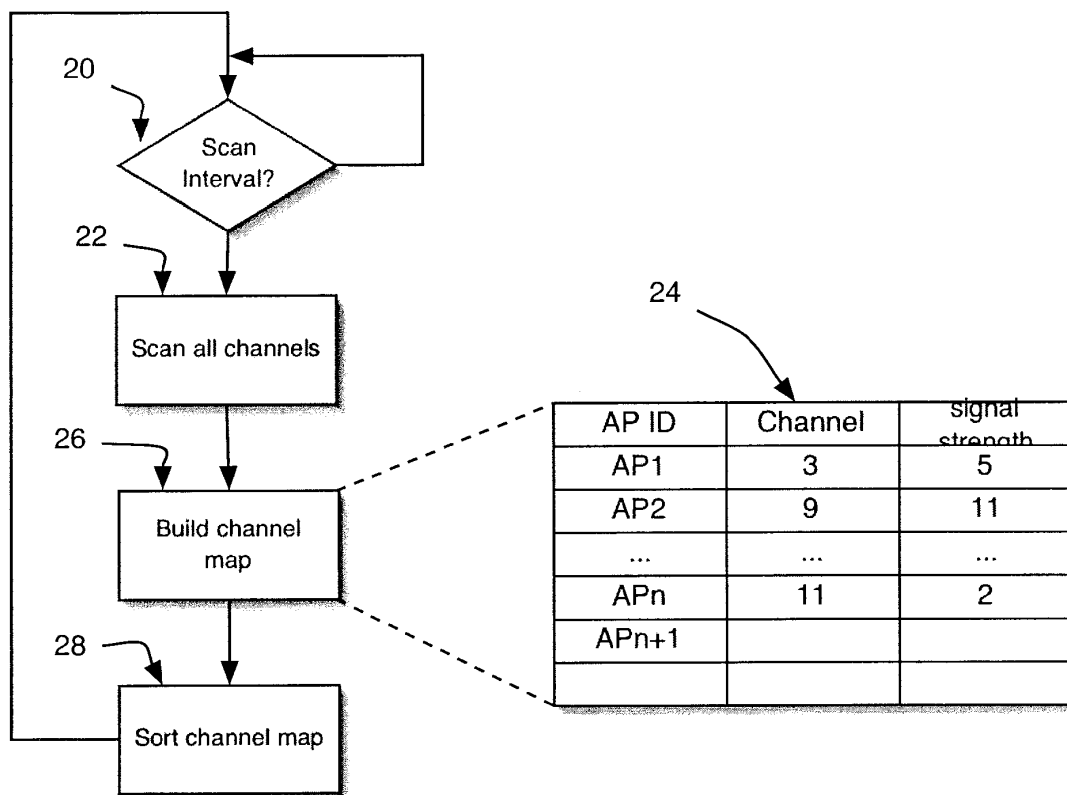


Fig. 4

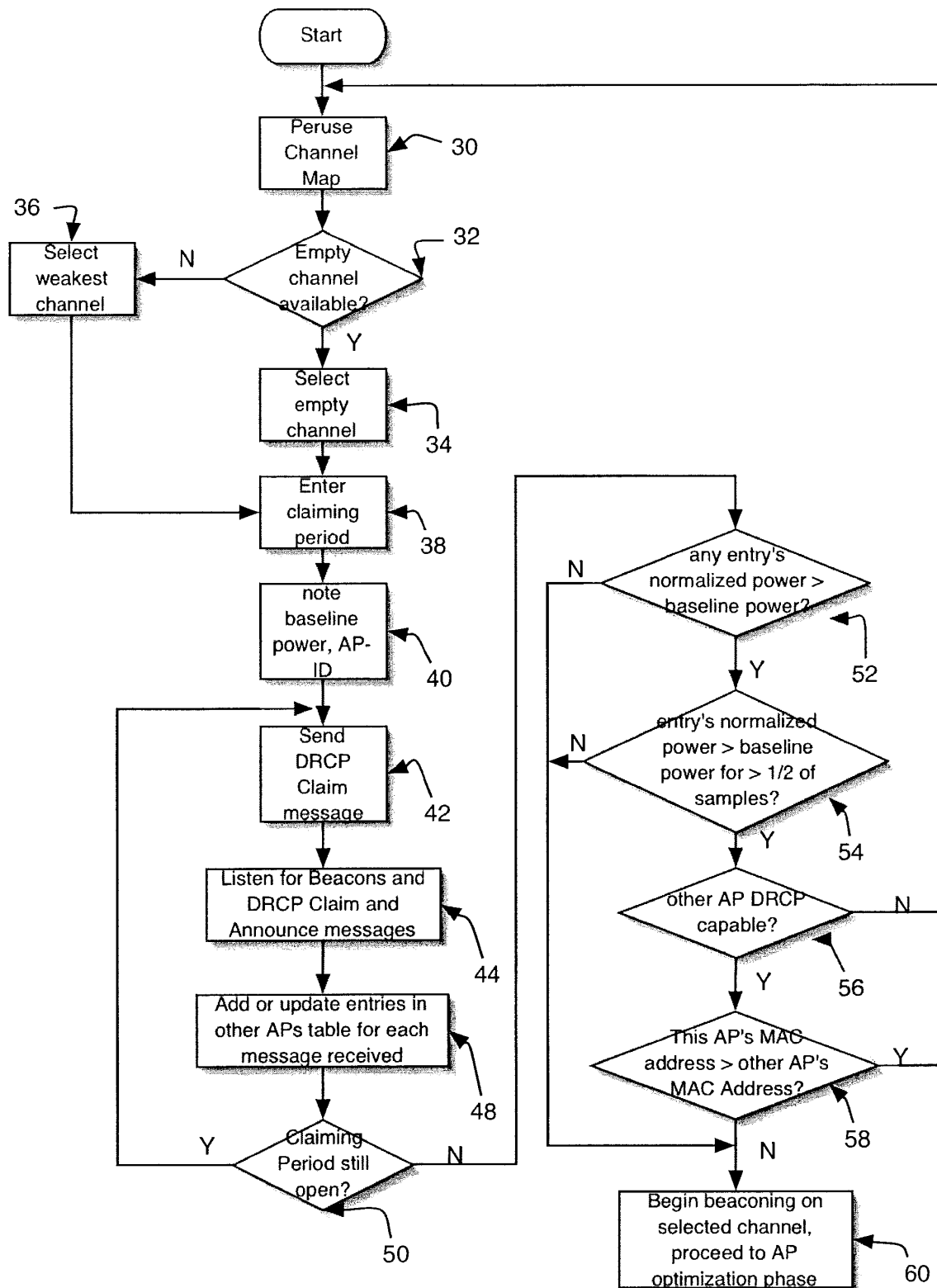


Fig. 5

46

AP_ID	received power	TP Backoff	DRCP	Normalized received power
AP[1]	<list>	<list>	1	
AP[2]	0	?	0	
...	...	...	...	...
AP[n]	<list>	<list>	1	

Other APs Table

Fig. 6

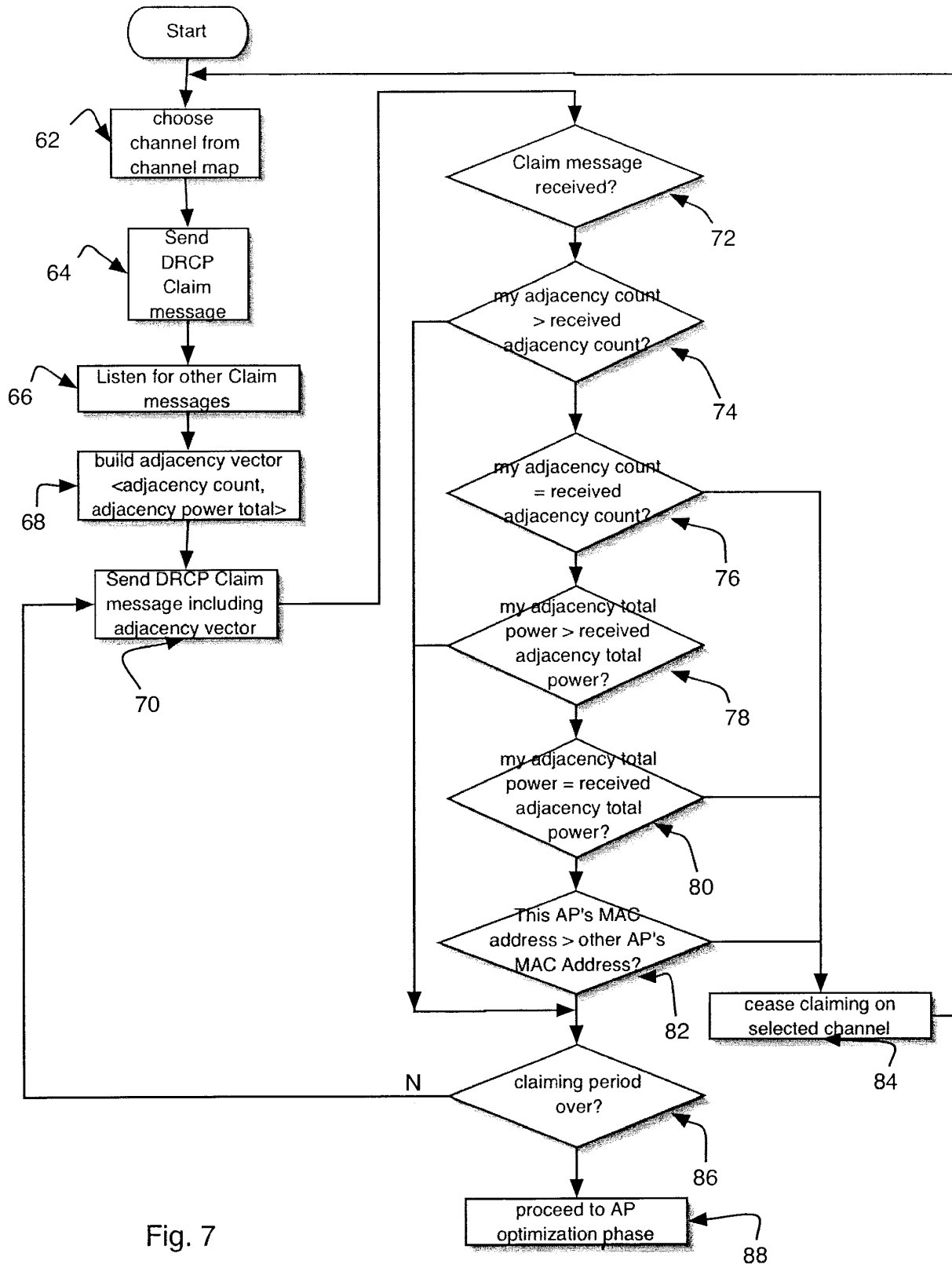


Fig. 7

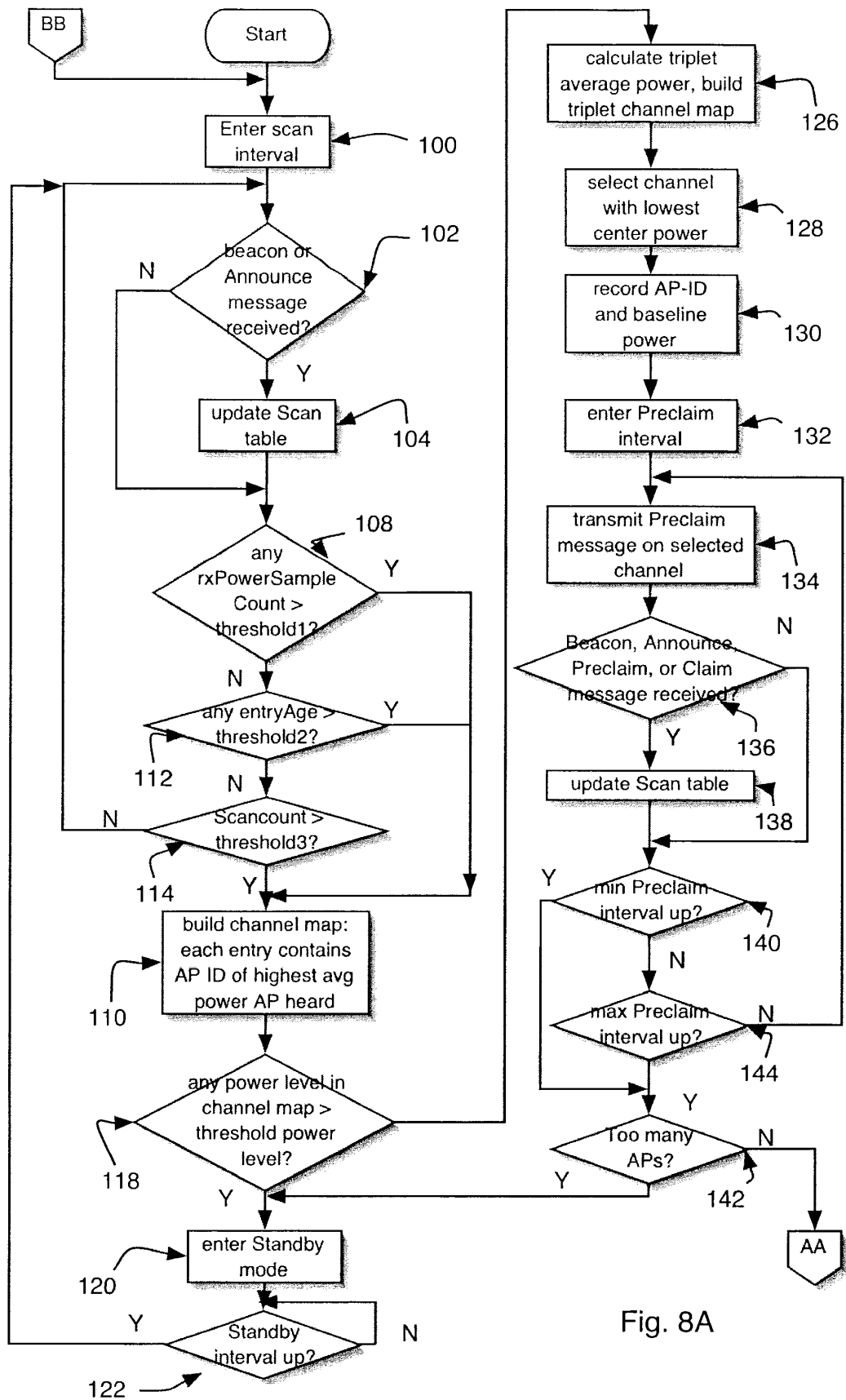


Fig. 8A

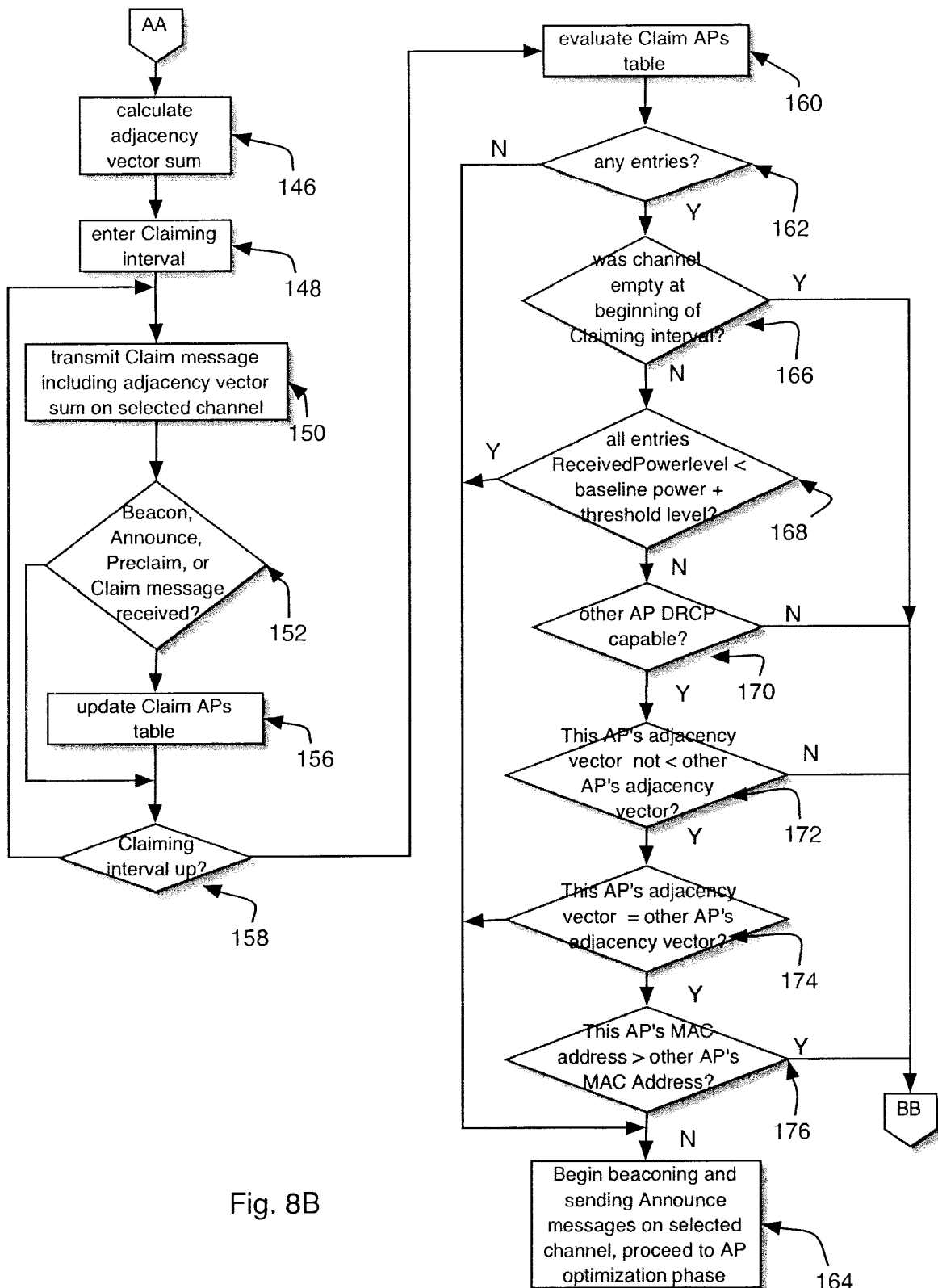


Fig. 8B

106



AP_ID	Channel_ID	rxPowerRunning Total	rxPowerSample Count	rxPowerAvg	DRCP	Age
AP[1]	3	dbm	3	dbm	1	3
AP[2]	3	dbm	5	dbm	0	7
...	...	dbm	...	...	...	...
AP[n]	5	dbm	8	dbm	1	4

Scan Table

Fig. 9

116



Channel_ ID	highestPwr AP_ID	highestPwrlevel
2	AP[1]	dbm
3	AP[2]	dbm
...	...	...
8	AP[n]	dbm

Channel Map

Fig. 10

124 →

Channel	signal strength	Triplet avg	AP ID
2	5	5	3
3	2	5	11
4	8	5	2
1	3	6	8
2	9	6	6
3	6	6	1

Triplet channel map

Fig. 11

154 

AP-ID	ReceivedPowerlevel	DRCP
2	<list>	5
3	<list>	7
4	<list>	3
7	<list>	6
9	<list>	9
11	<list>	12

Claim APs table

Fig. 12

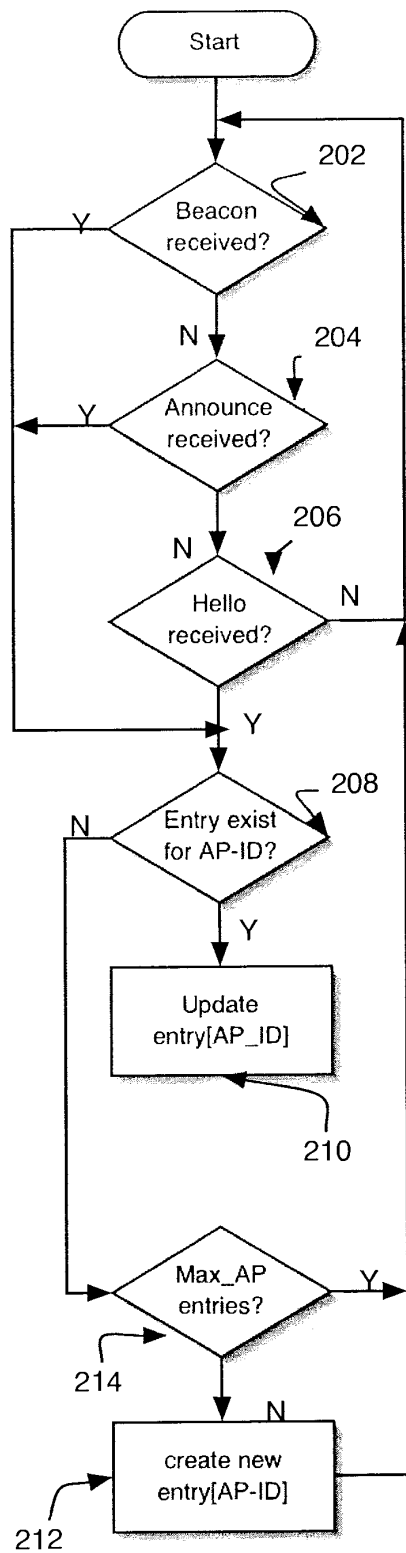


Fig. 13

200 

AP_ID	TP_Backoff	Max Power	DRCP	Age	Normalized power	sample size	corrected power
AP[1]	<list>	<list>	1	2	dbm	3	dbm
AP[2]	0	max power	0	3	dbm	4	dbm
...	...	...	...	...	...	...	...
AP[MAX_AP]	<list>	<list>	1	1	dbm	1	dbm

AP Known APs Table

Fig. 14

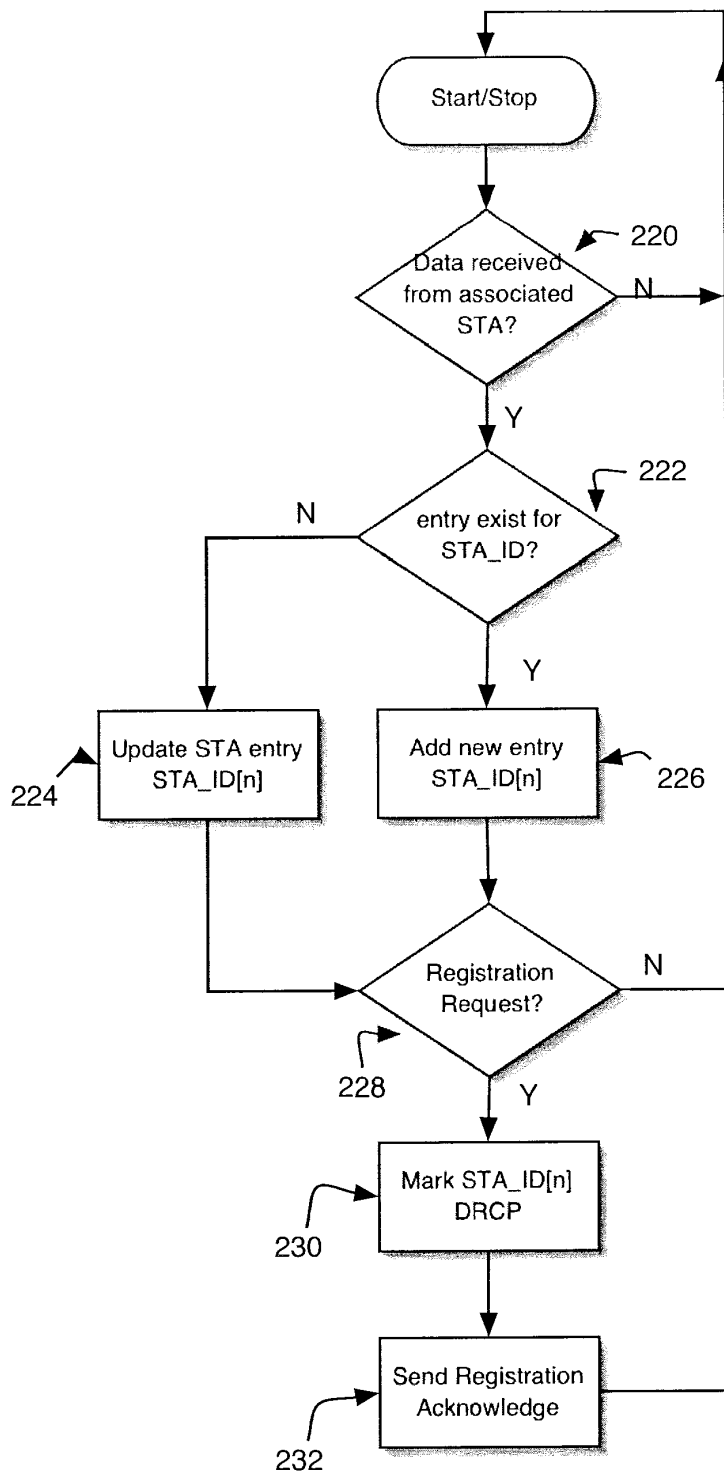


Fig. 15

240 

STA_ID	Quiet-time	DRCP-Active	Distance	max power	sta_load_factor	power samples	normalized_power	corrected_power
STA[1]	4	1	1	1	2	1	1	1
STA[2]	0	0	0	0	3	0	0	0
...	...	...	...	...	...	...	...	...
STA[n]	6	1	3	1	1	1	1	1

AP Associated STA Table

Fig. 16

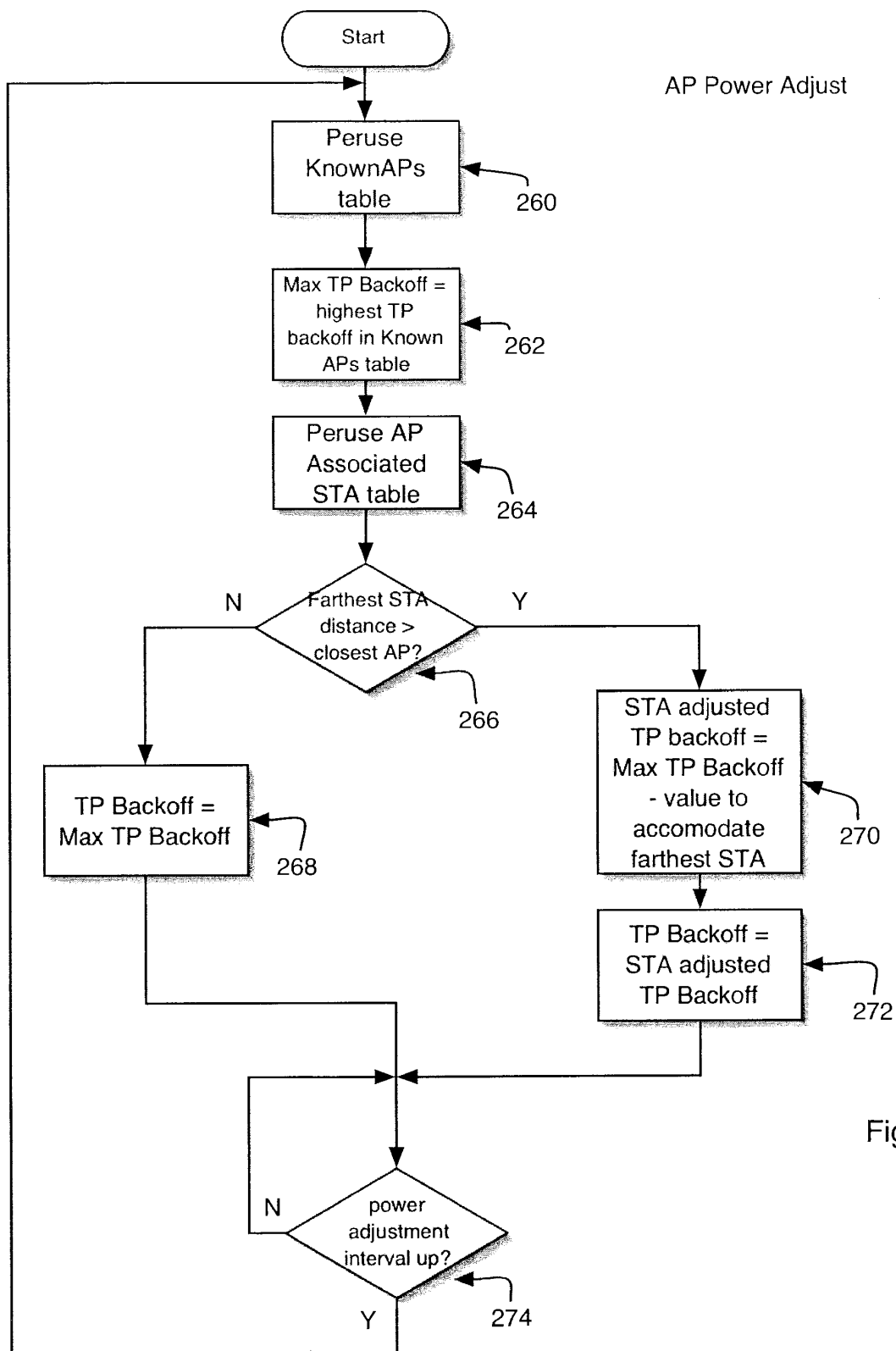


Fig. 17

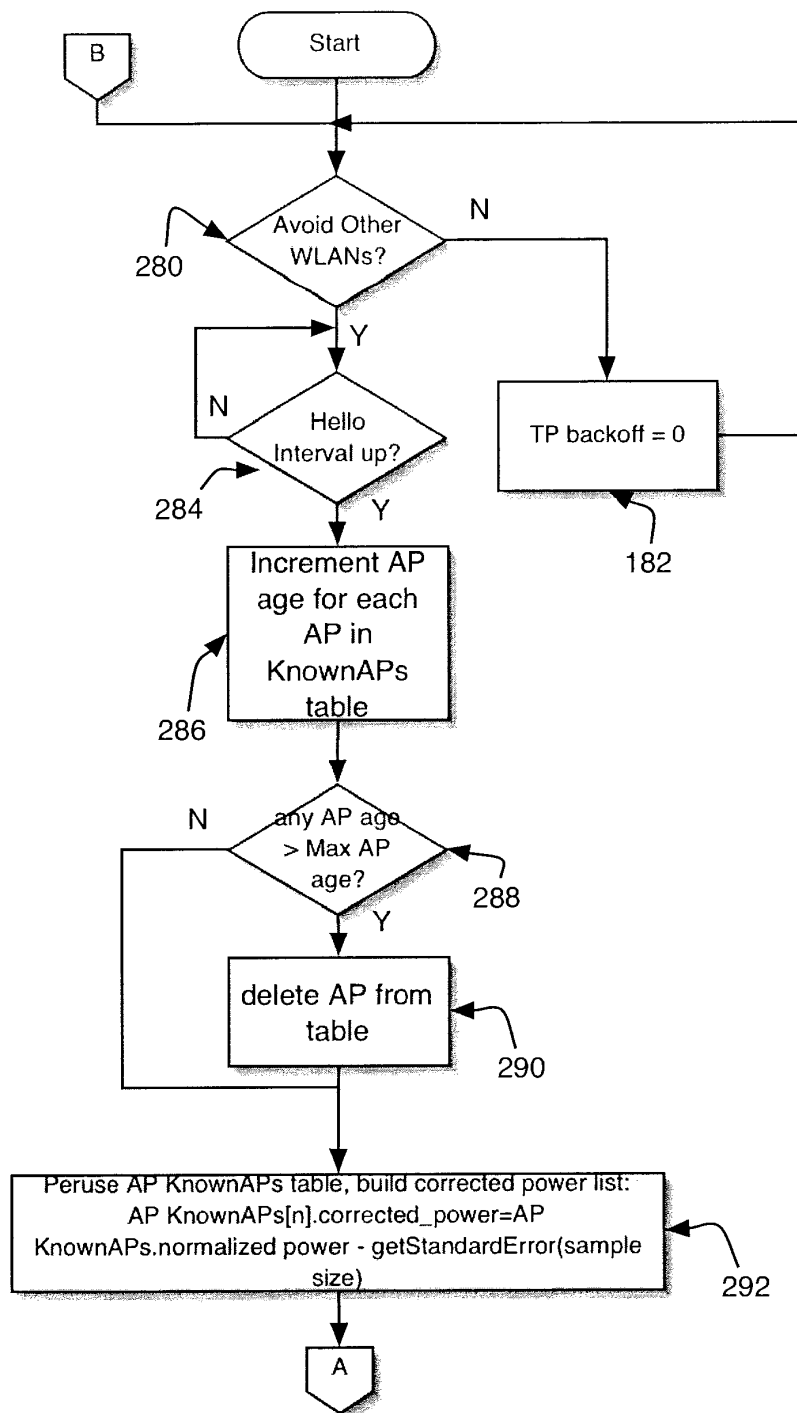


Fig. 18A

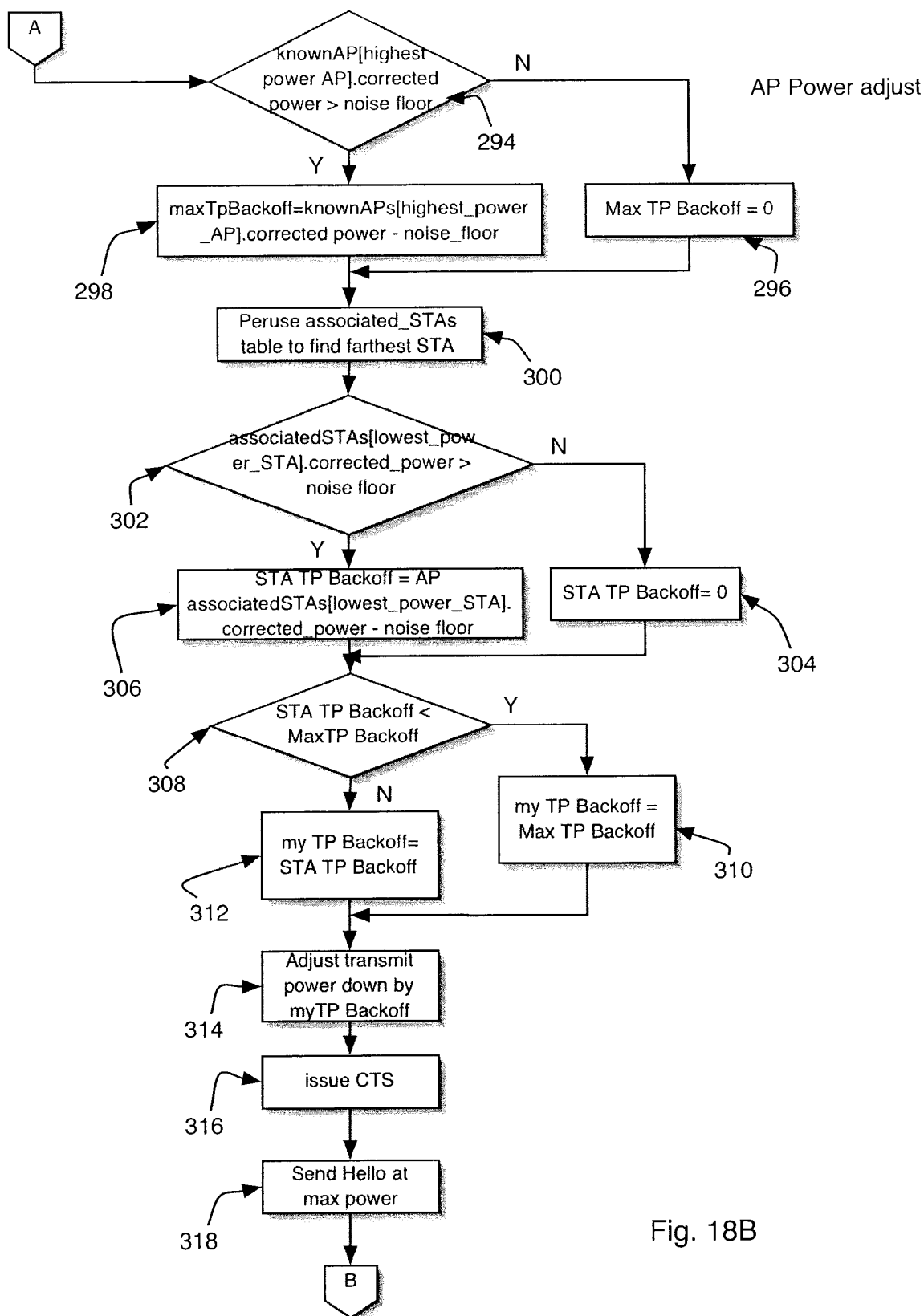


Fig. 18B

Number of Samples	Calculated Standard Error (+/- dB)	Rounded Standard Error (+/- dB)
2	38.6	39
4	22.3	22
8	14.6	15
16	9.94	10
32	6.9	7
64	4.9	5
128	3.4	3
256	2.3	2
512	1.7	2
1024	.8<dB<1.7	1
2000	.8	1
2048	0<dB<.8	1

Table I

Standard error for 99% confidence on received power values averaged over number of samples for standard deviation = 15 dB.

Fig. 19

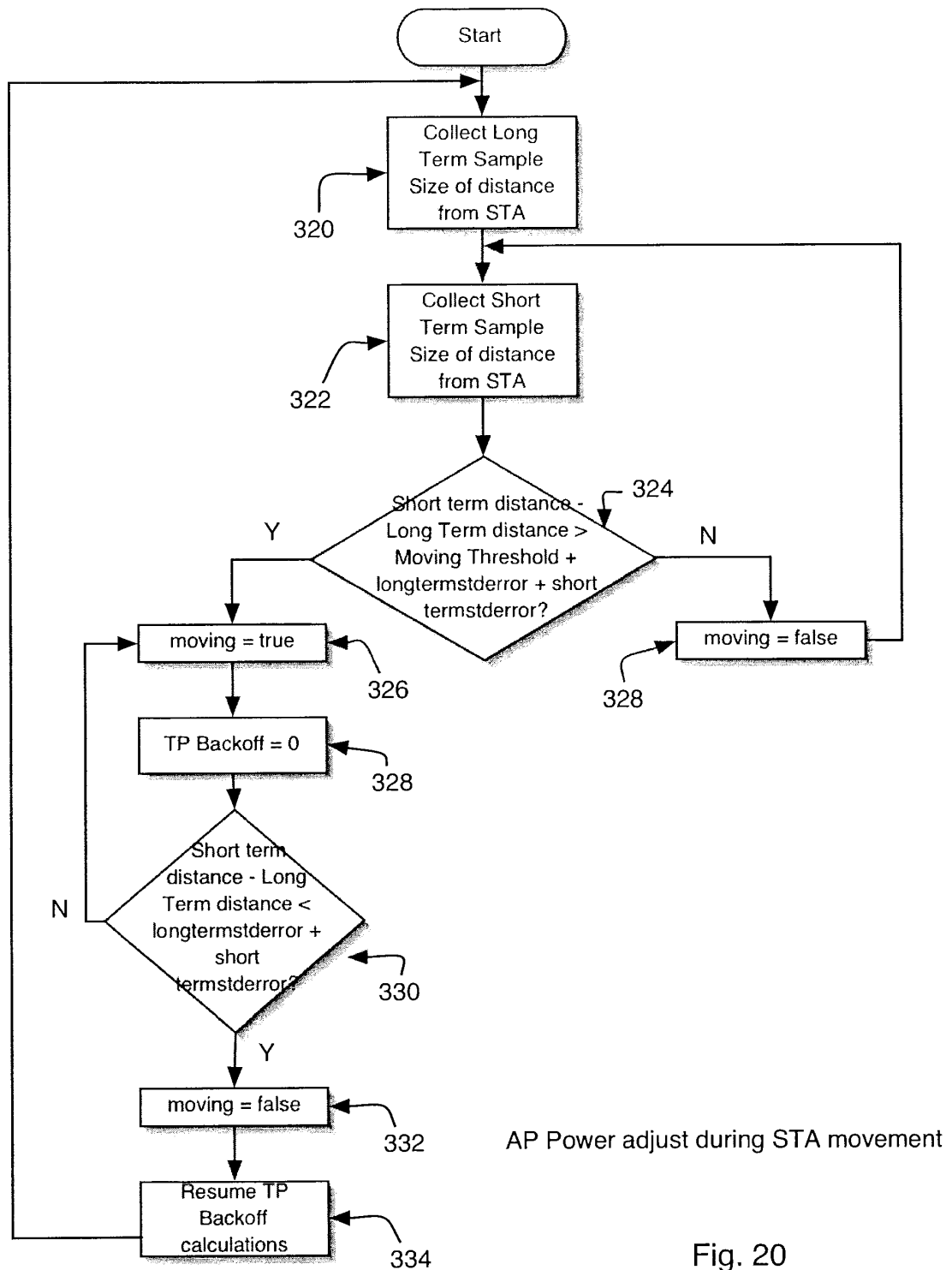


Fig. 20

AP Auction

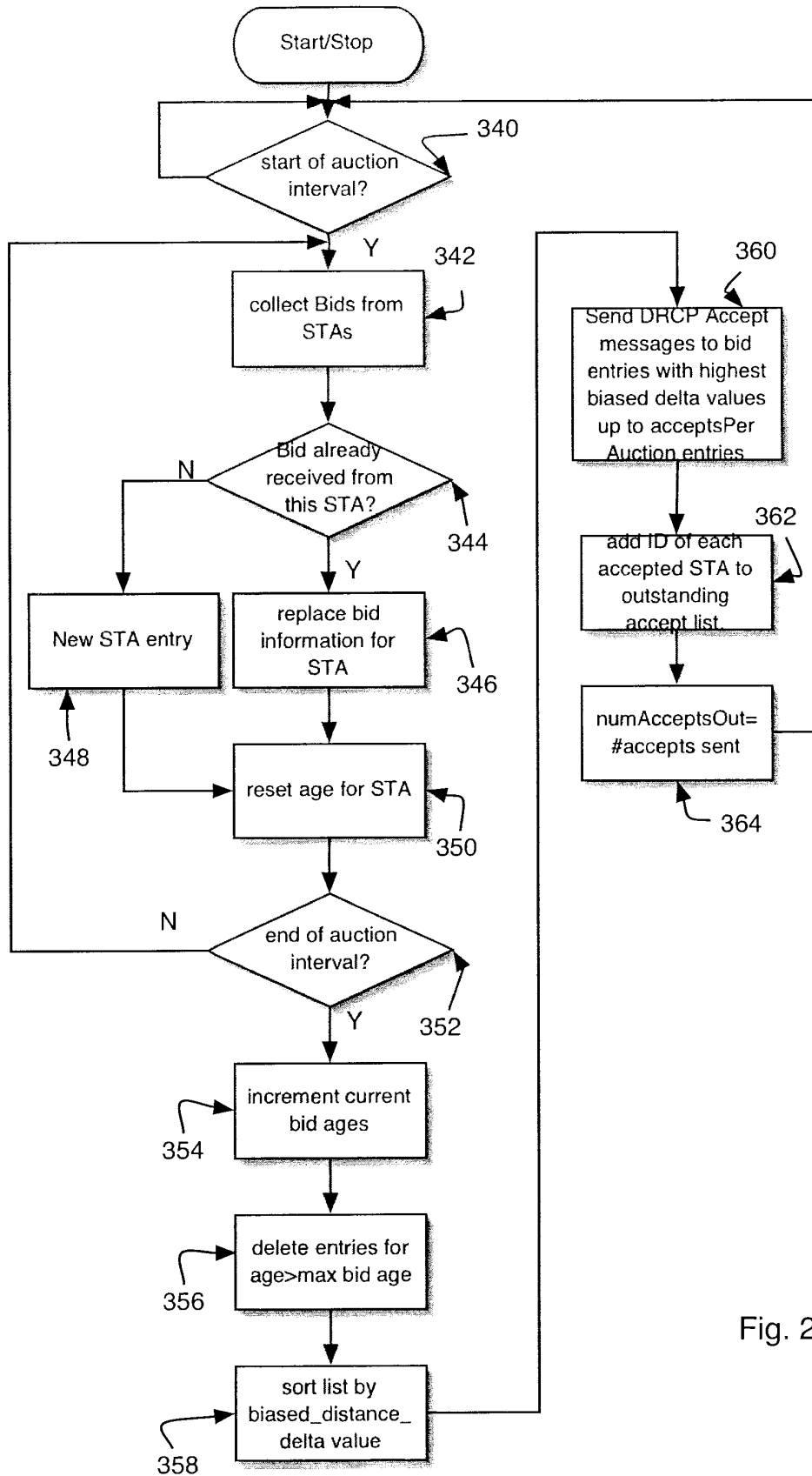


Fig. 21

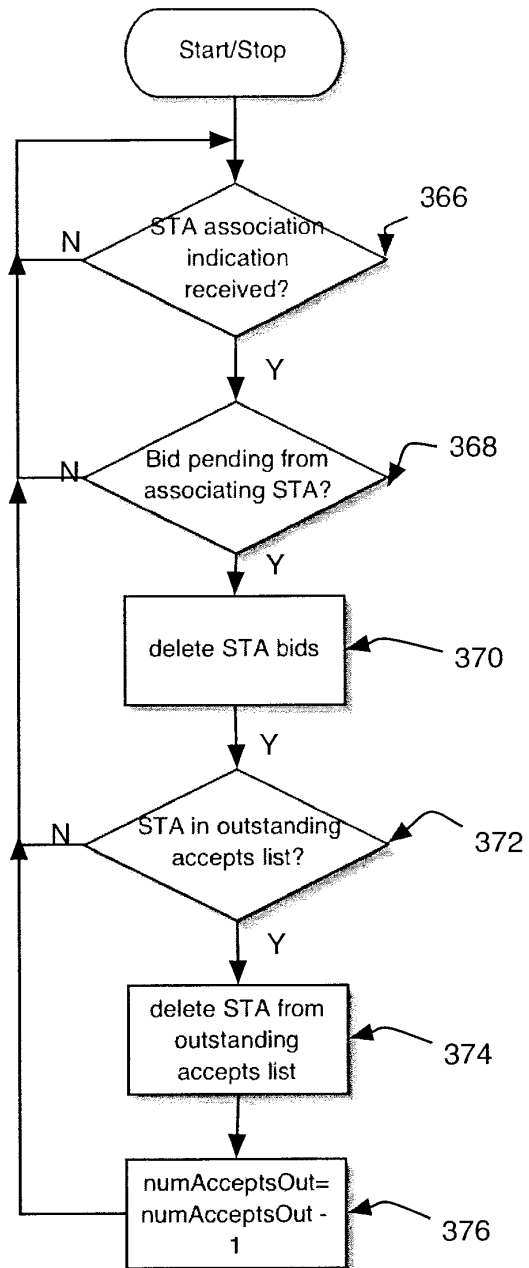


Fig. 22

STA Initialization

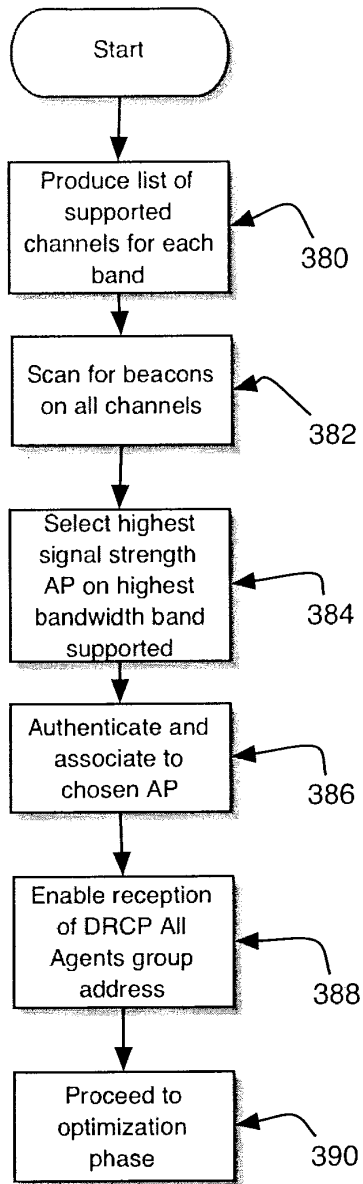


Fig. 23

STA Canvassing

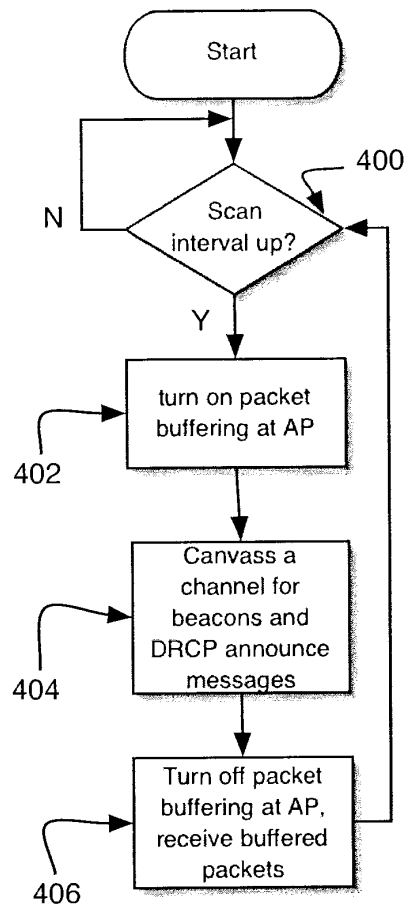


Fig. 24

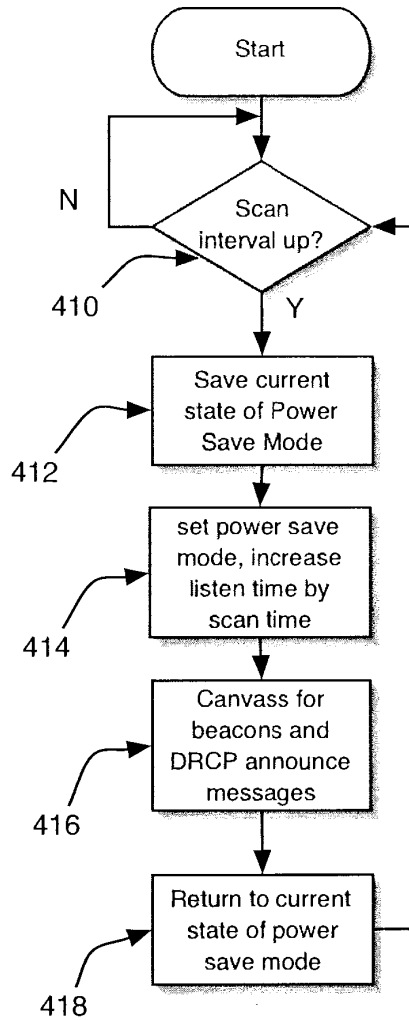


Fig. 25

430 →

AP_ID	Channel ID	age	Load Factor	TP Backoff	Max Power	distance_sample_s	distance	my_Load Factor	biased distance	corrected distance
AP[1]	3	2	2	<list>	<list>	10	avg	2	2	2
AP[2]	7	3	3	<list>	<list>	7		3	3	3
...	5	...	...	...	...	...	...	...	...	...
AP[MAX_AP]	2	1	1	<list>	<list>	13		1	1	1

STA Known APs Table

Fig. 26

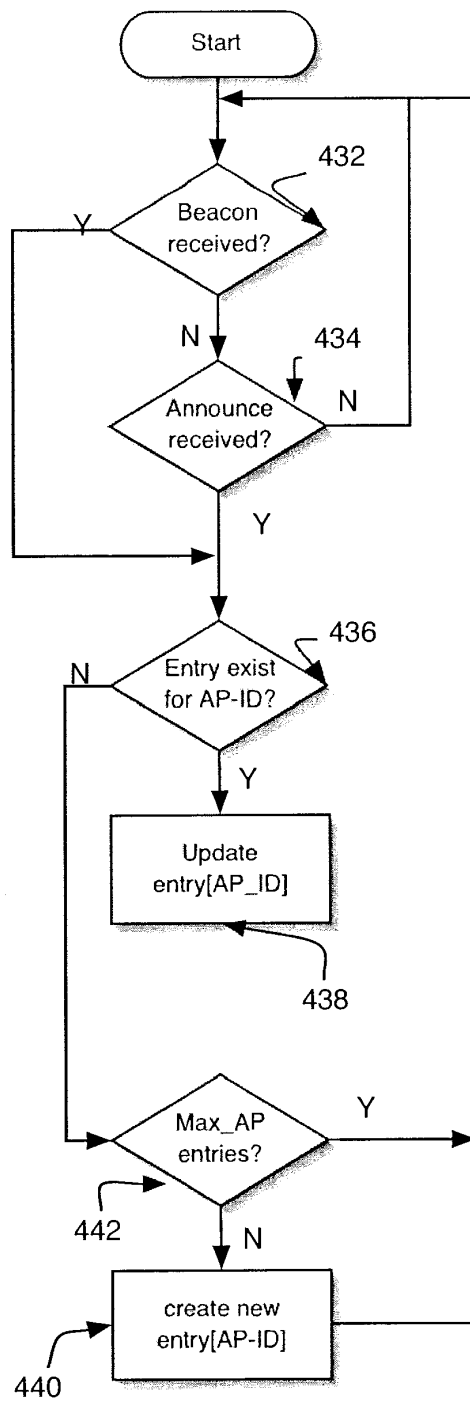


Fig. 27

STA Power Adjustment

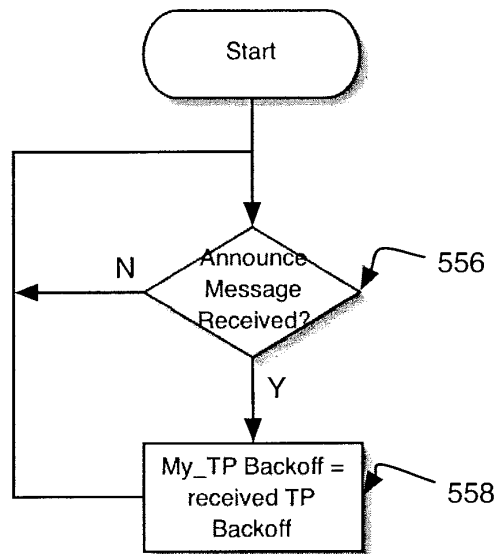


Fig. 28

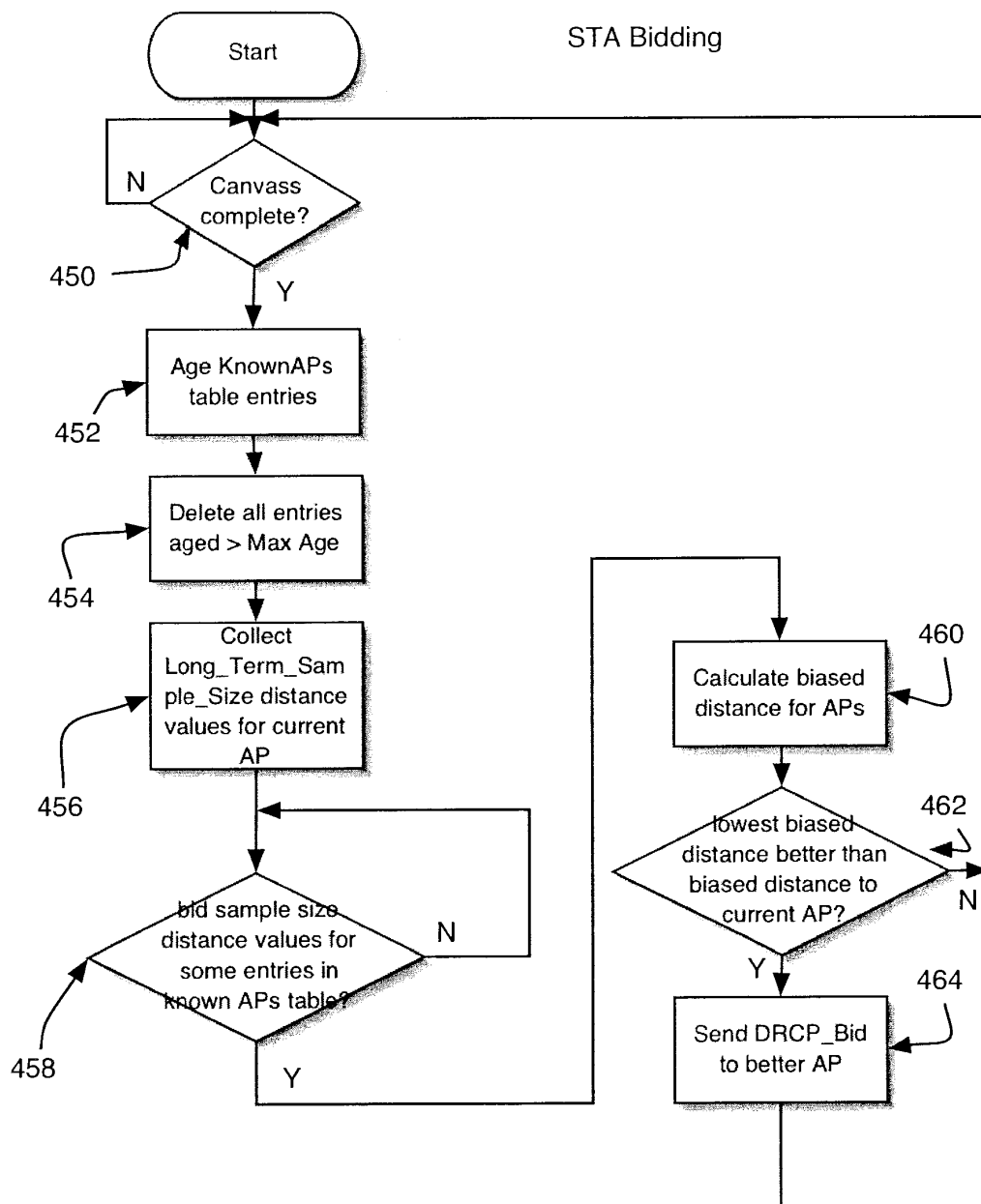


Fig. 29

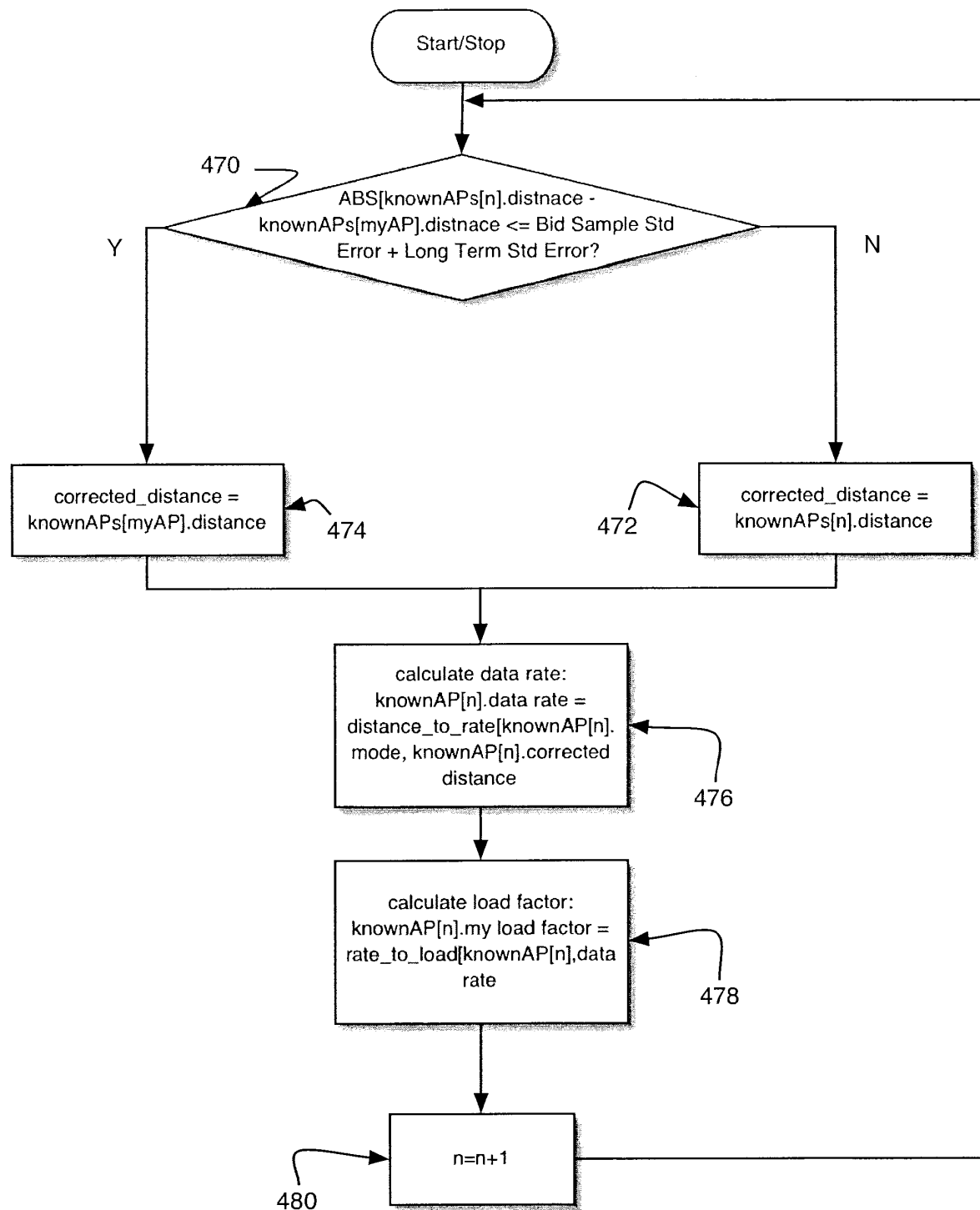


Fig. 30

Distance in Banzais	802.11a, g Mb/s	802.11b Mb/s
0-68	54	11
69-72	48	11
73-76	36	11
77-80	24	11
81-83	18	11
84-85	12	5.5
86	9	5.5
87	9	2
88	6	2
89	2	2
90-91	2	1
92-94	1	0
95-97	.5	0

Table II
Distance_to_Rate Table, 802.11

Fig. 31

Data Rate	Load Factor
108	4
72	6
54	8
48	9
36	12
24	18
18	24
11	39
9	48
6	72
5.5	79
2	216
1	432
.5	864
0	65,535

Table III

Rate_to_Load table for 802.11

Fig. 32

Biased Distance Calculation

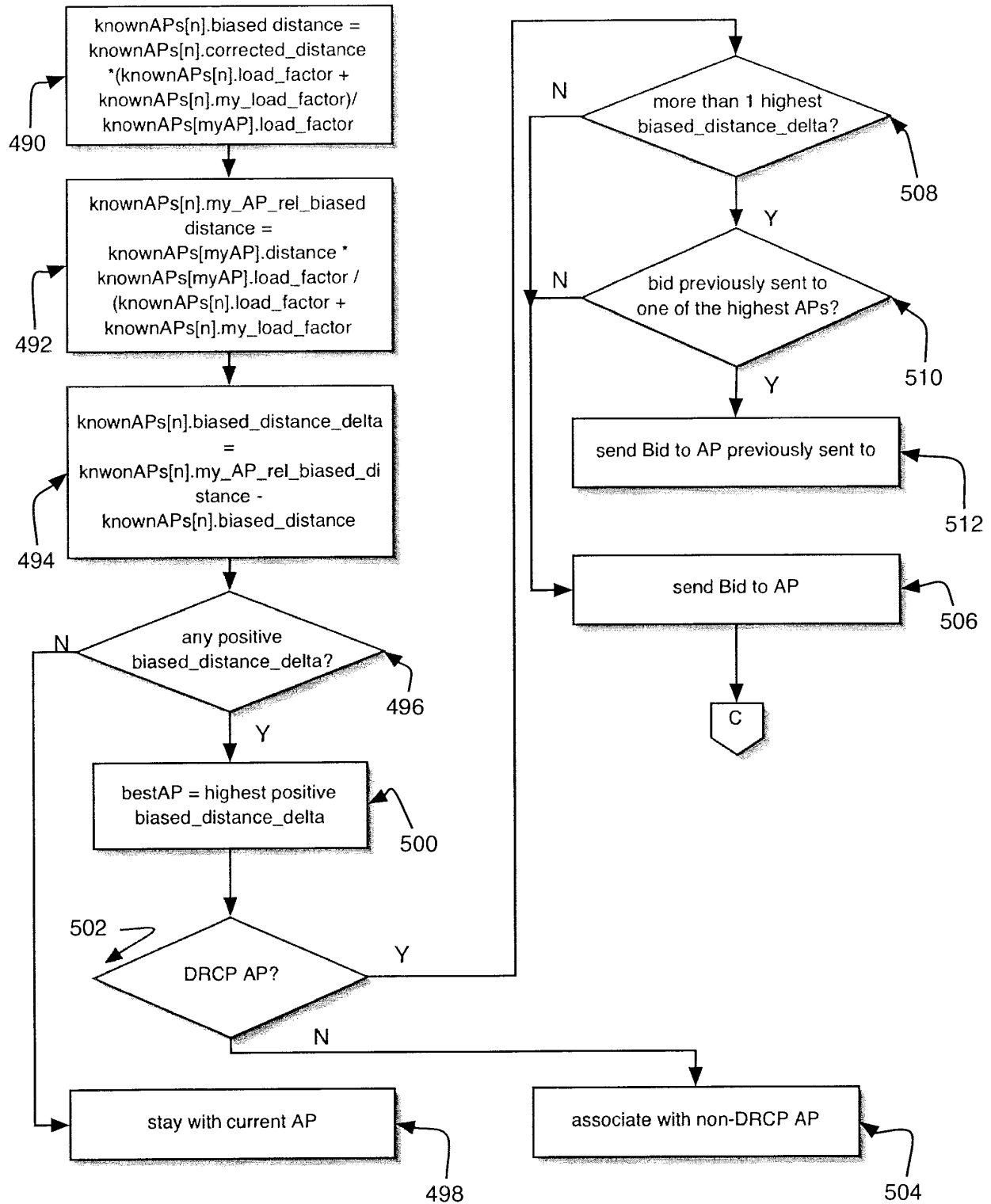


Fig. 33A

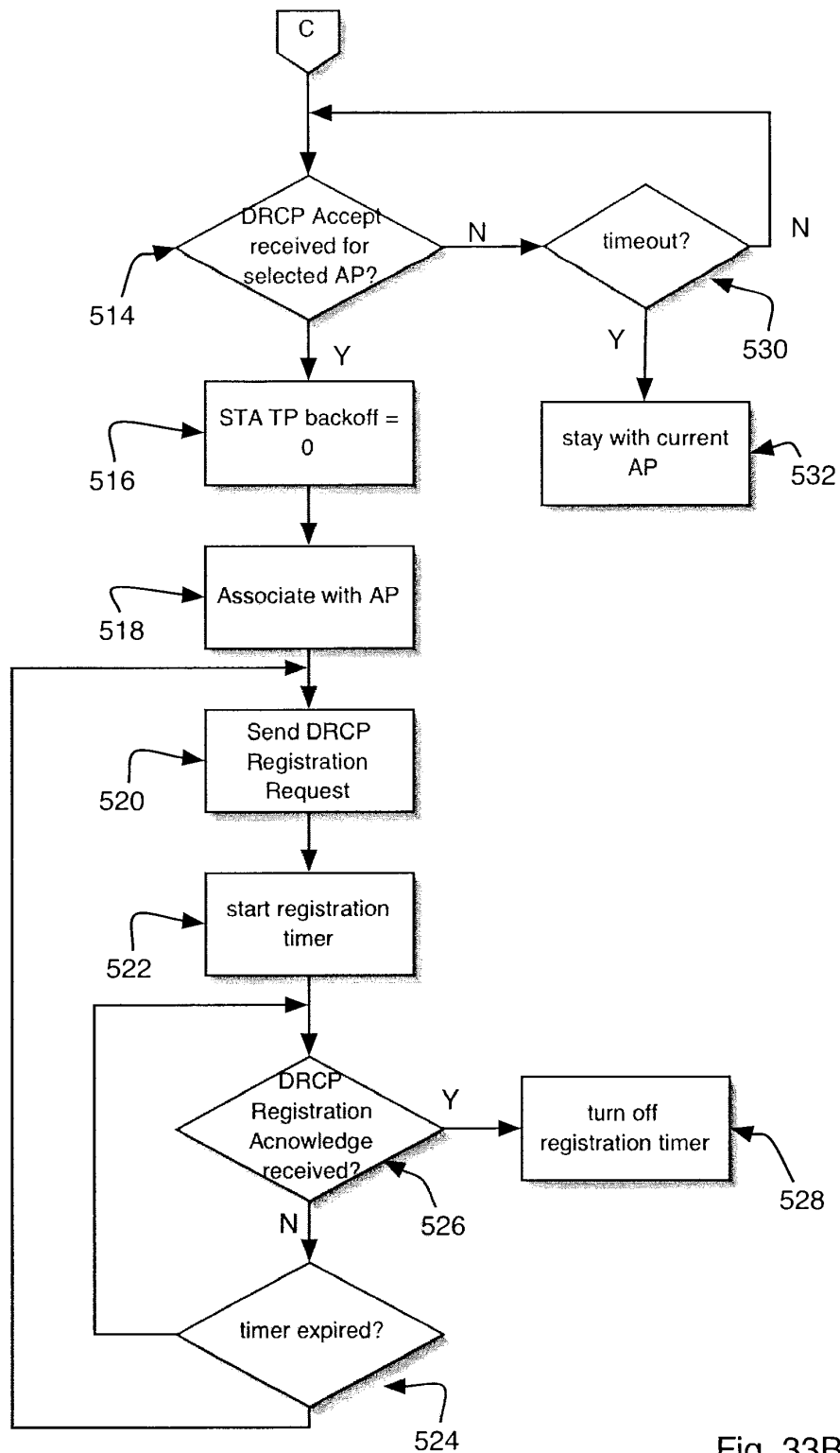


Fig. 33B

STA movement detection

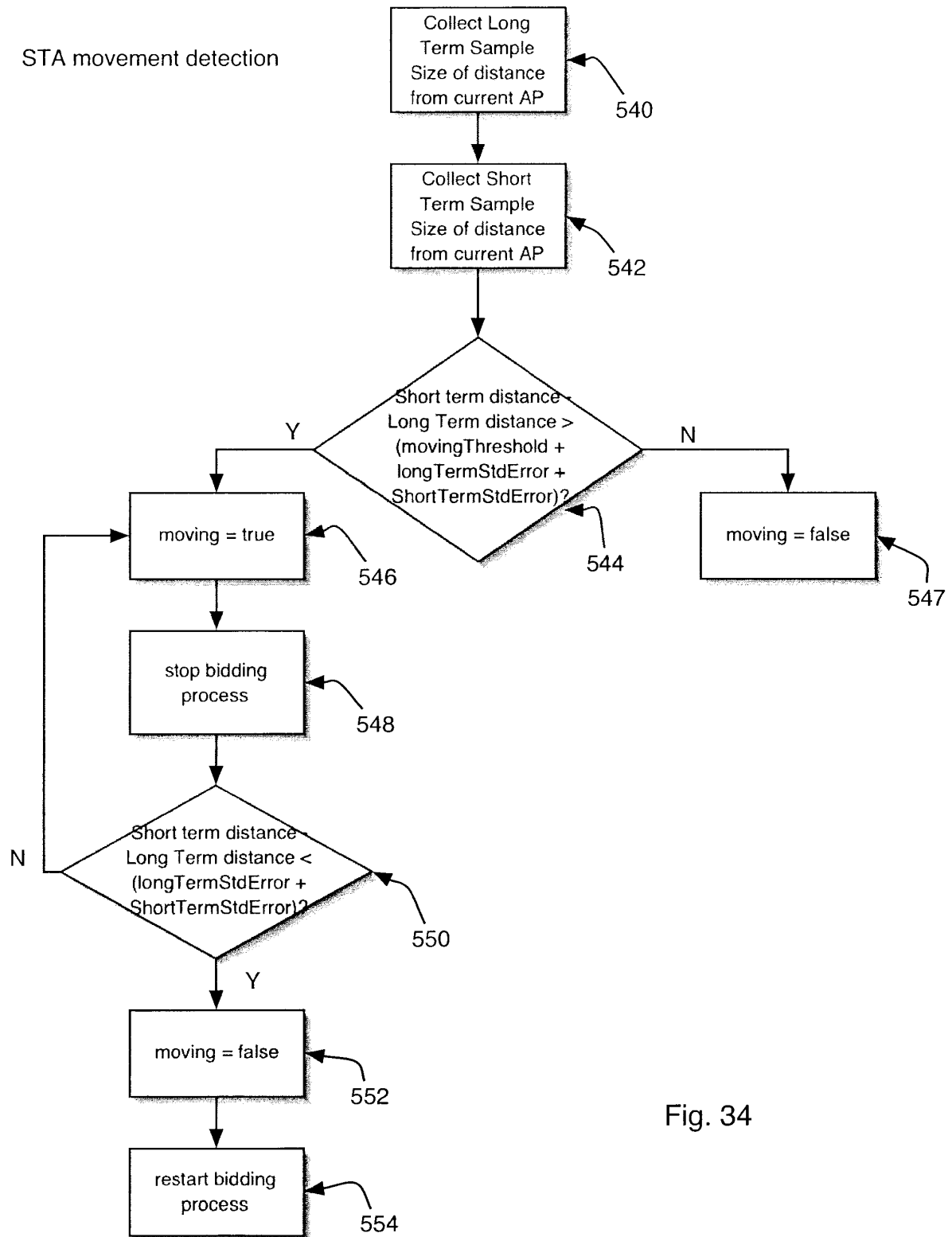


Fig. 34

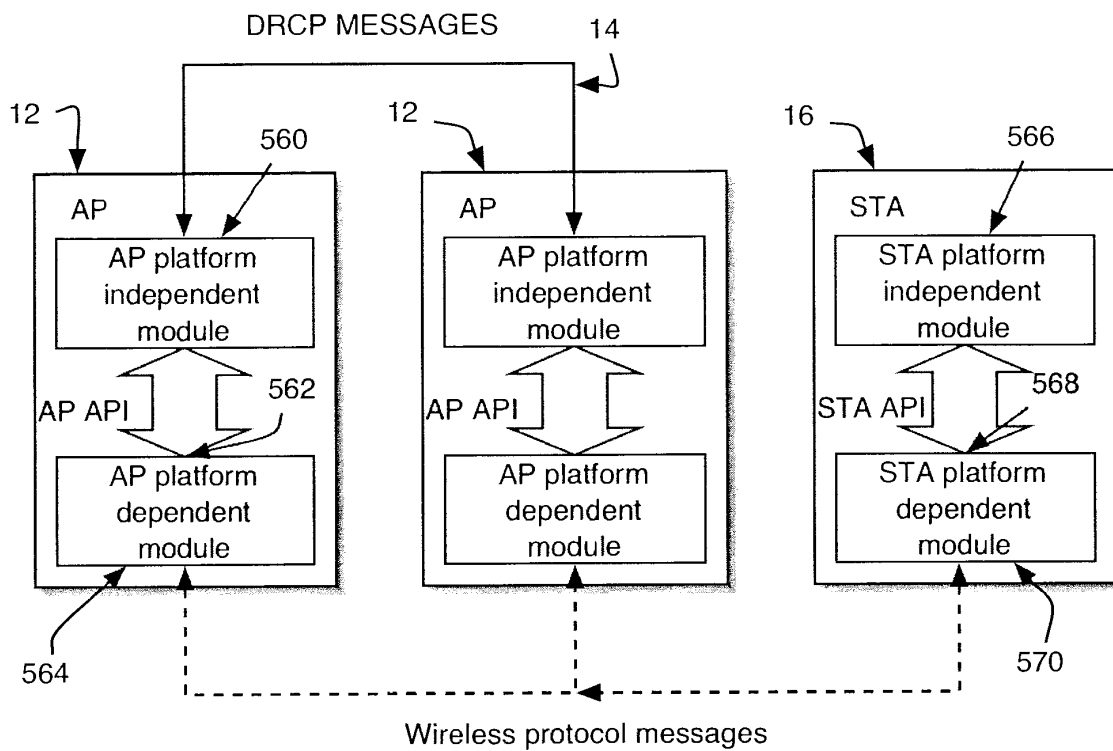


Fig. 35

802.11 AP DRCP Architecture

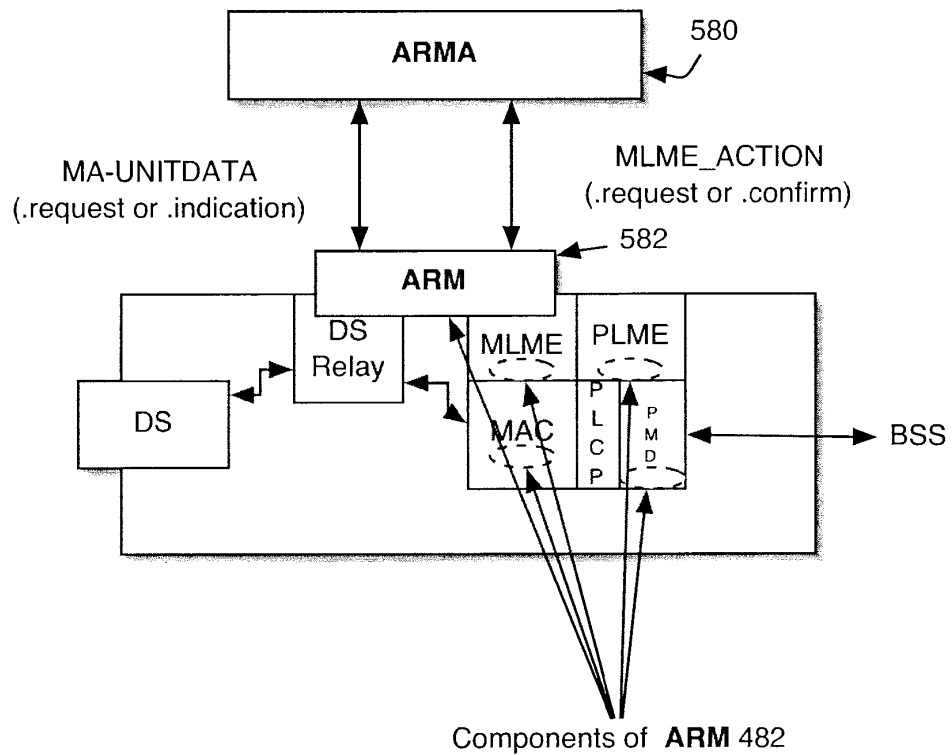


Fig. 36

802.11 STA DRCP Architecture

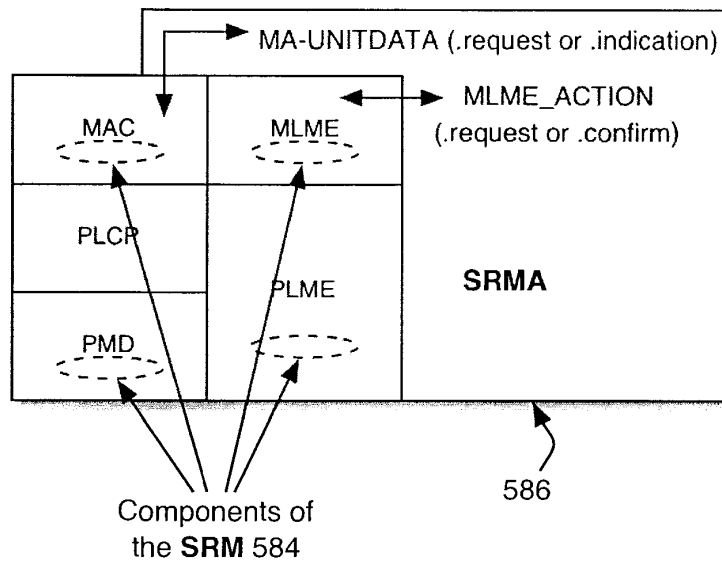


Fig. 37

Encoding of DRCP Message in an 802.11 Management Frame of Subtype Beacon

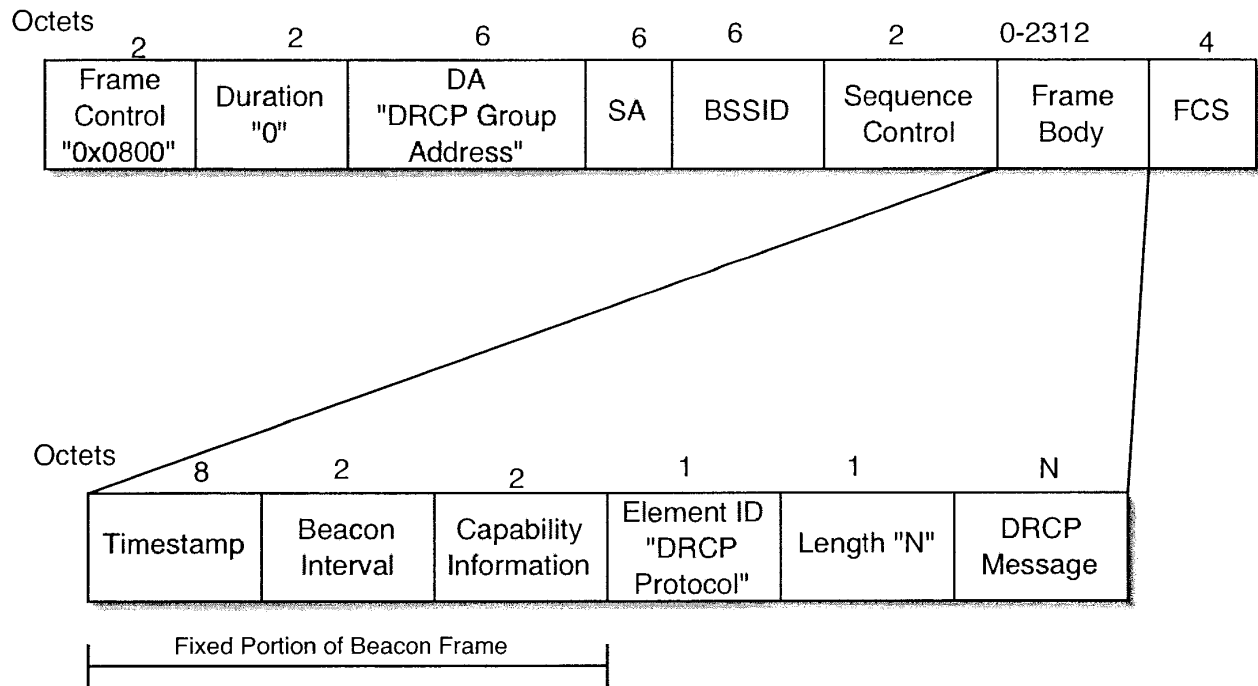


Fig. 38

Encoding of DRCP Message in an 802.11 Data Frame

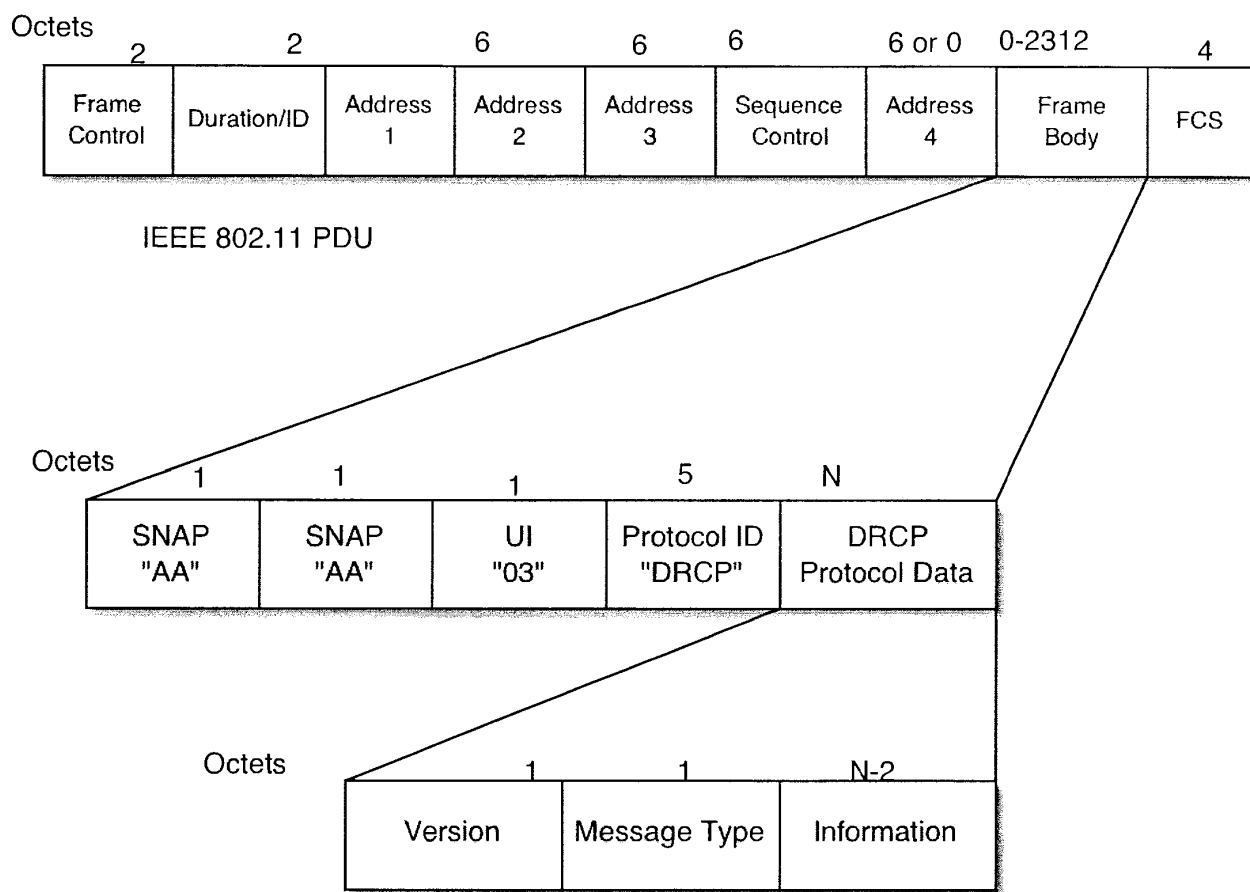


Fig. 39

Message Type	Usage	Data Rate	Max Power
DRCP Preclaim	Used by ARMAs in the channel selection process	Lowest Datarate	Max Power
DRCP Claim	Used by ARMAs in the channel selection process	Lowest Datarate	Max Power
DRCP Announce	Used by ARMAs to announce their presence to SRMAs and other ARMAs.	Lowest Datarate	Max Power
DRCP Bid	Used by SRMAs to bid for slots on ARMAs	STA Datarate	Max Power - TP Backoff
DRCP Accept	Used by ARMAs to signal to SRMAs permission to associate	STA Datarate	Max Power - TP Backoff
DRCP Registration Request	Used by STAs to tell ARMAs they will associate	STA Datarate	Max Power - TP Backoff
DRCP Registration Acknowledge	Used by ARMAs to tell STA it received registration request	STA Datarate	Max Power - TP Backoff

Fig. 40

Name	Size	Description
Type	1	Message type. Values: 1 = DRCP Claim 2 = DRCP Announce 3 = DRCP Preclaim 4 = DRCP Bid 5 = DRCP Accept 6 = DRCP Registration Request 7 = DRCP Registration Acknowledge
Channel ID	1	Indicates the channel of the originating station
AP-ID	6	The MAC Address of the AP in which the transmitting ARMA is instantiated
SSID	32	The Service Set ID (SSID) of the AP in which the transmitting ARMA is instantiated. This value is also referred to as the "Network Name".
Load Factor	2	The sum of the loads of the ATAs currently associated to the transmitting AP.
TP Backoff	2	Transmit power backoff value in use by the transmitting AP.
Max Power	2	Maximum power output, in dBm, of the transmitting AP's radio.
Biased Distance Delta	4	The difference between the biased distance from the transmitting STA to its current AP and the destination AP.
STA ID	6	The MAC address of the STA in which the transmitting SRMA is instantiated.
STA Assoc AP ID	6	The MAC address of the AP to which the transmitting STA is currently associated.
Bid AP ID	6	The MAC address of the AP to which the transmitting STA is bidding.
Accepted STA ID	6	The MAC address of the STA that the sending AP is accepting.
STA Reported AP ID	6	The MAC address of the AP that was identified in the last Bid message as the accepted STA's associated AP.
Max TP Backoff	2	Max dB's backoff capable of an AP
Adjacency Vector Sum	2	Sum of received power levels from all APs heard during scanning and preclaiming.

Fig. 41

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Max Backoff Max power	

DRCP Preclaim Message

Fig. 42

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Max Backoff Max Power	
12	Adjacency Vector Sum		Reserved	

DRCP Claim Message

Fig. 43

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Max Backoff Max Power	
12	TP Backoff Reserved		Load Factor	

DRCP Announce Message

Fig. 44

Byte Address

0	Version	Type	Flags	Channel ID
4	Biased Distance Delta			
8	STA ID (MSBs)			
12	STA ID (LSBs)		STA Assoc AP ID (MSBs)	
16	STA Assoc AP ID (LSBs)			
20	Bid AP ID (MSBs)			
24	Bid AP (LSBs)		Reserved	

DRCP Bid Message

Fig. 45

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Accepted STA ID (MSBs)	
12	Accepted STA ID (LSBs)			
16	STA Reported AP ID (MSBs)			
20	STA Reported AP ID (LSBs)		Reserved	

DRCP Accept Message

Fig. 46

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Accepted STA ID (MSBs)	
12	Accepted STA ID (LSBs)			

DRCP Registration Request Message

Fig. 47

Byte Address

0	Version	Type	Flags	Channel ID
4	AP ID (MSBs)			
8	AP ID (LSBs)		Accepted STA ID (MSBs)	
12	Accepted STA ID (LSBs)			

DRCP Registration Acknowledge Message

Fig. 48

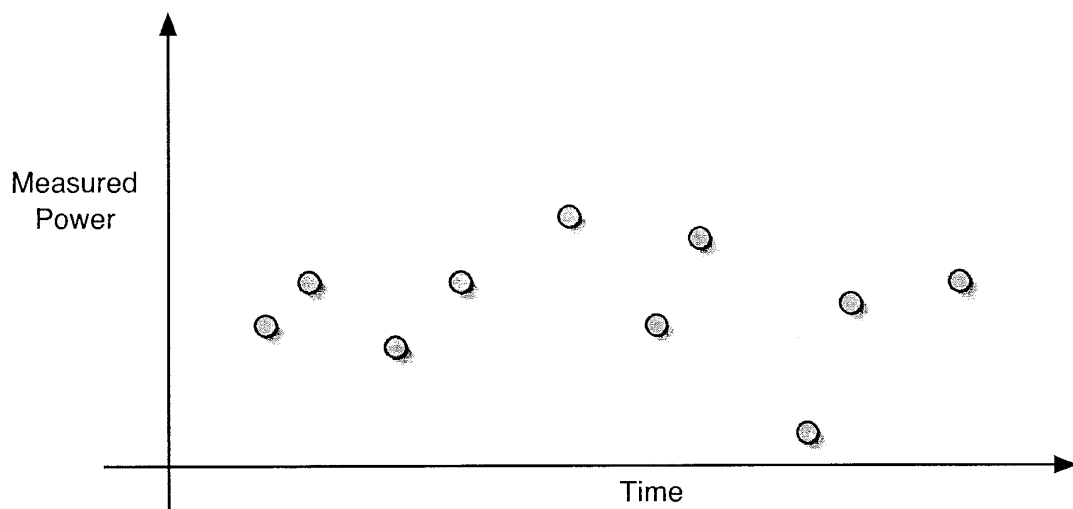


Fig. 49

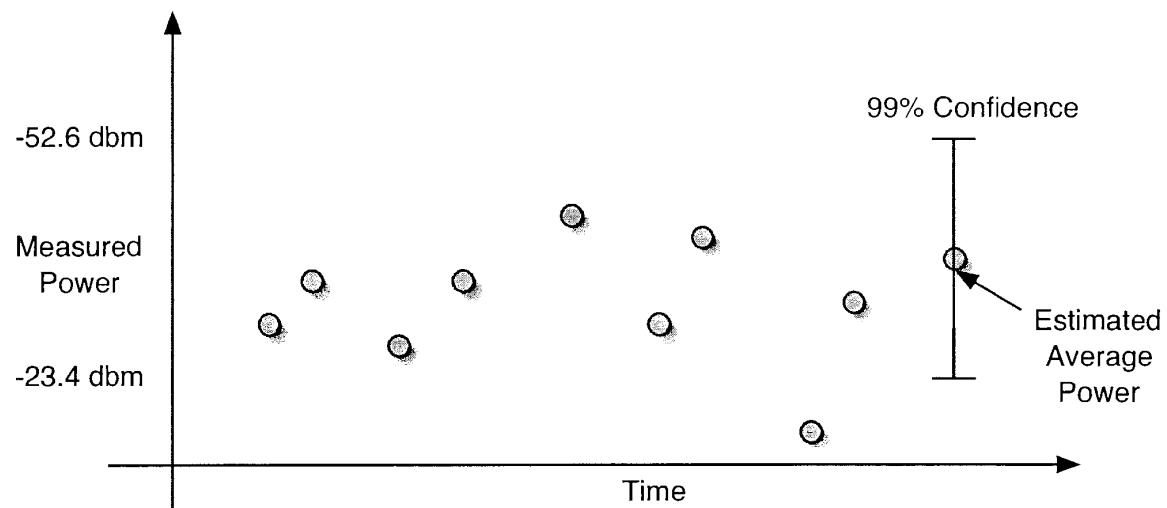


Fig. 50

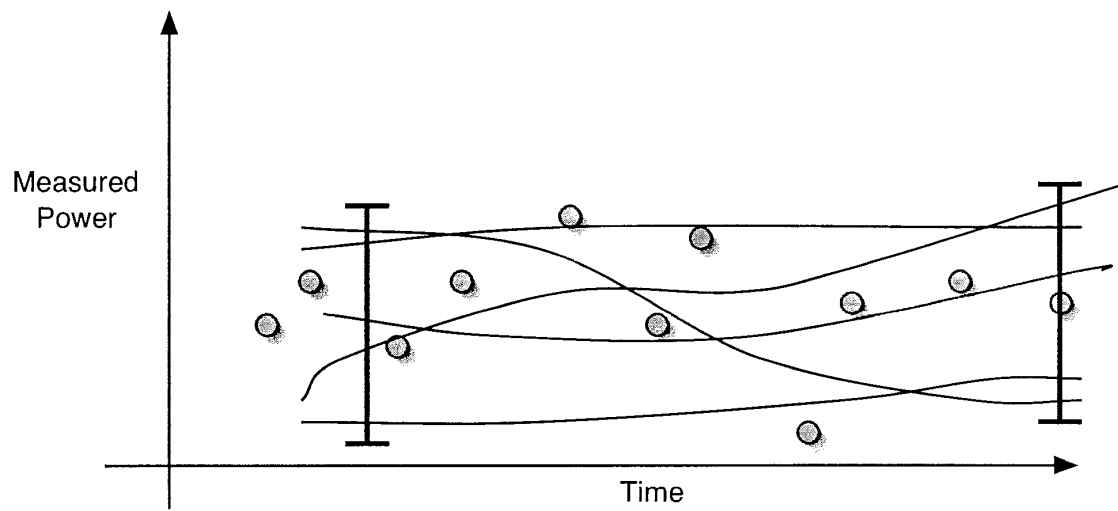


Fig. 51

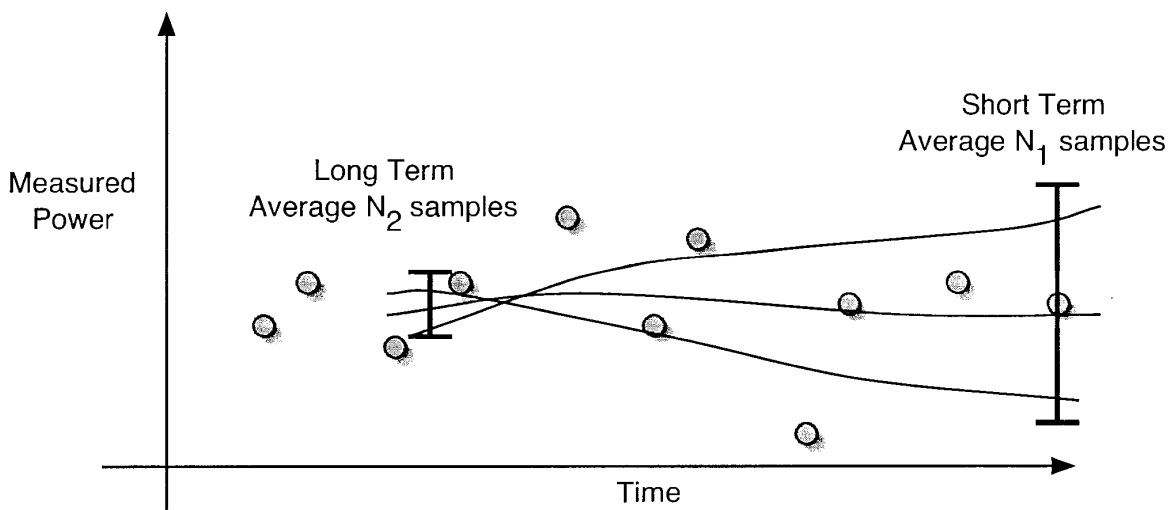


Fig. 52

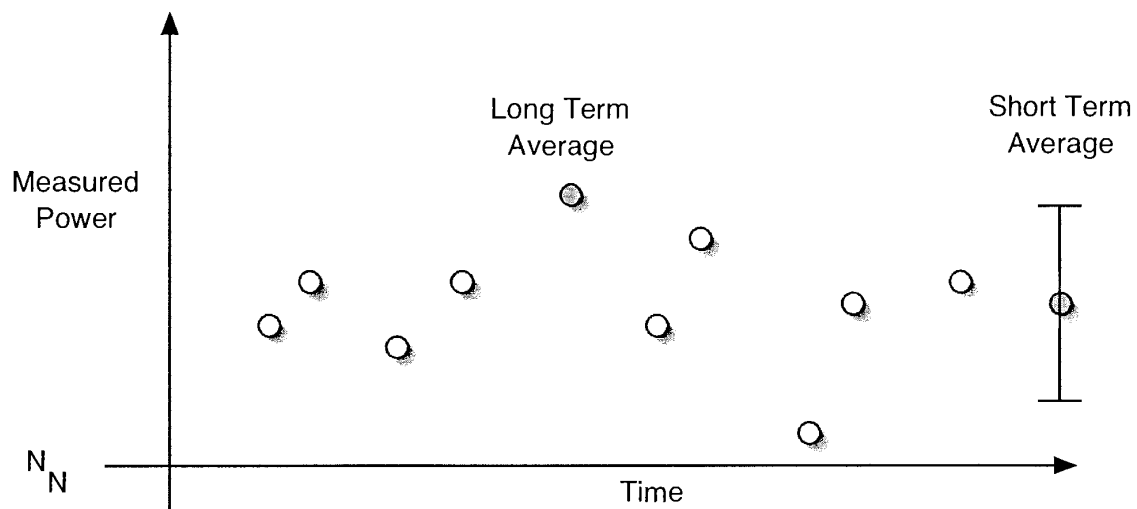


Fig. 53

Sample Time Duration	# Power Samples (N2)	Upper 99% Confidence Interval	Lower 99% Confidence Interval
1 sec	20	-29.1 dbm	-46.9 dbm
10 sec	200	-35.3 dbm	-40.7 dbm
100 sec	2000	-37.2 dbm	-38.3 dbm
1000 sec	20,000	-37.7 dbm	-38.3 dbm

Fig. 54

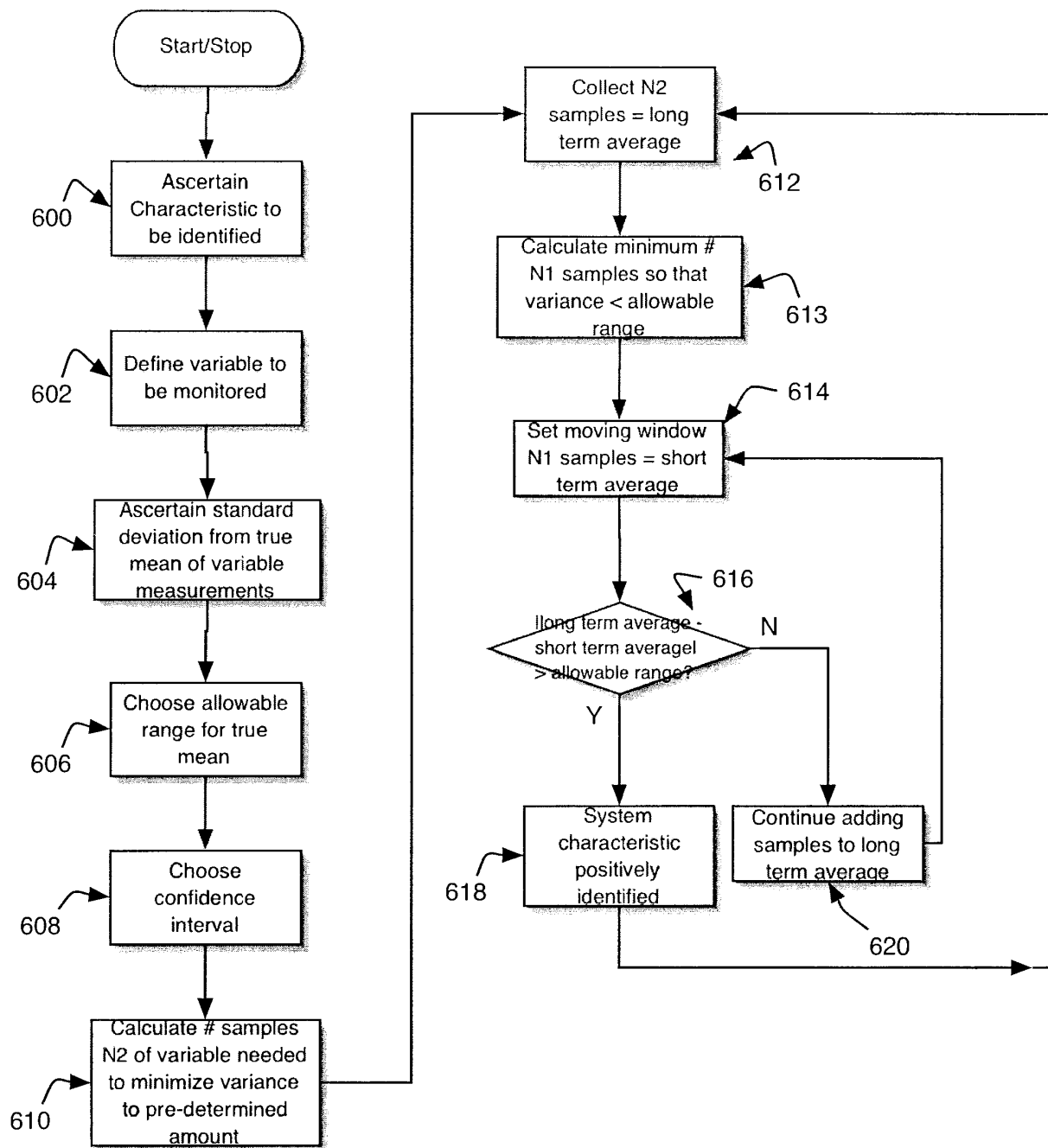


Fig. 55

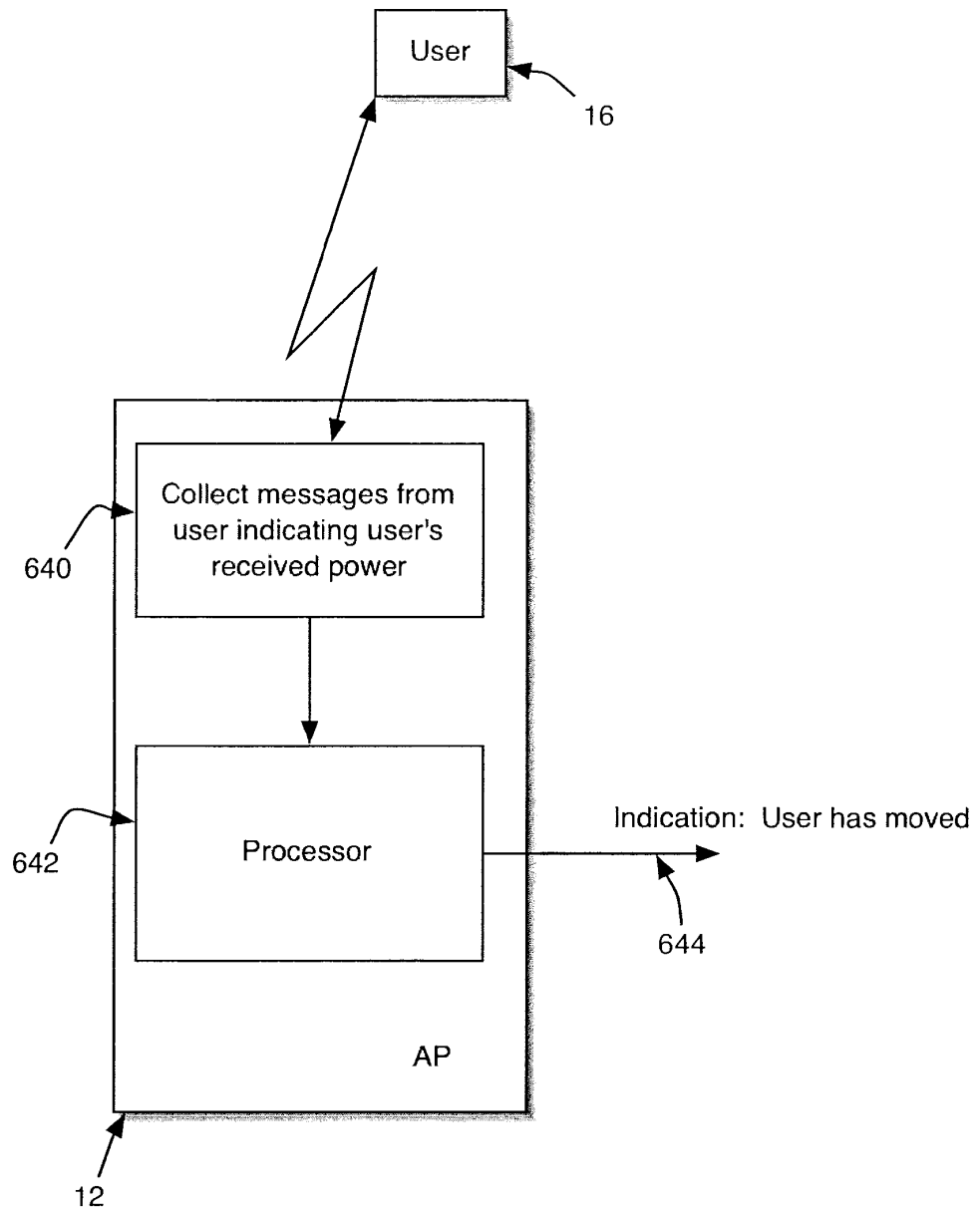


Fig. 56

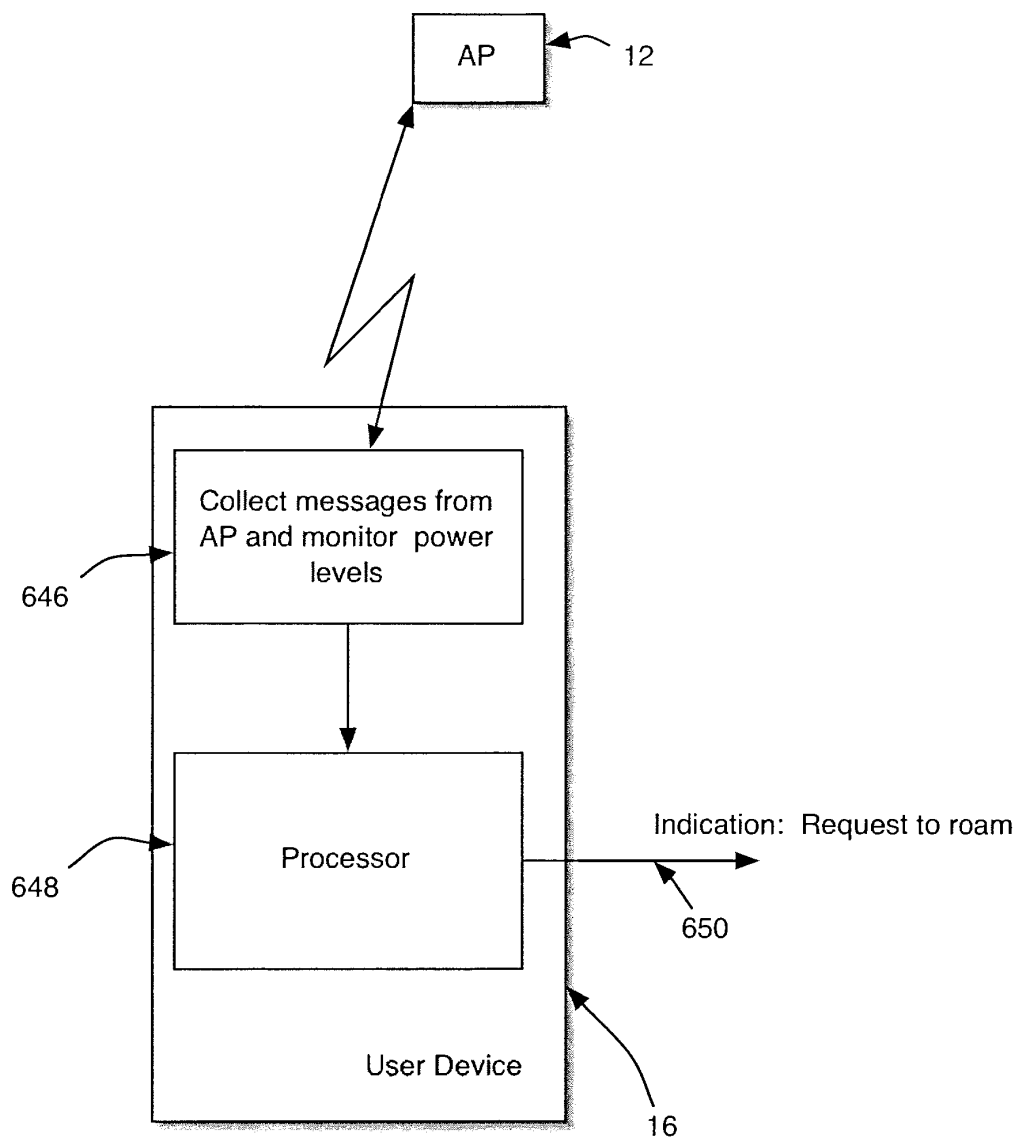


Fig. 57

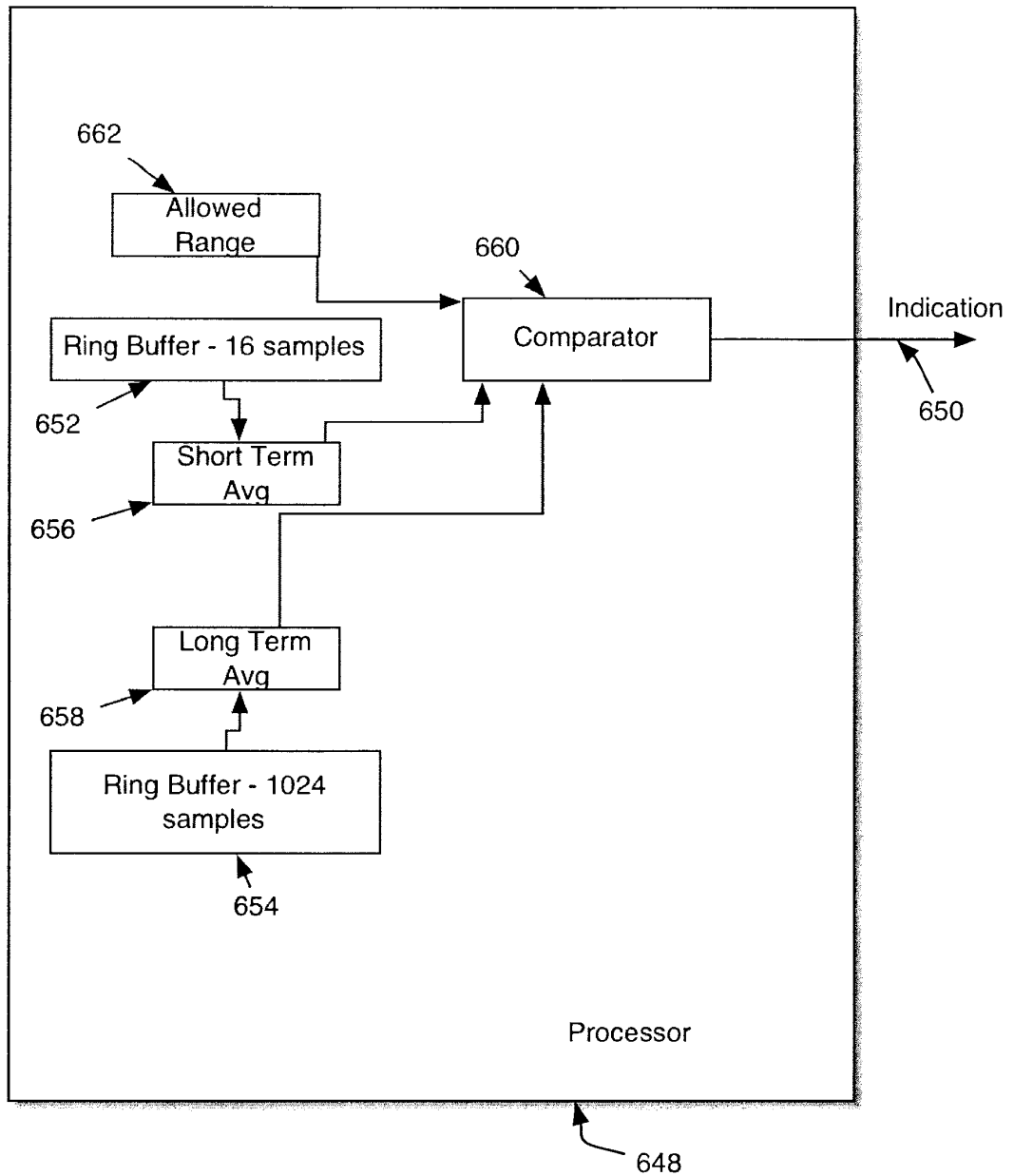


Fig. 58

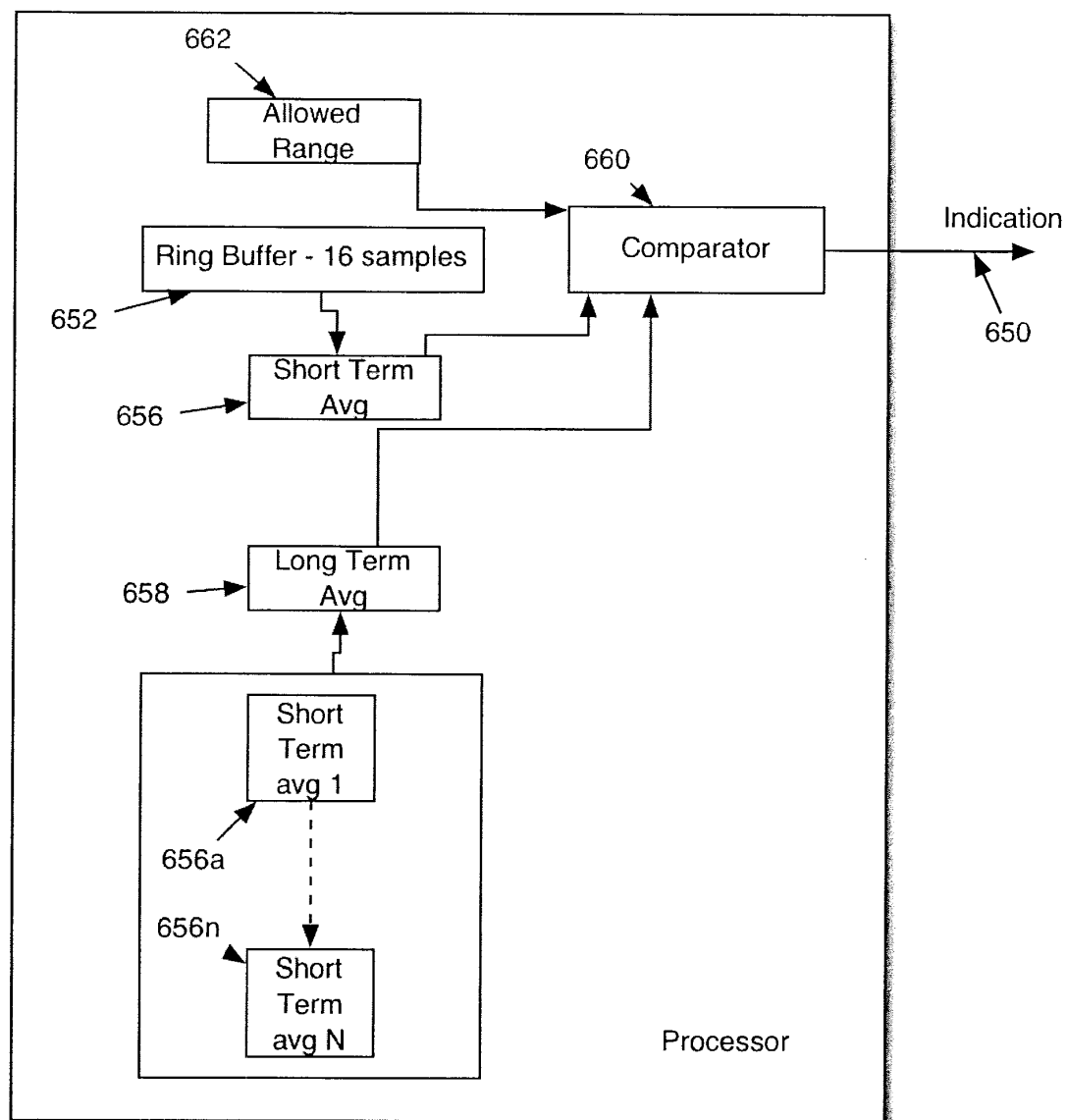


Fig. 59

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd J. Backes		
Filer:		Holmes W. Anderson/Christine Morrissette		
Attorney Docket Number:		160-125		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility application filing	1011	1	330	330
Utility Search Fee	1111	1	540	540
Utility Examination Fee	1311	1	220	220
Pages:				
Utility Appl Size fee per 50 sheets >100	1081	1	270	270
Claims:				
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1360

Electronic Acknowledgement Receipt	
EFS ID:	6749334
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd J. Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	05-JAN-2010
Filing Date:	
Time Stamp:	12:34:36
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$1360
RAM confirmation Number	8114
Deposit Account	504416
Authorized User	
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File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	UtilityTransmittal.pdf	99419	no	1
			d3826fea85f8e39196a95887e434914e0b9b43b7		
Warnings:					
Information:					
2	Power of Attorney	CombinedPowerOfAttorneyAndStatement.pdf	43907	no	1
			69f30cf925326b2cc437a263db9b3fdda6b11c53		
Warnings:					
Information:					
3	Nonpublication request from applicant.	NONPUB.pdf	48234	no	1
			d9b4716f81f2eda45e84279b3a7b43e8367badaf		
Warnings:					
Information:					
4	Oath or Declaration filed	CopyOfDeclaration.pdf	133375	no	3
			00ee9ef4189962bffc4350989ab639bdd2b71bf		
Warnings:					
Information:					
5		ContinuationApplication.pdf	479854	yes	96
			e42de4d4c4590eebed38742232943365ac2c8995		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	1	
	Specification		2	93	
	Claims		94	95	
	Appendix to the Specification		96	96	
Warnings:					
Information:					
6	Drawings-only black and white line drawings	Drawings.pdf	1251069	no	62
			66a723a1bc0be78fe98c0c33b6041a39864b98ca		
Warnings:					
Information:					

7	Fee Worksheet (PTO-875)	fee-info.pdf	36770 e377495d873f876ee01f996cc7cab80c456900b3	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			2092628		
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Filing Date: 01/05/2010

PTO/SB/06 (12-04)

Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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PATENT APPLICATION FEE DETERMINATION RECORD					Application or Docket Number 12/652,146	
Substitute for Form PTO-875						
APPLICATION AS FILED – PART I						
(Column 1)		(Column 2)				
FOR	NUMBER FILED					
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A				
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A				
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	0				
TOTAL CLAIMS (37 CFR 1.16(i))	6	2	0			
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2	minus 3	= 0			
APPLICATION SIZE FEE (37 CFR 1.16(s))						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))						
* If the difference in column 1 is less than zero, enter "0" in column 2.						
APPLICATION AS AMENDED – PART II						
(Column 1)		(Column 2)		(Column 3)		
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA			
	Total (37 CFR 1.16(i))	Minus	**	=		
	Independent (37 CFR 1.16(h))	Minus	***	=		
	Application Size Fee (37 CFR 1.16(s))					
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					
(Column 1)		(Column 2)		(Column 3)		
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA			
	Total (37 CFR 1.16(i))	Minus	**	=		
	Independent (37 CFR 1.16(h))	Minus	***	=		
	Application Size Fee (37 CFR 1.16(s))					
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.						

RATE (\$)	FEE (\$)
N/A	
X\$ 26	
X\$110	
195	
TOTAL	

OR

RATE (\$)	FEE (\$)
N/A	330
N/A	540
N/A	220
2X\$52	0
1X\$220	0
270	
390	
TOTAL	1360

OR

RATE (\$)	ADDITIONAL FEE (\$)
X =	
X =	
N/A	
TOTAL ADD'T FEE	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO.	TOT CLAIMS	IND CLAIMS
12/652,146	01/05/2010	2618	1360	160-125	6	2

CONFIRMATION NO. 1578

34845

Anderson Gorecki & Manaras LLP
33 NAGOG PARK
ACTON, MA 01720

FILING RECEIPT



0000000039741067

Date Mailed: 01/22/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Floyd Backes, Sharon, NH;
Gary Vacon, East Falmouth, MA;
Paul Callahan, Carlisle, MA;
William Hawe, Hollis, NH;
Roger Durand, Amherst, NH;

Power of Attorney: The patent practitioners associated with Customer Number 34845

Domestic Priority data as claimed by applicant

This application is a CON of 10/781,137 02/18/2004
which claims benefit of 60/449,602 02/24/2003
and claims benefit of 60/466,448 04/29/2003
and claims benefit of 60/472,320 05/21/2003
and claims benefit of 60/472,239 05/21/2003

Foreign Applications

If Required, Foreign Filing License Granted: 01/15/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/652,146**

Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No

Title

Program for Adjusting Channel Interference between Access Points in a Wireless Network

Preliminary Class

455

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO.	TOT CLAIMS	IND CLAIMS
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CONFIRMATION NO. 1578

34845

Anderson Gorecki & Manaras LLP
33 NAGOG PARK
ACTON, MA 01720

FILING RECEIPT



0000000039741067

Date Mailed: 01/22/2010

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Projected Publication Date: Request for Non-Publication Acknowledged

Non-Publication Request: Yes

Early Publication Request: No

Title

Program for Adjusting Channel Interference between Access Points in a Wireless Network

Preliminary Class

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NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/652,146	01/05/2010	Floyd Backes	160-125

CONFIRMATION NO. 1578

POA ACCEPTANCE LETTER

34845

Anderson Gorecki & Manaras LLP
33 NAGOG PARK
ACTON, MA 01720



Date Mailed: 01/22/2010

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/05/2010.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/vvan/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Backes	
Serial No.: 12/652,146	Group Art Unit: 2618
Filed: 01/05/2010	Examiner: Unknown
Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network	
Attorney Docket No.: 160-125	
Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Applicants respectfully request consideration of the references submitted herewith and listed on the attached PTO-1449. The Examiner is respectfully requested to initial next to each reference indicating that it has been considered and return a copy of the PTO-1449 to applicant with the first action on the merits in this application.

No fees are believed due in connection with this filing. If any fees are due in connection with this filing, the Commissioner is hereby authorized to charge payment of the fees associated with this communication or credit any overpayment to Deposit Account No. 504416.

Respectfully submitted,

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Signature: /Christine M. Morrisette/

/Holmes W. Anderson/
Holmes W. Anderson
Attorney/Agent for Applicant(s)
Reg. No. 37272

Date: March 11, 2010

Telephone No.: 978-264-4001

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			Application Number	12/652,146	
			Filing Date	01/05/2010	
			First Named Inventor	Backes	
			Art Unit	2618	
			Examiner Name	Unknown	
			Attorney Docket Number	160-125	
Sheet	1	of	10		

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number - Kind Code ² (if known)			
		US-5,212,831	May 1993	Chuang et al.	
		US-5,345,597	Sep. 1994	Strawczynski et al.	
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		US-5,386,589	Jan. 1995	Kanai, Toshihito	
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		US-5,574,968	Nov. 1996	Olds et al.	
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				Art Unit	2618
				Examiner Name	Unknown
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		US-6,907,229	Jun. 2005	Shpak	
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		US-6,993,334	Jan. 2006	Andrus et al.	
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				Art Unit	2618
				Examiner Name	Unknown
				Attorney Docket Number	160-125
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		US-2001/0046879	Nov. 2001	Schramm et al.	
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		US-2002/0012332	Jan. 2002	Tiedemann et al.	
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		US-2002/0191554	Dec. 2002	Kondo	

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				First Named Inventor	Backes
				Art Unit	2618
				Examiner Name	Unknown
				Attorney Docket Number	160-125
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U.S. PATENT DOCUMENTS					
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		Number - Kind Code ² (if known)			
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FOREIGN PATENT DOCUMENTS						
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146-662

INTERNATIONAL STANDARD

**ISO/IEC
8802-11**

**ANSI/IEEE
Std 802.11**

First edition
1999-00-00

**Information technology —
Telecommunications and information
exchange between systems — Local and
metropolitan area networks — Specific
requirements —**

**Part 11:
Wireless LAN Medium Access Control (MAC)
and Physical Layer (PHY) specifications**

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux locaux et métropolitains —
Exigences spécifiques —*

*Partie 11: Spécifications pour le contrôle d'accès au support et la couche
physique*



Reference number
ISO/IEC 8802-11:1999(E)
ANSI/IEEE
Std 802.11, 1999 edition

Abstract: The medium access control (MAC) and physical characteristics for wireless local area networks (LANs) are specified in this standard, part of a series of standards for local and metropolitan area networks. The medium access control unit in this standard is designed to support physical layer units as they may be adopted dependent on the availability of spectrum. This standard contains three physical layer units: two radio units, both operating in the 2400–2500 MHz band, and one baseband infrared unit. One radio unit employs the frequency-hopping spread spectrum technique, and the other employs the direct sequence spread spectrum technique.

Keywords: ad hoc network, infrared, LAN, local area network, mobility, radio frequency, wireless

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20 August 1999

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International Standard ISO/IEC 8802-11:1999(E)

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In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 8802-11 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

ISO/IEC 8802 consists of the following parts, under the general title *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements*:

- *Part 1: Overview of Local Area Network Standards*
- *Part 2: Logical link control*
- *Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*
- *Part 4: Token-passing bus access method and physical layer specifications*
- *Part 5: Token ring access method and physical layer specifications*
- *Part 6: Distributed Queue Dual Bus (DQDB) access method and physical layer specifications*
- *Part 7: Slotted ring access method and physical layer specification*
- *Part 9: Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- *Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*
- *Part 12: Demand-Priority access method, physical layer and repeater specifications*

Annexes A, C and D form a normative part of this part of ISO/IEC 8802. Annexes B and E are for information only.



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International Standard ISO/IEC 8802-11: 1999(E)
ANSI/IEEE Std 802.11, 1999 Edition

**Information technology—
Telecommunications and information
exchange between systems—
Local and metropolitan area networks—
Specific requirements—**

**Part 11: Wireless LAN Medium Access
Control (MAC) and Physical Layer
(PHY) Specifications**

Sponsor

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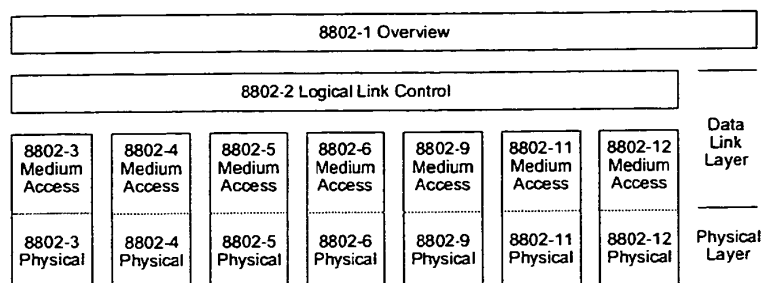


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Foreword to International Standard ISO/IEC 8802-11: 1999

This International Standard is part of a family of International Standards for Local and Metropolitan Area Networks. The relationship between this International Standard, which provides extensions to the behavior of ISO/IEC 10038, and the other members of the family is shown below. (The numbers in the figure refer to ISO/IEC Standard numbers.)



This family of International Standards deals with the Physical and Data Link layers as defined by the ISO Open Systems Interconnection (OSI) Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define seven types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The International Standards defining the access technologies are as follows:

- ISO/IEC 8802-3, utilizing carrier sense multiple access with collision detection (CSMA/CD) as the access method.
- ISO/IEC 8802-4, utilizing token passing bus as the access method.
- ISO/IEC 8802-5, utilizing token passing ring as the access method.
- ISO/IEC 8802-6, utilizing distributed queuing dual bus as the access method.
- ISO/IEC 8802-9, a unified access method offering integrated services for backbone networks.
- ISO/IEC 8802-11, a wireless LAN utilizing carrier sense multiple access with collision avoidance (CSMA/CA) as the access method.
- ISO/IEC 8802-12, utilizing Demand Priority as the access method.

ISO/IEC TR 8802-1, *Overview of Local Area Network Standards*, provides an overview of the series of ISO/IEC 8802 standards.

ISO/IEC 8802-2, *Logical Link Control*, is used in conjunction with the medium access standards to provide the data link layer service to network layer protocols.

ISO/IEC 15802-1, *Medium Access Control (MAC) service definition*, specifies the characteristics of the common MAC Service provided by all IEEE 802 LAN MACs. The service is defined in terms of primitives that can be passed between peer service users, their parameters, their interrelationship and valid sequences, and the associated events of the service.

ISO/IEC 15802-2, *LAN/MAN Management*, defines an OSI management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.

ISO/IEC 10038, *Media Access Control (MAC) bridges*, specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the level of the logical link control protocol (to be renumbered 15802-3).

ISO/IEC 15802-4, *System Load Protocol*, specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.

ISO/IEC 15802-5, *Remote Media Access Control (MAC) bridging*, specifies extensions for the interconnection, using non-LAN communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.

ANSI/IEEE Std 802.11, 1999 Edition

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Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

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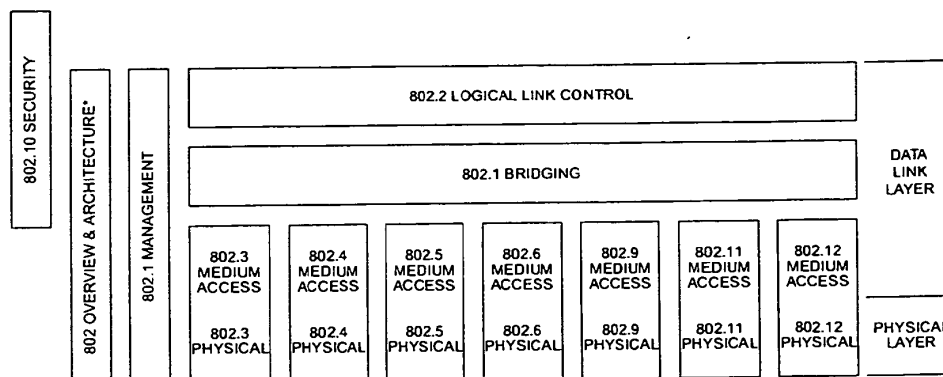
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Introduction to ANSI/IEEE Std 802.11, 1999 Edition

(This introduction is not a part of ANSI/IEEE Std 802.11, 1999 Edition or of ISO/IEC 8802-11: 1999, but is included for information purpose only.)

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard numbers.)



* Formerly IEEE Std 802.1A.

This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define seven types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining the access technologies are as follows:

- IEEE Std 802 *Overview and Architecture.* This standard provides an overview to the family of IEEE 802 Standards.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] *LAN/MAN Management.* Defines an OSI management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ANSI/IEEE Std 802.1D [ISO/IEC 15802-3] *Media Access Control (MAC) Bridges.* Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- ANSI/IEEE Std 802.1E [ISO/IEC 15802-4] *System Load Protocol.* Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- IEEE Std 802.1F *Common Definitions and Procedures for IEEE 802 Management Information*
- ANSI/IEEE Std 802.1G [ISO/IEC 15802-5] *Remote Media Access Control (MAC) Bridging.* Specifies extensions for the interconnection, using non-LAN communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.
- ANSI/IEEE Std 802.2 [ISO/IEC 8802-2] *Logical Link Control*

- ANSI/IEEE Std 802.3 [ISO/IEC 8802-3] *CSMA/CD Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.4 [ISO/IEC 8802-4] *Token Passing Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.5 [ISO/IEC 8802-5] *Token Ring Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.6 [ISO/IEC 8802-6] *Distributed Queue Dual Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.9 [ISO/IEC 8802-9] *Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security*
- IEEE Std 802.11 [ISO/IEC DIS 8802-11] *Wireless LAN Medium Access Control (MAC) and Physical Layer Specifications*
- ANSI/IEEE Std 802.12 [ISO/IEC DIS 8802-12] *Demand Priority Access Method, Physical Layer and Repeater Specifications*

In addition to the family of standards, the following is a recommended practice for a common Physical Layer technology:

- IEEE Std 802.7 *IEEE Recommended Practice for Broadband Local Area Networks*

The following additional working group has authorized standards projects under development:

- IEEE 802.14 *Standard Protocol for Cable-TV Based Broadband Communication Network*

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3.

ANSI/IEEE Std 802.11, 1999 Edition [ISO/IEC 8802-11: 1999]

This standard is a revision of IEEE Std 802.11-1997. The Management Information Base according to OSI rules has been removed, many redundant management items have been removed, and Annex D has been completed with the Management Information Base according to SNMP. Minor changes have been made throughout the document.

This standard defines the protocol and compatible interconnection of data communication equipment via the “air”, radio or infrared, in a local area network (LAN) using the carrier sense multiple access protocol with collision avoidance (CSMA/CA) medium sharing mechanism. The medium access control (MAC) supports operation under control of an access point as well as between independent stations. The protocol includes authentication, association, and reassociation services, an optional encryption/decryption procedure, power management to reduce power consumption in mobile stations, and a point coordination function for time-bounded transfer of data. The standard includes the definition of the management information base (MIB) using Abstract Syntax Notation I (ASN.1) and specifies the MAC protocol in a formal way, using the Speci-

fication and Description Language (SDL). Both ASN.1 and SDL source code have been added on a floppy diskette.

The infrared implementation of the PHY supports 1 Mbit/s data rate with an optional 2 Mbit/s extension. The radio implementations of the PHY specify either a frequency-hopping spread spectrum (FHSS) supporting 1 Mbit/s and an optional 2 Mbit/s data rate or a direct sequence spread spectrum (DSSS) supporting both 1 and 2 Mbit/s data rates.

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision state of this and other IEEE 802 standards may be obtained from

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Participants

At the time the draft of the 1999 version of this standard was sent to sponsor ballot, the IEEE 802.11 working group had the following voting members:

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Bob O'Hara and Greg Ennis, Chief Technical Editors	
George Fishel and Carolyn L. Heide, Secretaries	

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Information technology—

**Telecommunications and information exchange
between systems—**

Local and metropolitan area networks—

Specific requirements—

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

1. Overview

1.1 Scope

The scope of this standard is to develop a medium access control (MAC) and physical layer (PHY) specification for wireless connectivity for fixed, portable, and moving stations within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity to automatic machinery, equipment, or stations that require rapid deployment, which may be portable or hand-held, or which may be mounted on moving vehicles within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

Specifically, this standard

- Describes the functions and services required by an IEEE 802.11 compliant device to operate within ad hoc and infrastructure networks as well as the aspects of station mobility (transition) within those networks.
- Defines the MAC procedures to support the asynchronous MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the IEEE 802.11 MAC.
- Permits the operation of an IEEE 802.11 conformant device within a wireless local area network (LAN) that may coexist with multiple overlapping IEEE 802.11 wireless LANs.
- Describes the requirements and procedures to provide privacy of user information being transferred over the wireless medium (WM) and authentication of IEEE 802.11 conformant devices.

2. Normative references

The following standards contain provisions which, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.¹

IEEE Std C95.1-1991 (Reaff 1997), IEEE Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

ISO/IEC 7498-1: 1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.²

ISO/IEC 8802-2: 1998, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control.

ISO/IEC 8824-1: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Specification of basic notation.

ISO/IEC 8824-2: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Information object specification.

ISO/IEC 8824-3: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Constraint specification.

ISO/IEC 8824-4: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications.

ISO/IEC 8825-1: 1995, Information technology—ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).

ISO/IEC 8825-2: 1996, Information technology—ASN.1 encoding rules: Specification of Packed Encoding Rules (PER).

ISO/IEC 15802-1: 1995, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 1: Medium Access Control (MAC) service definition.

ITU Radio Regulations, volumes 1–4.³

ITU-T Recommendation X.210 (11/93), Information technology—Open systems interconnection—Basic Reference Model: Conventions for the definition of OSI services (*common text with ISO/IEC*).

ITU-T Recommendation Z.100 (03/93), CCITT specification and description language (SDL).

ITU-T Recommendation Z.105 (03/95), SDL combined with ASN.1 (SDL/ASN.1).

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.standards.ieee.org/>).

²ISO and ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>). They are also available in the United States from the U.S. Department of Commerce, Technology Administration, National Technical Information Service (NTIS), Springfield, VA 22161, USA.

3. Definitions

3.1 access control: The prevention of unauthorized usage of resources.

3.2 access point (AP): Any entity that has station functionality and provides access to the distribution services, via the wireless medium (WM) for associated stations.

3.3 ad hoc network: A network composed solely of stations within mutual communication range of each other via the wireless medium (WM). An ad hoc network is typically created in a spontaneous manner. The principal distinguishing characteristic of an ad hoc network is its limited temporal and spatial extent. These limitations allow the act of creating and dissolving the ad hoc network to be sufficiently straightforward and convenient so as to be achievable by nontechnical users of the network facilities; i.e., no specialized “technical skills” are required and little or no investment of time or additional resources is required beyond the stations that are to participate in the ad hoc network. The term *ad hoc* is often used as slang to refer to an independent basic service set (IBSS).

3.4 association: The service used to establish access point/station (AP/STA) mapping and enable STA invocation of the distribution system services (DSSs).

3.5 authentication: The service used to establish the identity of one station as a member of the set of stations authorized to associate with another station.

3.6 basic service area (BSA): The conceptual area within which members of a basic service set (BSS) may communicate.

3.7 basic service set (BSS): A set of stations controlled by a single coordination function.

3.8 basic service set (BSS) basic rate set: The set of data transfer rates that all the stations in a BSS will be capable of using to receive frames from the wireless medium (WM). The BSS basic rate set data rates are preset for all stations in the BSS.

3.9 broadcast address: A unique multicast address that specifies all stations.

3.10 channel: An instance of medium use for the purpose of passing protocol data units (PDUs) that may be used simultaneously, in the same volume of space, with other instances of medium use (on other channels) by other instances of the same physical layer (PHY), with an acceptably low frame error ratio due to mutual interference. Some PHYs provide only one channel, whereas others provide multiple channels. Examples of channel types are as shown in the following table:

Single channel	n-channel
Narrowband radio-frequency (RF) channel	Frequency division multiplexed channels
Baseband infrared	Direct sequence spread spectrum (DSSS) with code division multiple access

3.11 clear channel assessment (CCA) function: That logical function in the physical layer (PHY) that determines the current state of use of the wireless medium (WM).

3.12 confidentiality: The property of information that is not made available or disclosed to unauthorized individuals, entities, or processes.

3.13 coordination function: The logical function that determines when a station operating within a basic service set (BSS) is permitted to transmit and may be able to receive protocol data units (PDUs) via the wireless medium (WM). The coordination function within a BSS may have one point coordination function (PCF) and will have one distributed coordination function (DCF).

3.14 coordination function pollable: A station able to (1) respond to a coordination function poll with a data frame, if such a frame is queued and able to be generated, and (2) interpret acknowledgments in frames sent to or from the point coordinator.

3.15 deauthentication: The service that voids an existing authentication relationship.

3.16 directed address: *See:* unicast frame.

3.17 disassociation: The service that removes an existing association.

3.18 distributed coordination function (DCF): A class of coordination function where the same coordination function logic is active in every station in the basic service set (BSS) whenever the network is in operation.

3.19 distribution: The service that, by using association information, delivers medium access control (MAC) service data units (MSDUs) within the distribution system (DS).

3.20 distribution system (DS): A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).

3.21 distribution system medium (DSM): The medium or set of media used by a distribution system (DS) for communications between access points (APs) and portals of an extended service set (ESS).

3.22 distribution system service (DSS): The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service data units (MSDUs) between stations that are not in direct communication with each other over a single instance of the wireless medium (WM). These services include transport of MSDUs between the access points (APs) of basic service sets (BSSs) within an extended service set (ESS), transport of MSDUs between portals and BSSs within an ESS, and transport of MSDUs between stations in the same BSS in cases where the MSDU has a multicast or broadcast destination address or where the destination is an individual address, but the station sending the MSDU chooses to involve DSS. DSSs are provided between pairs of IEEE 802.11 MACs.

3.23 extended rate set (ERS): The set of data transfer rates supported by a station (if any) beyond the extended service set (ESS) basic rate set. This set may include data transfer rates that will be defined in future physical layer (PHY) standards.

3.24 extended service area (ESA): The conceptual area within which members of an extended service set (ESS) may communicate. An ESA is larger than or equal to a basic service area (BSA) and may involve several basic service sets (BSSs) in overlapping, disjointed, or both configurations.

3.25 extended service set (ESS): A set of one or more interconnected basic service sets (BSSs) and integrated local area networks (LANs) that appears as a single BSS to the logical link control layer at any station associated with one of those BSSs.

3.26 Gaussian frequency shift keying (GFSK): A modulation scheme in which the data is first filtered by a Gaussian filter in the baseband and then modulated with a simple frequency modulation.

3.27 independent basic service set (IBSS): A BSS that forms a self-contained network, and in which no access to a distribution system (DS) is available.

3.28 infrastructure: The infrastructure includes the distribution system medium (DSM), access point (AP), and portal entities. It is also the logical location of distribution and integration service functions of an extended service set (ESS). An infrastructure contains one or more APs and zero or more portals in addition to the distribution system (DS).

3.29 integration: The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and an existing, non-IEEE 802.11 local area network (via a portal).

3.30 medium access control (MAC) management protocol data unit (MMPDU): The unit of data exchanged between two peer MAC entities to implement the MAC management protocol.

3.31 medium access control (MAC) protocol data unit (MPDU): The unit of data exchanged between two peer MAC entities using the services of the physical layer (PHY).

3.32 medium access control (MAC) service data unit (MSDU): Information that is delivered as a unit between MAC service access points (SAPs).

3.33 minimally conformant network: An IEEE 802.11 network in which two stations in a single basic service area (BSA) are conformant with ISO/IEC 8802-11: 1999.

3.34 mobile station: A type of station that uses network communications while in motion.

3.35 multicast: A medium access control (MAC) address that has the group bit set. A multicast MAC service data unit (MSDU) is one with a multicast destination address. A multicast MAC protocol data unit (MPDU) or control frame is one with a multicast receiver address.

3.36 network allocation vector (NAV): An indicator, maintained by each station, of time periods when transmission onto the wireless medium (WM) will not be initiated by the station whether or not the station's clear channel assessment (CCA) function senses that the WM is busy.

3.37 point coordination function (PCF): A class of possible coordination functions in which the coordination function logic is active in only one station in a basic service set (BSS) at any given time that the network is in operation.

3.38 portable station: A type of station that may be moved from location to location, but that only uses network communications while at a fixed location.

3.39 portal: The logical point at which medium access control (MAC) service data units (MSDUs) from a non-IEEE 802.11 local area network (LAN) enter the distribution system (DS) of an extended service set (ESS).

3.40 privacy: The service used to prevent the content of messages from being read by other than the intended recipients.

3.41 reassociation: The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

3.42 station (STA): Any device that contains an IEEE 802.11 conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

3.43 station basic rate: A data transfer rate belonging to the extended service set (ESS) basic rate set that is used by a station for specific transmissions. The station basic rate may change dynamically as frequently as

each medium access control (MAC) protocol data unit (MPDU) transmission attempt, based on local considerations at that station.

3.44 station service (SS): The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations within a basic service set (BSS).

3.45 time unit (TU): A measurement of time equal to 1024 μ s.

3.46 unauthorized disclosure: The process of making information available to unauthorized individuals, entities, or processes.

3.47 unauthorized resource use: Use of a resource not consistent with the defined security policy.

3.48 unicast frame: A frame that is addressed to a single recipient, not a broadcast or multicast frame. *Syn:* directed address.

3.49 wired equivalent privacy (WEP): The optional cryptographic confidentiality algorithm specified by IEEE 802.11 used to provide data confidentiality that is subjectively equivalent to the confidentiality of a wired local area network (LAN) medium that does not employ cryptographic techniques to enhance privacy.

3.50 wireless medium (WM): The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).

4. Abbreviations and acronyms

ACK	acknowledgment
AID	association identifier
AP	access point
ATIM	announcement traffic indication message
BSA	basic service area
BSS	basic service set
BSSID	basic service set identification
CCA	clear channel assessment
CF	contention free
CFP	contention-free period
CID	connection identifier
CP	contention period
CRC	cyclic redundancy code
CS	carrier sense
CTS	clear to send
CW	contention window
DA	destination address
DBPSK	differential binary phase shift keying
DCE	data communication equipment
DCF	distributed coordination function
DCLA	direct current level adjustment
DIFS	distributed (coordination function) interframe space
DLL	data link layer
Dp	desensitization
DQPSK	differential quadrature phase shift keying
DS	distribution system
DSAP	destination service access point
DSM	distribution system medium

DSS	distribution system service
DSSS	direct sequence spread spectrum
DTIM	delivery traffic indication message
ED	energy detection
EIFS	extended interframe space
EIRP	equivalent isotropically radiated power
ERS	extended rate set
ESA	extended service area
ESS	extended service set
FC	frame control
FCS	frame check sequence
FER	frame error ratio
FH	frequency hopping
FHSS	frequency-hopping spread spectrum
FIFO	first in first out
GFSK	Gaussian frequency shift keying
IBSS	independent basic service set
ICV	integrity check value
IDU	interface data unit
IFS	interframe space
IMp	intermodulation protection
IR	infrared
ISM	industrial, scientific, and medical
IV	initialization vector
LAN	local area network
LLC	logical link control
LME	layer management entity
LRC	long retry count
lsb	least significant bit
MAC	medium access control
MDF	management-defined field
MIB	management information base
MLME	MAC sublayer management entity
MMPDU	MAC management protocol data unit
MPDU	MAC protocol data unit
msb	most significant bit
MSDU	MAC service data unit
N/A	not applicable
NAV	network allocation vector
PC	point coordinator
PCF	point coordination function
PDU	protocol data unit
PHY	physical (layer)
PHY-SAP	physical layer service access point
PIFS	point (coordination function) interframe space
PLCP	physical layer convergence protocol
PLME	physical layer management entity
PMD	physical medium dependent
PMD-SAP	physical medium dependent service access point
PN	pseudo-noise (code sequence)
PPDU	PLCP protocol data unit
ppm	parts per million
PPM	pulse position modulation
PRNG	pseudo-random number generator

PS	power save (mode)
PSDU	PLCP SDU
RA	receiver address
RF	radio frequency
RSSI	received signal strength indication
RTS	request to send
RX	receive or receiver
SA	source address
SAP	service access point
SDU	service data unit
SFD	start frame delimiter
SIFS	short interframe space
SLRC	station long retry count
SME	station management entity
SMT	station management
SQ	signal quality (PN code correlation strength)
SRC	short retry count
SS	station service
SSAP	source service access point
SSID	service set identifier
SSRC	station short retry count
STA	station
TA	transmitter address
TBTT	target beacon transmission time
TIM	traffic indication map
TSF	timing synchronization function
TU	time unit
TX	transmit or transmitter
TXE	transmit enable
UCT	unconditional transition
WAN	wide area network
WDM	wireless distribution media
WDS	wireless distribution system
WEP	wired equivalent privacy
WM	wireless medium

5. General description

5.1 General description of the architecture

This subclause presents the concepts and terminology used within the ISO/IEC 8802-11: 1999 document (referred to throughout the text as IEEE 802.11). Specific terms are defined in Clause 3. Illustrations convey key IEEE 802.11 concepts and the interrelationships of the architectural components. IEEE 802.11 uses an architecture to describe functional components of an IEEE 802.11 LAN. The architectural descriptions are not intended to represent any specific physical implementation of IEEE 802.11.

5.1.1 How wireless LAN systems are different

Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard.

5.1.1.1 Destination address does not equal destination location

In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.

5.1.1.2 The media impact the design

The physical layers used in IEEE 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

- a) Use a medium that has neither absolute nor readily observable boundaries outside of which stations with conformant PHY transceivers are known to be unable to receive network frames.
- b) Are unprotected from outside signals.
- c) Communicate over a medium significantly less reliable than wired PHYs.
- d) Have dynamic topologies.
- e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other).
- f) Have time-varying and asymmetric propagation properties.

Because of limitations on wireless PHY ranges, wireless LANs intended to cover reasonable geographic distances may be built from basic coverage building blocks.

5.1.1.3 The impact of handling mobile stations

One of the requirements of IEEE 802.11 is to handle *mobile* as well as *portable* stations. A *portable* station is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* stations actually access the LAN while in motion.

For technical reasons, it is not sufficient to handle only portable stations. Propagation effects blur the distinction between portable and mobile stations; stationary stations often appear to be mobile due to propagation effects.

Another aspect of mobile stations is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a station's receiver will always be powered on.

5.1.1.4 Interaction with other IEEE 802 layers

IEEE 802.11 is required to appear to higher layers [logical link control (LLC)] as a current style IEEE 802 LAN. This requires that the IEEE 802.11 network handle station mobility within the MAC sublayer. To meet reliability assumptions (that LLC makes about lower layers), it is necessary for IEEE 802.11 to incorporate functionality that is untraditional for MAC sublayers.

5.2 Components of the IEEE 802.11 architecture

The IEEE 802.11 architecture consists of several components that interact to provide a wireless LAN that supports station mobility transparently to upper layers.

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 1 shows two BSSs, each of which has two stations that are members of the BSS.

It is useful to think of the ovals used to depict a BSS as the coverage area within which the member stations of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) If a station moves out of its BSS, it can no longer directly communicate with other members of the BSS.

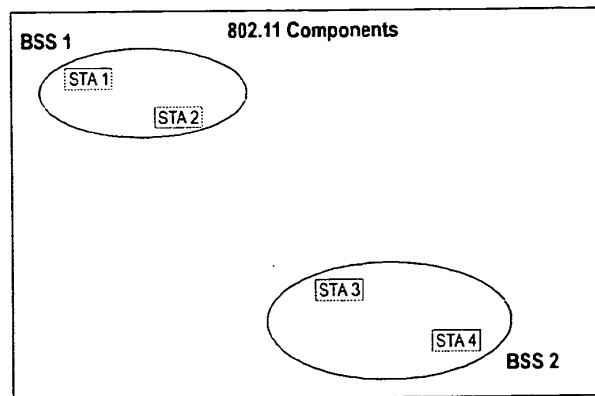


Figure 1—Basic service sets

5.2.1 The independent BSS as an ad hoc network

The independent BSS (IBSS) is the most basic type of IEEE 802.11 LAN. A minimum IEEE 802.11 LAN may consist of only two stations.

Figure 1 shows two IBSSs. This mode of operation is possible when IEEE 802.11 stations are able to communicate directly. Because this type of IEEE 802.11 LAN is often formed without pre-planning, for only as long as the LAN is needed, this type of operation is often referred to as an *ad hoc network*.

5.2.1.1 STA to BSS association is dynamic

The association between a STA and a BSS is dynamic (STAs turn on, turn off, come within range, and go out of range). To become a member of an infrastructure BSS, a station shall become "associated." These associations are dynamic and involve the use of the distribution system service (DSS), which is described in 5.3.2.

5.2.2 Distribution system concepts

PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the *distribution system* (DS).

IEEE 802.11 logically separates the wireless medium (WM) from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.

The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

An access point (AP) is a STA that provides access to the DS by providing DS services in addition to acting as a STA.

Figure 2 adds the DS and AP components to the IEEE 802.11 architecture picture.

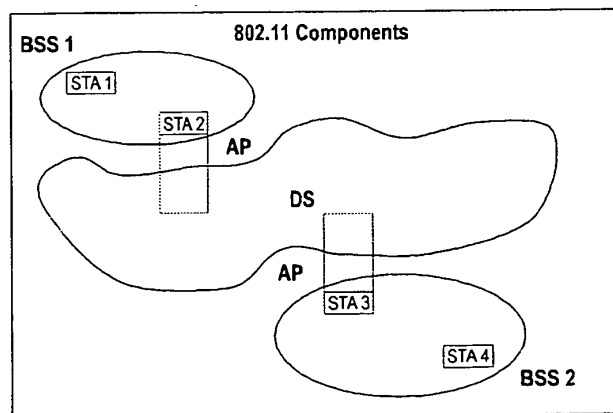


Figure 2—Distribution systems and access points

Data move between a BSS and the DS via an AP. Note that all APs are also STAs; thus they are addressable entities. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

5.2.2.1 Extended service set (ESS): The large coverage network

The DS and BSSs allow IEEE 802.11 to create a wireless network of arbitrary size and complexity. IEEE 802.11 refers to this type of network as the *extended service set* network.

The key concept is that the ESS network appears the same to an LLC layer as an IBSS network. Stations within an ESS may communicate and mobile stations may move from one BSS to another (within the same ESS) transparently to LLC.

Nothing is assumed by IEEE 802.11 about the relative physical locations of the BSSs in Figure 3.

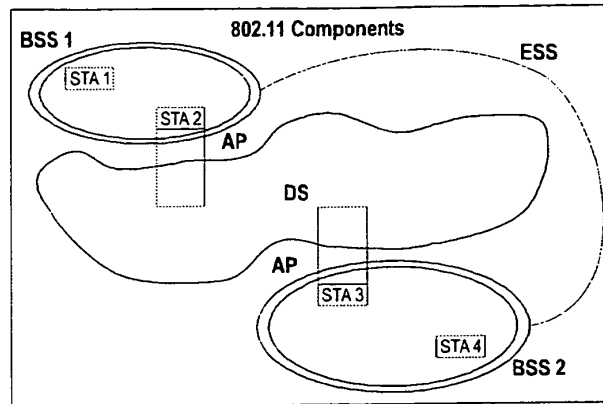


Figure 3—Extended service set

All of the following are possible:

- The BSSs may partially overlap. This is commonly used to arrange contiguous coverage within a physical volume.
- The BSSs could be physically disjointed. Logically there is no limit to the distance between BSSs.
- The BSSs may be physically collocated. This may be done to provide redundancy.
- One (or more) IBSS or ESS networks may be physically present in the same space as one (or more) ESS networks. This may arise for a number of reasons. Two of the most common are when an ad hoc network is operating in a location that also has an ESS network, and when physically overlapping IEEE 802.11 networks have been set up by different organizations.

5.2.3 Area concepts

For wireless PHYs, well-defined coverage areas simply do not exist. Propagation characteristics are dynamic and unpredictable. Small changes in position or direction may result in dramatic differences in signal strength. Similar effects occur whether a STA is stationary or mobile (as moving objects may impact station-to-station propagation).

Figure 4 shows a signal strength map for a simple square room with a standard metal desk and an open doorway. Figure 4 is a static snapshot; the propagation patterns change dynamically as stations and objects in the environment move. In Figure 4 the dark (solid) blocks in the lower left are a metal desk and there is a doorway at the top right of the figure. The figure indicates relative differences in field strength with different intensities and indicates the variability of field strength even in a static environment.

While the architecture diagrams show sharp boundaries for BSSs, this is an artifact of the pictorial representation, not a physical reality. Since dynamic three-dimensional field strength pictures are difficult to draw, well-defined shapes are used by IEEE 802.11 architectural diagrams to represent the coverage of a BSS.

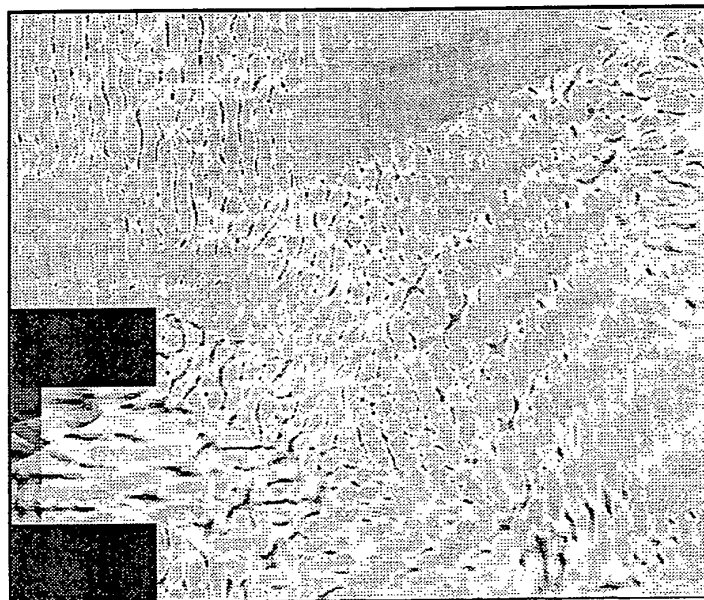


Figure 4—A representative signal intensity map

Further description difficulties arise when attempting to describe collocated coverage areas. Consider Figure 5, in which STA 6 could belong to BSS 2 or BSS 3.

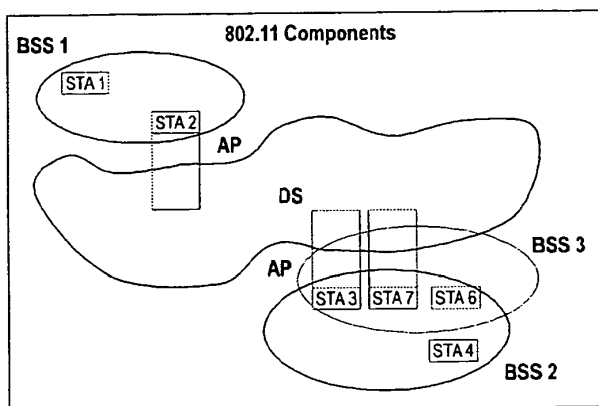


Figure 5—Collocated coverage areas

While the concept of sets of stations is correct, it is often convenient to talk about areas. For many topics the concept of area is sufficient. *Volume* is a more precise term than area, though still not technically correct. For historical reasons and convenience, this standard uses the common term *area*.

5.2.4 Integration with wired LANs

To integrate the IEEE 802.11 architecture with a traditional wired LAN, a final *logical* architectural component is introduced—a *portal*.

A portal is the logical point at which MSDUs from an integrated non-IEEE 802.11 LAN enter the IEEE 802.11 DS. For example, a portal is shown in Figure 6 connecting to a wired IEEE 802 LAN.

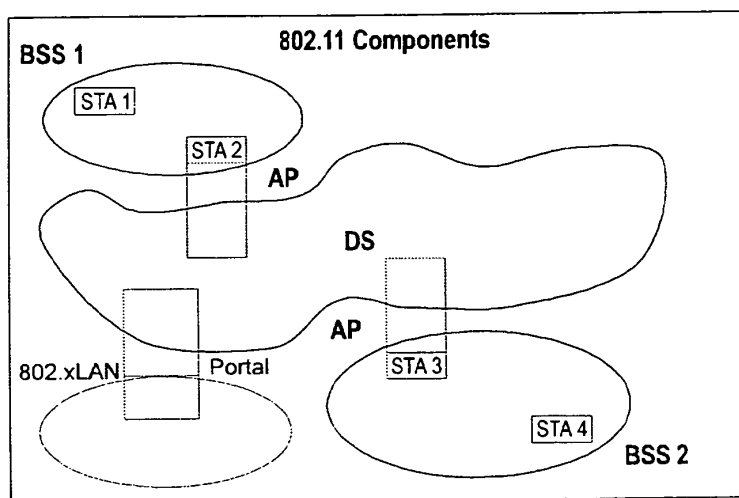


Figure 6—Connecting to other IEEE 802 LANs

All data from non-IEEE 802.11 LANs enter the IEEE 802.11 architecture via a portal. The portal provides logical integration between the IEEE 802.11 architecture and existing wired LANs. It is possible for one device to offer both the functions of an AP and a portal; this could be the case when a DS is implemented from IEEE 802 LAN components.

In IEEE 802.11, the ESS architecture (APs and the DS) provides traffic segmentation and range extension. Logical connections between IEEE 802.11 and other LANs are via the portal. Portals connect between the DSM and the LAN medium that is to be integrated.

5.3 Logical service interfaces

The IEEE 802.11 architecture allows for the possibility that the DS may not be identical to an existing wired LAN. A DS may be created from many different technologies including current IEEE 802 wired LANs. IEEE 802.11 does not constrain the DS to be either data link or network layer based. Nor does IEEE 802.11 constrain a DS to be either centralized or distributed in nature.

IEEE 802.11 explicitly does not specify the details of DS implementations. Instead, IEEE 802.11 specifies *services*. The services are associated with different components of the architecture. There are two categories of IEEE 802.11 service—the station service (SS) and the distribution system service (DSS). Both categories of service are used by the IEEE 802.11 MAC sublayer.

The complete set of IEEE 802.11 architectural services are as follows:

- a) Authentication
- b) Association
- c) Deauthentication
- d) Disassociation
- e) Distribution
- f) Integration
- g) Privacy
- h) Reassociation
- i) MSDU delivery

This set of services is divided into two groups: those that are part of every STA, and those that are part of a DS.

5.3.1 Station service (SS)

The service provided by stations is known as the *station service*.

The SS is present in every IEEE 802.11 station (including APs, as APs include station functionality). The SS is specified for use by MAC sublayer entities. All conformant stations provide SS.

The SS is as follows:

- a) Authentication
- b) Deauthentication
- c) Privacy
- d) MSDU delivery

5.3.2 Distribution system service (DSS)

The service provided by the DS is known as the *distribution system service*.

These services are represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the services are used to cross media and address space logical boundaries. This is the convenient place to show the services in the picture. The physical embodiment of various services may or may not be within a physical AP.

The DSSs are provided by the DS. They are accessed via a STA that also provides DSSs. A STA that is providing access to DSS is an AP.

The DSSs are as follows:

- a) Association
- b) Disassociation
- c) Distribution
- d) Integration
- e) Reassociation

DSSs are specified for use by MAC sublayer entities.

Figure 7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

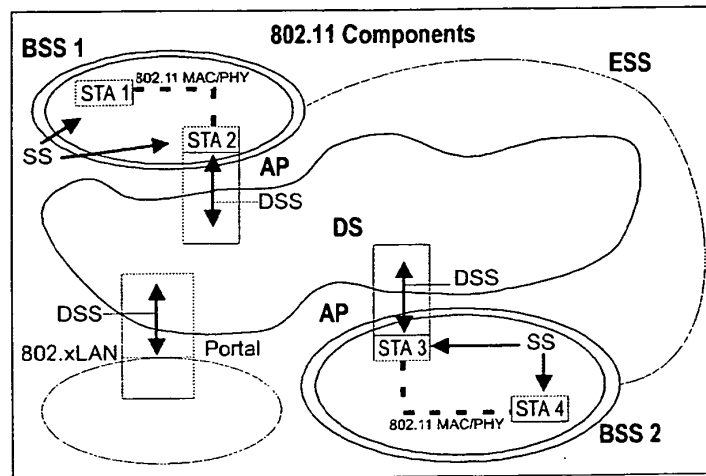


Figure 7—Complete IEEE 802.11 architecture

5.3.3 Multiple logical address spaces

Just as the IEEE 802.11 architecture allows for the possibility that the WM, DSM, and an integrated wired LAN may all be different physical media, it also allows for the possibility that each of these components may be operating within different address spaces. IEEE 802.11 only uses and specifies the use of the WM address space.

Each IEEE 802.11 PHY operates in a single medium—the WM. The IEEE 802.11 MAC operates in a single address space. MAC addresses are used on the WM in the IEEE 802.11 architecture. Therefore, it is unnecessary for the standard to explicitly specify that its addresses are “WM addresses.” This is assumed throughout this standard.

IEEE 802.11 has chosen to use the IEEE 802 48-bit address space (see 7.1.3.3.1). Thus IEEE 802.11 addresses are compatible with the address space used by the IEEE 802 LAN family.

The IEEE 802.11 choice of address space implies that for many instantiations of the IEEE 802.11 architecture, the wired LAN MAC address space and the IEEE 802.11 MAC address space may be the same. In those situations where a DS that uses MAC level IEEE 802 addressing is appropriate, all three of the logical address spaces used within a system could be identical. While this is a common case, it is not the only combination allowed by the architecture. The IEEE 802.11 architecture allows for all three logical address spaces to be distinct.

A multiple address space example is one in which the DS implementation uses network layer addressing. In this case, the WM address space and the DS address space would be different.

The ability of the architecture to handle multiple logical media and address spaces is key to the ability of IEEE 802.11 to be independent of the DS implementation and to interface cleanly with network layer mobility approaches. The implementation of the DS is unspecified and is beyond the scope of this standard.

5.4 Overview of the services

There are nine services specified by IEEE 802.11. Six of the services are used to support MSDU delivery between STAs. Three of the services are used to control IEEE 802.11 LAN access and confidentiality.

This subclause presents the services, an overview of how each service is used, and a description of how each service relates to other services and the IEEE 802.11 architecture. The services are presented in an order designed to help build an understanding of the operation of an IEEE 802.11 ESS network. As a result, the SSs and DSSs are intermixed in order (rather than being grouped by category).

Each of the services is supported by one or more MAC frame types. Some of the services are supported by MAC management messages and some by MAC data messages. All of the messages gain access to the WM via the IEEE 802.11 MAC sublayer medium access method specified in Clause 9.

The IEEE 802.11 MAC sublayer uses three types of messages—*data*, *management*, and *control* (see Clause 7). The data messages are handled via the MAC data service path.

MAC management messages are used to support the IEEE 802.11 services and are handled via the MAC management service data path.

MAC control messages are used to support the delivery of IEEE 802.11 data and management messages.

The examples here assume an ESS network environment. The differences between the ESS and the IBSS network environments are discussed separately in 5.6.

5.4.1 Distribution of messages within a DS

5.4.1.1 Distribution

This is the primary service used by IEEE 802.11 STAs. It is conceptually invoked by every data message to or from an IEEE 802.11 STA operating in an ESS (when the frame is sent via the DS). Distribution is via a DSS.

Refer to the ESS network in Figure 7 and consider a data message being sent from STA 1 to STA 4. The message is sent from STA 1 and received by STA 2 (the “input” AP). The AP gives the message to the distribution service of the DS. It is the job of the distribution service to deliver the message within the DS in such a way that it arrives at the appropriate DS destination for the intended recipient. In this example, the message is distributed to STA 3 (the “output” AP) and STA 3 accesses the WM to send the message to STA 4 (the intended destination).

How the message is distributed within the DS is not specified by IEEE 802.11. All IEEE 802.11 is required to do is to provide the DS with enough information for the DS to be able to determine the “output” point that corresponds to the desired recipient. The necessary information is provided to the DS by the three association related services (association, reassociation, and disassociation).

The previous example was a case in which the AP that invoked the distribution service was different from the AP that received the distributed message. If the message had been intended for a station that was a member of the same BSS as the sending station, then the “input” and “output” APs for the message would have been the same.

In either example, the distribution service was logically invoked. Whether the message actually had to traverse the physical DSM or not is a DS implementation matter and is not specified by this standard.

While IEEE 802.11 does not specify DS implementations, it does recognize and support the use of the WM as the DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to Clause 7 for details.)

5.4.1.2 Integration

If the distribution service determines that the intended recipient of a message is a member of an integrated LAN, the “output” point of the DS would be a portal instead of an AP.

Messages that are distributed to a portal cause the DS to invoke the Integration function (conceptually after the distribution service). The Integration function is responsible for accomplishing whatever is needed to deliver a message from the DSM to the integrated LAN media (including any required media or address space translations). Integration is a DSS.

Messages received from an integrated LAN (via a portal) by the DS for an IEEE 802.11 STA will invoke the Integration function before the message is distributed by the distribution service.

The details of an Integration function are dependent on a specific DS implementation and are outside the scope of this standard.

5.4.2 Services that support the distribution service

The primary purpose of a MAC sublayer is to transfer MSDUs between MAC sublayer entities. The information required for the distribution service to operate is provided by the association services. Before a data message can be handled by the distribution service, a STA shall be “associated.”

To understand the concept of association, it is necessary first to understand the concept of mobility.

5.4.2.1 Mobility types

The three transition types of significance to this standard that describe the mobility of stations within a network are as follows:

- a) **No-transition:** In this type, two subclasses that are usually indistinguishable are identified:
 - 1) Static—no motion.
 - 2) Local movement—movement within the PHY range of the communicating STAs [i.e., movement within a basic service area (BSA)].
- b) **BSS-transition:** This type is defined as a station movement from one BSS in one ESS to another BSS within the same ESS.
- c) **ESS-transition:** This type is defined as station movement from a BSS in one ESS to a BSS in a different ESS. This case is supported only in the sense that the STA may move. Maintenance of upper-layer connections cannot be guaranteed by IEEE 802.11; in fact, disruption of service is likely to occur.

The different association services support the different categories of mobility.

5.4.2.2 Association

To deliver a message within a DS, the distribution service needs to know which AP to access for the given IEEE 802.11 STA. This information is provided to the DS by the concept of association. Association is necessary, but not sufficient, to support BSS-transition mobility. Association is sufficient to support no-transition mobility. Association is a DSS.

Before a STA is allowed to send a data message via an AP, it shall first become associated with the AP. The act of becoming associated invokes the association service, which provides the STA to AP mapping to the

DS. The DS uses this information to accomplish its message distribution service. How the information provided by the association service is stored and managed within the DS is not specified by this standard.

At any given instant, a STA may be associated with no more than one AP. This ensures that the DS may determine a unique answer to the question, "Which AP is serving STA X?" Once an association is completed, a STA may make full use of a DS (via the AP) to communicate. Association is always initiated by the mobile STA, not the AP.

An AP may be associated with many STAs at one time.

A STA learns what APs are present and then requests to establish an association by invoking the association service. For details of how a station learns about what APs are present, see 11.1.3.

5.4.2.3 Reassociation

Association is sufficient for no-transition message delivery between IEEE 802.11 stations. Additional functionality is needed to support BSS-transition mobility. The additional required functionality is provided by the reassociation service. Reassociation is a DSS.

The reassociation service is invoked to "move" a current association from one AP to another. This keeps the DS informed of the current mapping between AP and STA as the station moves from BSS to BSS within an ESS. Reassociation also enables changing association attributes of an established association while the STA remains associated with the same AP. Reassociation is always initiated by the mobile STA.

5.4.2.4 Disassociation

The disassociation service is invoked whenever an existing association is to be terminated. Disassociation is a DSS.

In an ESS, this tells the DS to void existing association information. Attempts to send messages via the DS to a disassociated STA will be unsuccessful.

The disassociation service may be invoked by either party to an association (non-AP STA or AP). Disassociation is a notification, not a request. Disassociation cannot be refused by either party to the association.

APs may need to disassociate STAs to enable the AP to be removed from a network for service or for other reasons.

STAs shall attempt to disassociate whenever they leave a network. However, the MAC protocol does not depend on STAs invoking the disassociation service. (MAC management is designed to accommodate loss of an associated STA.)

5.4.3 Access and confidentiality control services

Two services are required for IEEE 802.11 to provide functionality equivalent to that which is inherent to wired LANs. The design of wired LANs assumes the physical attributes of wire. In particular, wired LAN design assumes the physically closed and controlled nature of wired media. The physically open medium nature of an IEEE 802.11 LAN violates those assumptions.

Two services are provided to bring the IEEE 802.11 functionality in line with wired LAN assumptions; authentication and privacy. Authentication is used instead of the wired media physical connection. Privacy is used to provide the confidential aspects of closed wired media.

5.4.3.1 Authentication

In wired LANs, physical security can be used to prevent unauthorized access. This is impractical in wireless LANs since they have a medium without precise bounds.

IEEE 802.11 provides the ability to control LAN access via the authentication service. This service is used by all stations to establish their identity to stations with which they will communicate. This is true for both ESS and IBSS networks. If a mutually acceptable level of authentication has not been established between two stations, an association shall not be established. Authentication is an SS.

IEEE 802.11 supports several authentication processes. The IEEE 802.11 authentication mechanism also allows expansion of the supported authentication schemes. IEEE 802.11 does not mandate the use of any particular authentication scheme.

IEEE 802.11 provides link-level authentication between IEEE 802.11 STAs. IEEE 802.11 does not provide either end-to-end (message origin to message destination) or user-to-user authentication. IEEE 802.11 authentication is used simply to bring the wireless link up to the assumed physical standards of a wired link. (This use of authentication is independent of any authentication process that may be used in higher levels of a network protocol stack.) If authentication other than that described here is desired, it is recommended that IEEE Std 802.10-1992 [B3]⁴ be implemented.

If desired, an IEEE 802.11 network may be operated using Open System authentication (see 8.1.1). This may violate implicit assumptions made by higher network layers. In an Open System, any station may become authenticated.

IEEE 802.11 also supports Shared Key authentication. Use of this authentication mechanism requires implementation of the wired equivalent privacy (WEP) option (see 8.2). In a Shared Key authentication system, identity is demonstrated by knowledge of a shared, secret, WEP encryption key.

Management information base (MIB) functions are provided to support the standardized authentication schemes.

IEEE 802.11 requires mutually acceptable, successful, authentication.

A STA may be authenticated with many other STAs at any given instant.

5.4.3.1.1 Preauthentication

Because the authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

Preauthentication is typically done by a STA while it is already associated with an AP (with which it previously authenticated). IEEE 802.11 does not require that STAs preauthenticate with APs. However, authentication is required before an association can be established.

If the authentication is left until reassociation time, this may impact the speed with which a STA can reassociate between APs, limiting BSS-transition mobility performance. The use of preauthentication takes the authentication service overhead out of the time-critical reassociation process.

⁴The numbers in brackets correspond to those of the bibliography in Annex E.

5.4.3.2 Deauthentication

The deauthentication service is invoked whenever an existing authentication is to be terminated. Deauthentication is an SS.

In an ESS, since authentication is a prerequisite for association, the act of deauthentication shall cause the station to be disassociated. The deauthentication service may be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. Deauthentication shall not be refused by either party. When an AP sends a deauthentication notice to an associated STA, the association shall also be terminated.

5.4.3.3 Privacy

In a wired LAN, only those stations physically connected to the wire may hear LAN traffic. With a wireless shared medium, this is not the case. Any IEEE 802.11-compliant STA may hear all like-PHY IEEE 802.11 traffic that is within range. Thus the connection of a single wireless link (without privacy) to an existing wired LAN may seriously degrade the security level of the wired LAN.

To bring the functionality of the wireless LAN up to the level implicit in wired LAN design, IEEE 802.11 provides the ability to encrypt the contents of messages. This functionality is provided by the privacy service. Privacy is an SS.

IEEE 802.11 specifies an optional privacy algorithm, WEP, that is designed to satisfy the goal of wired LAN "equivalent" privacy. The algorithm is not designed for ultimate security but rather to be "at least as secure as a wire." See Clause 8 for more details.

IEEE 802.11 uses the WEP mechanism (see Clause 8) to perform the actual encryption of messages. MIB functions are provided to support WEP.

Note that privacy may only be invoked for data frames and some Authentication Management frames. All stations initially start "in the clear" in order to set up the authentication and privacy services.

The default privacy state for all IEEE 802.11 STAs is "in the clear." If the privacy service is not invoked, all messages shall be sent unencrypted. If this default is not acceptable to one party or the other, data frames shall not be successfully communicated between the LLC entities. Unencrypted data frames received at a station configured for mandatory privacy, as well as encrypted data frames using a key not available at the receiving station, are discarded without an indication to LLC (or without indication to distribution services in the case of "To DS" frames received at an AP). These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries.

5.5 Relationships between services

A STA keeps two state variables for each STA with which direct communication via the WM is needed:

- *Authentication state*: The values are unauthenticated and authenticated.
- *Association state*: The values are unassociated and associated.

These two variables create three local states for each remote STA:

- *State 1*: Initial start state, unauthenticated, unassociated.
- *State 2*: Authenticated, not associated.
- *State 3*: Authenticated and associated.

The relationships between these station state variables and the services are given in Figure 8.

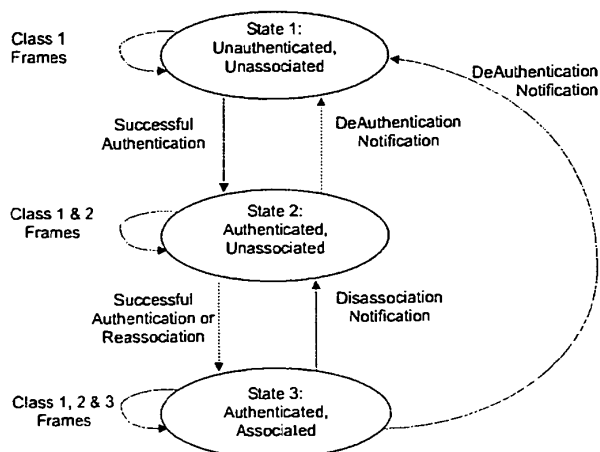


Figure 8—Relationship between state variables and services

The current state existing between the source and destination station determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 7). The state of the sending STA given by Figure 8 is with respect to the intended receiving STA. The allowed frame types are grouped into classes and the classes correspond to the station state. In State 1, only Class 1 frames are allowed. In State 2, either Class 1 or Class 2 frames are allowed. In State 3, all frames are allowed (Classes 1, 2, and 3). The frame classes are defined as follows:

- a) Class 1 frames (permitted from within States 1, 2, and 3):
 - 1) Control frames
 - i) Request to send (RTS)
 - ii) Clear to send (CTS)
 - iii) Acknowledgment (ACK)
 - iv) Contention-Free (CF)-End+ACK
 - v) CF-End
 - 2) Management frames
 - i) Probe request/response
 - ii) Beacon
 - iii) Authentication: Successful authentication enables a station to exchange Class 2 frames. Unsuccessful authentication leaves the STA in State 1.
 - iv) Deauthentication: Deauthentication notification when in State 2 or State 3 changes the STA's state to State 1. The STA shall become authenticated again prior to sending Class 2 frames.
 - v) Announcement traffic indication message (ATIM)
 - 3) Data frames
 - i) Data: Data frames with frame control (FC) bits "To DS" and "From DS" both false.
- b) Class 2 frames (if and only if authenticated; allowed from within States 2 and 3 only):
 - 1) Management frames:
 - i) Association request/response
 - Successful association enables Class 3 frames.
 - Unsuccessful association leaves STA in State 2.
 - ii) Reassociation request/response
 - Successful reassociation enables Class 3 frames.

- Unsuccessful reassociation leaves the STA in State 2 (with respect to the STA that was sent the reassociation message). Reassociation frames shall only be sent if the sending STA is already associated in the same ESS.
- iii) Disassociation
 - Disassociation notification when in State 3 changes a Station's state to State 2. This station shall become associated again if it wishes to utilize the DS.

If STA A receives a Class 2 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

- c) Class 3 frames (if and only if associated; allowed only from within State 3):
- 1) Data frames
 - Data subtypes: Data frames allowed. That is, either the "To DS" or "From DS" FC bits may be set to true to utilize DSSs.
 - 2) Management frames
 - Deauthentication: Deauthentication notification when in State 3 implies disassociation as well, changing the STA's state from 3 to 1. The station shall become authenticated again prior to another association.
 - 3) Control frames
 - PS-Poll

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is authenticated but not associated with STA A, STA A shall send a disassociation frame to STA B.

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

(The use of the word "receive" in this subclause refers to a frame that meets all of the filtering criteria specified in Clauses 8 and 9.)

5.6 Differences between ESS and IBSS LANs

In 5.2.1 the concept of the IBSS LAN was introduced. It was noted that an IBSS is often used to support an ad hoc network. In an IBSS network, a STA communicates directly with one or more other STAs.

Consider the full IEEE 802.11 architecture as shown in Figure 9.

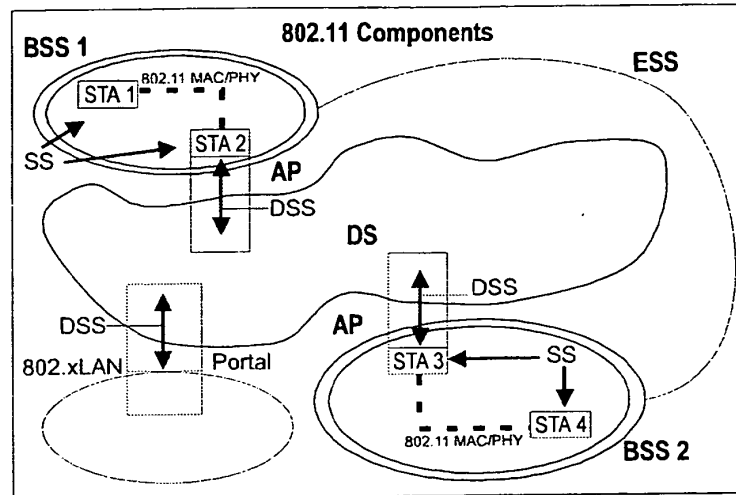


Figure 9—IEEE 802.11 architecture (again)

An IBSS consists of STAs that are directly connected. Thus there is (by definition) only one BSS. Further, since there is no physical DS, there cannot be a portal, an integrated wired LAN, or the DSSs. The logical picture reduces to Figure 10.

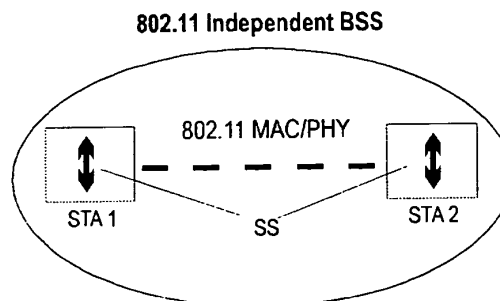


Figure 10—Logical architecture of an IBSS

Only the minimum two stations are shown in Figure 10. An IBSS may have an arbitrary number of members. In an IBSS, only Class 1 and Class 2 frames are allowed since there is no DS in an IBSS.

The services that apply to an IBSS are the SSs.

5.7 Message information contents that support the services

Each service is supported by one or more IEEE 802.11 messages. Information items are given by name; for corresponding values, see Clause 7.

5.7.1 Data

For a STA to send data to another STA, it sends a data message, as shown below:

Data messages

- Message type: Data
- Message subtype: Data
- Information items:
 - IEEE source address of message
 - IEEE destination address of message
 - BSS ID
- Direction of message: From STA to STA

5.7.2 Association

For a STA to associate, the association service causes the following messages to occur:

Association request

- Message type: Management
- Message subtype: Association request
- Information items:
 - IEEE address of the STA initiating the association
 - IEEE address of the AP with which the initiating station will associate
 - ESS ID
- Direction of message: From STA to AP

Association response

- Message type: Management
- Message subtype: Association response
- Information items:
 - Result of the requested association. This is an item with values “successful” and “unsuccessful.”
 - If the association is successful, the response shall include the association identifier (AID).
- Direction of message: From AP to STA

5.7.3 Reassociation

For a STA to reassociate, the reassociation service causes the following message to occur:

Reassociation request

- Message type: Management
- Message subtype: Reassociation request
- Information items:
 - IEEE address of the STA initiating the reassociation
 - IEEE address of the AP with which the initiating station will reassociate
 - IEEE address of the AP with which the initiating station is currently associated
 - ESS ID
- Direction of message:
 - From STA to AP (The AP with which the STA is requesting reassociation)

The address of the current AP is included for efficiency. The inclusion of the current AP address facilitates MAC reassociation to be independent of the DS implementation.

Reassociation response

- Message type: Management
- Message subtype: Reassociation response
- Information items:
 - Result of the requested reassociation. This is an item with values “successful” and “unsuccessful.”
 - If the reassociation is successful, the response shall include the AID.
- Direction of message: From AP to STA

5.7.4 Disassociation

For a STA to terminate an active association, the disassociation service causes the following message to occur:

Disassociation

- Message type: Management
- Message subtype: Disassociation
- Information items:
 - IEEE address of the station that is being disassociated. This shall be the broadcast address in the case of an AP disassociating with all associated stations.
 - IEEE address of the AP with which the station is currently associated.
- Direction of message: From STA to STA (e.g., STA to AP or AP to STA)

5.7.5 Privacy

For a STA to invoke the WEP privacy algorithm (as controlled by the related MIB attributes, see Clause 11), the privacy service causes MPDU encryption and sets the WEP frame header bit appropriately (see Clause 7).

5.7.6 Authentication

For a STA to authenticate with another STA, the authentication service causes one or more authentication management frames to be exchanged. The exact sequence of frames and their content is dependent on the authentication scheme invoked. For all authentication schemes, the authentication algorithm is identified within the management frame body.

In an IBSS environment, either station may be the initiating STA (STA 1). In an ESS environment, STA 1 is the mobile STA, and STA 2 is the AP.

Authentication (first frame of sequence)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Station identity assertion
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
- Direction of message: First frame in the transaction sequence is always from STA 1 to STA 2.

The first frame in an authentication sequence shall always be unencrypted.

Authentication (intermediate sequence frames)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
- Direction of message:
 - Even transaction sequence numbers: From STA 2 to STA 1
 - Odd transaction sequence numbers: From STA 1 to STA 2

Authentication (final frame of sequence)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
 - The result of the requested authentication. This is an item with values “successful” and “unsuccessful.”
- Direction of message: From STA 2 to STA 1

5.7.7 Deauthentication

For a STA to invalidate an active authentication, the following message is sent:

Deauthentication

- Message type: Management
- Message subtype: Deauthentication
- Information items:
 - IEEE address of the STA that is being deauthenticated
 - IEEE address of the STA with which the STA is currently authenticated
 - This shall be the broadcast address in the case of a STA deauthenticating all STAs currently authenticated.
- Direction of message: From STA to STA

5.8 Reference model

This standard presents the architectural view, emphasizing the separation of the system into two major parts: the MAC of the data link layer and the PHY. These layers are intended to correspond closely to the lowest

layers of the ISO/IEC basic reference model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1: 1994⁵). The layers and sublayers described in this standard are shown in Figure 11.

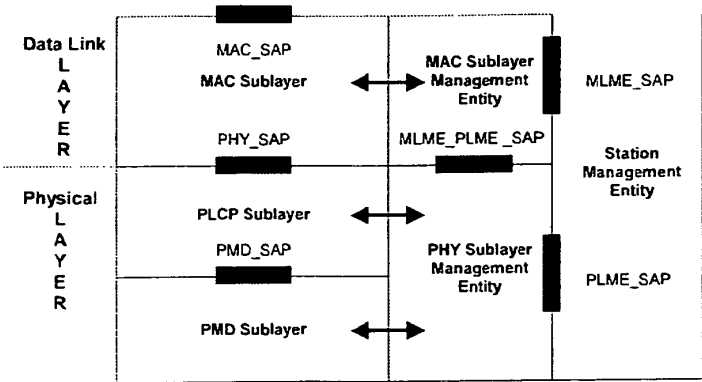


Figure 11—Portion of the ISO/IEC basic reference model covered in this standard

⁵Information on normative references can be found in Clause 2.

6. MAC service definition

6.1 Overview of MAC services

6.1.1 Asynchronous data service

This service provides peer LLC entities with the ability to exchange MAC service data units (MSDUs). To support this service, the local MAC uses the underlying PHY-level services to transport an MSDU to a peer MAC entity, where it will be delivered to the peer LLC. Such asynchronous MSDU transport is performed on a best-effort connectionless basis. There are no guarantees that the submitted MSDU will be delivered successfully. Broadcast and multicast transport is part of the asynchronous data service provided by the MAC. Due to the characteristics of the WM, broadcast and multicast MSDUs may experience a lower quality of service, compared to that of unicast MSDUs. All STAs will support the asynchronous data service. Because operation of certain functions of the MAC may cause reordering of some MSDUs, as discussed in more detail below, there are two service classes within the asynchronous data service. By selecting the desired service class, each LLC entity initiating the transfer of MSDUs is able to control whether MAC entities are or are not allowed to reorder those MSDUs.

6.1.2 Security services

Security services in IEEE 802.11 are provided by the authentication service and the WEP mechanism. The scope of the security services provided is limited to station-to-station data exchange. The privacy service offered by an IEEE 802.11 WEP implementation is the encryption of the MSDU. For the purposes of this standard, WEP is viewed as a logical service located within the MAC sublayer as shown in the reference model, Figure 11. Actual implementations of the WEP service are transparent to the LLC and other layers above the MAC sublayer.

The security services provided by the WEP in IEEE 802.11 are as follows:

- a) Confidentiality;
- b) Authentication; and
- c) Access control in conjunction with layer management.

During the authentication exchange, parties A and B exchange authentication information as described in Clause 8.

The MAC sublayer security services provided by WEP rely on information from non-layer 2 management or system entities. Management entities communicate information to WEP through a set of MIB attributes.

6.1.3 MSDU ordering

The services provided by the MAC sublayer permit, and may in certain cases require, the reordering of MSDUs. The MAC does not intentionally reorder MSDUs except as may be necessary to improve the likelihood of successful delivery based on the current operational ("power management") mode of the designated recipient station(s). The sole effect of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single station, is a change in the delivery order of broadcast and multicast MSDUs, relative to directed MSDUs, originating from a single source station address. If a higher-layer protocol using the asynchronous data service cannot tolerate this possible reordering, the optional StrictlyOrdered service class should be used. MSDUs transferred between any pair of stations using the StrictlyOrdered service class are not subject to the relative reordering that is possible when the ReorderableMulticast service class is used. However, the desire to receive MSDUs sent using the StrictlyOrdered service class at a station precludes simultaneous use of the MAC power management facilities at that station.

In order for the MAC to operate properly, the DS must meet the requirements of ISO/IEC 15802-1: 1995.

Operational restrictions that ensure the appropriate ordering of MSDUs are specified in 9.8.

6.2 Detailed service specification

6.2.1 MAC data services

The IEEE 802.11 MAC supports the following service primitives as defined in ISO/IEC 8802-2: 1998:

- MA-UNITDATA.request
- MA-UNITDATA.indication
- MA-UNITDATA-STATUS.indication

The LLC definitions of the primitives and specify parameter value restrictions imposed by IEEE 802.11 are given in 6.2.1.1 through 6.2.1.3.

6.2.1.1 MA-UNITDATA.request

6.2.1.1.1 Function

This primitive requests a transfer of an MSDU from a local LLC sublayer entity to a single peer LLC sublayer entity, or multiple peer LLC sublayer entities in the case of group addresses.

6.2.1.1.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.request  (
    source address,
    destination address,
    routing information,
    data,
    priority,
    service class
)
```

The source address (SA) parameter specifies an individual MAC sublayer address of the sublayer entity to which the MSDU is being transferred.

The destination address (DA) parameter specifies either an individual or a group MAC sublayer entity address.

The routing information parameter specifies the route desired for the data transfer (a null value indicates source routing is not to be used). For IEEE 802.11, the routing information parameter must be null.

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. For IEEE 802.11, the length of the MSDU must be less than or equal to 2304 octets.

The priority parameter specifies the priority desired for the data unit transfer. IEEE 802.11 allows two values: Contention or ContentionFree.

The service class parameter specifies the service class desired for the data unit transfer. IEEE 802.11 allows two values: `ReorderableMulticast` or `StrictlyOrdered`.

6.2.1.1.3 When generated

This primitive is generated by the LLC sublayer entity whenever an MSDU is to be transferred to a peer LLC sublayer entity or entities.

6.2.1.1.4 Effect of receipt

The receipt of this primitive causes the MAC sublayer entity to append all MAC specified fields, including DA, SA, and all fields that are unique to IEEE 802.11, and pass the properly formatted frame to the lower layers for transfer to a peer MAC sublayer entity or entities.

6.2.1.2 MA-UNITDATA.indication

6.2.1.2.1 Function

This primitive defines the transfer of an MSDU from the MAC sublayer entity to the LLC sublayer entity, or entities in the case of group addresses. In the absence of error, the contents of the data parameter are logically complete and unchanged relative to the data parameter in the associated `MA-UNITDATA.request` primitive.

6.2.1.2.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.indication (
    source address,
    destination address,
    routing information,
    data,
    reception status,
    priority,
    service class
)
```

The SA parameter is an individual address as specified by the SA field of the incoming frame.

The DA parameter is either an individual or a group address as specified by the DA field of the incoming frame.

The routing information parameter specifies the route that was used for the data transfer. IEEE 802.11 will always set this field to null.

The data parameter specifies the MSDU as received by the local MAC entity.

The reception status parameter indicates the success or failure of the received frame for those frames that IEEE 802.11 reports via an `MA-UNITDATA.indication`. This MAC only reports "success" when all failures of reception are discarded without generating `MA-UNITDATA.indication`.

The priority parameter specifies the receive processing priority that was used for the data unit transfer. IEEE 802.11 allows two values: `Contention` or `ContentionFree`.

The service class parameter specifies the receive service class that was used for the data unit transfer. IEEE 802.11 allows two values: `ReorderableMulticast` or `StrictlyOrdered`.

6.2.1.2.3 When generated

The `MA-UNITDATA.indication` primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of a frame at the local MAC sublayer entity. Frames are reported only if they are validly formatted at the MAC sublayer, received without error, received with valid (or null) WEP encryption, and their destination address designates the local MAC sublayer entity.

6.2.1.2.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer is dependent on the validity and content of the frame.

6.2.1.3 MA-UNITDATA-STATUS.indication

6.2.1.3.1 Function

This primitive has local significance and provides the LLC sublayer with status information for the corresponding preceding `MA-UNITDATA.request` primitive.

6.2.1.3.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA-STATUS.indication (
    source address,
    destination address,
    transmission status,
    provided priority,
    provided service class
)
```

The SA parameter is an individual MAC sublayer entity address as specified in the associated `MA-UNITDATA.request` primitive.

The DA parameter is either an individual or group MAC sublayer entity address as specified in the associated `MA-UNITDATA.request` primitive.

The transmission status parameter will be used to pass status information back to the local requesting LLC sublayer entity. IEEE 802.11 specifies the following values for transmission status:

- a) Successful;
- b) Undeliverable (for unacknowledged directed MSDUs when the `aShortRetryMax` or `aLongRetryMax` retry limit would otherwise be exceeded);
- c) Excessive data length;
- d) Non-null source routing;
- e) Unsupported priority (for priorities other than `ContentionFree`);
- f) Unsupported service class (for service classes other than `ReorderableMulticast` or `StrictlyOrdered`);
- g) Unavailable priority (for `ContentionFree` when no point coordinator is available, in which case the MSDU is transmitted with a provided priority of `Contention`);

- h) Unavailable service class (for StrictlyOrdered service when the station's power management mode is other than "active");
- i) Undeliverable (TransmitMSDUTimer reached aMaxTransmitMSDULifetime before successful delivery);
- j) Undeliverable (no BSS available);
- k) Undeliverable (cannot encrypt with a null key).

The provided priority parameter specifies the priority that was used for the associated data unit transfer (Contention or ContentionFree).

The provided service class parameter specifies the class of service used for the associated data unit transfer (ReorderableMulticast or StrictlyOrdered).

6.2.1.3.3 When generated

The MA-UNITDATA-STATUS.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity to indicate the status of the service provided for the corresponding MA-UNITDATA.request primitive.

6.2.1.3.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer is dependent upon the type of operation employed by the LLC sublayer entity.

7. Frame formats

The format of the MAC frames is specified in this clause. All stations shall be able to properly construct frames for transmission and decode frames upon reception, as specified in this clause.

7.1 MAC frame formats

Each frame consists of the following basic components:

- a) A *MAC header*, which comprises frame control, duration, address, and sequence control information;
- b) A variable length *frame body*, which contains information specific to the *frame type*;
- c) A *frame check sequence* (FCS), which contains an IEEE 32-bit cyclic redundancy code (CRC).

7.1.1 Conventions

The MAC protocol data units (MPDUs) or frames in the MAC sublayer are described as a sequence of fields in specific order. Each figure in Clause 7 depicts the fields/subfields as they appear in the MAC frame and in the order in which they are passed to the physical layer convergence protocol (PLCP), from left to right.

In figures, all bits within fields are numbered, from 0 to *k*, where the length of the field is *k* + 1 bit. The octet boundaries within a field can be obtained by taking the bit numbers of the field modulo 8. Octets within numeric fields that are longer than a single octet are depicted in increasing order of significance, from lowest numbered bit to highest numbered bit. The octets in fields longer than a single octet are sent to the PLCP in order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

Any field containing a CRC is an exception to this convention and is transmitted commencing with the coefficient of the highest-order term.

MAC addresses are assigned as ordered sequences of bits. The Individual/Group bit is always transferred first and is bit 0 of the first octet.

Values specified in decimal are coded in natural binary unless otherwise stated. The values in Table 1 are in binary, with the bit assignments shown in the table. Values in other tables are shown in decimal notation.

Reserved fields and subfields are set to 0 upon transmission and are ignored upon reception.

7.1.2 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 12 depicts the general MAC frame format. The fields Address 2, Address 3, Sequence Control, Address 4, and Frame Body are only present in certain frame types. Each field is defined in 7.1.3. The format of each of the individual frame types is defined in 7.2.

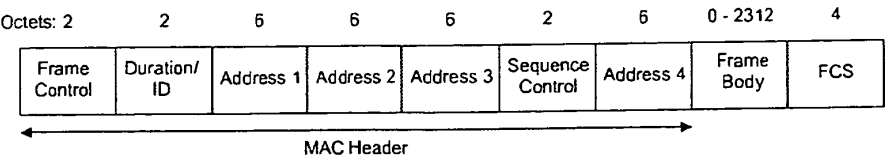


Figure 12—MAC frame format

7.1.3 Frame fields

7.1.3.1 Frame Control field

The Frame Control field consists of the following subfields: Protocol Version, Type, Subtype, To DS, From DS, More Fragments, Retry, Power Management, More Data, Wired Equivalent Privacy (WEP), and Order. The format of the Frame Control field is illustrated in Figure 13.

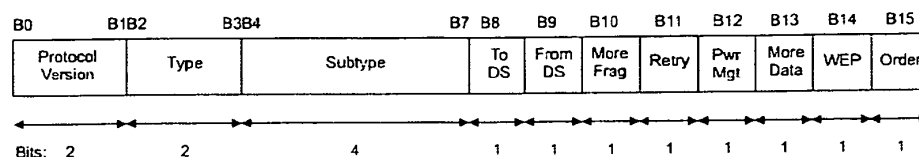


Figure 13—Frame Control field

7.1.3.1.1 Protocol Version field

The Protocol Version field is 2 bits in length and is invariant in size and placement across all revisions of this standard. For this standard, the value of the protocol version is 0. All other values are reserved. The revision level will be incremented only when a fundamental incompatibility exists between a new revision and the prior edition of the standard. A device that receives a frame with a higher revision level than it supports will discard the frame without indication to the sending station or to LLC.

7.1.3.1.2 Type and Subtype fields

The Type field is 2 bits in length, and the Subtype field is 4 bits in length. The Type and Subtype fields together identify the function of the frame. There are three frame types: control, data, and management. Each of the frame types have several defined subtypes. Table 1 defines the valid combinations of type and subtype.

7.1.3.1.3 To DS field

The To DS field is 1 bit in length and is set to 1 in data type frames destined for the DS. This includes all data type frames sent by STAs associated with an AP. The To DS field is set to 0 in all other frames.

7.1.3.1.4 From DS field

The From DS field is 1 bit in length and is set to 1 in data type frames exiting the DS. It is set to 0 in all other frames.

The permitted To/From DS bit combinations and their meanings are given in Table 2.

7.1.3.1.5 More Fragments field

The More Fragments field is 1 bit in length and is set to 1 in all data or management type frames that have another fragment of the current MSDU or current MMPDU to follow. It is set to 0 in all other frames.

Table 1—Valid type and subtype combinations

Type value b3 b2	Type description	Subtype value b7 b6 b5 b4	Subtype description
00	Management	0000	Association request
00	Management	0001	Association response
00	Management	0010	Reassociation request
00	Management	0011	Reassociation response
00	Management	0100	Probe request
00	Management	0101	Probe response
00	Management	0110–0111	Reserved
00	Management	1000	Beacon
00	Management	1001	Announcement traffic indication message (ATIM)
00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
00	Management	1101–1111	Reserved
01	Control	0000–1001	Reserved
01	Control	1010	Power Save (PS)-Poll
01	Control	1011	Request To Send (RTS)
01	Control	1100	Clear To Send (CTS)
01	Control	1101	Acknowledgment (ACK)
01	Control	1110	Contention-Free (CF)-End
01	Control	1111	CF-End + CF-Ack
10	Data	0000	Data
10	Data	0001	Data + CF-Ack
10	Data	0010	Data + CF-Poll
10	Data	0011	Data + CF-Ack + CF-Poll
10	Data	0100	Null function (no data)
10	Data	0101	CF-Ack (no data)
10	Data	0110	CF-Poll (no data)
10	Data	0111	CF-Ack + CF-Poll (no data)
10	Data	1000–1111	Reserved
11	Reserved	0000–1111	Reserved

Table 2—To/From DS combinations in data type frames

To/From DS values	Meaning
To DS = 0 From DS = 0	A data frame direct from one STA to another STA within the same IBSS, as well as all management and control type frames.
To DS = 1 From DS = 0	Data frame destined for the DS.
To DS = 0 From DS = 1	Data frame exiting the DS.
To DS = 1 From DS = 1	Wireless distribution system (WDS) frame being distributed from one AP to another AP.

7.1.3.1.6 Retry field

The Retry field is 1 bit in length and is set to 1 in any data or management type frame that is a retransmission of an earlier frame. It is set to 0 in all other frames. A receiving station uses this indication to aid in the process of eliminating duplicate frames.

7.1.3.1.7 Power Management field

The Power Management field is 1 bit in length and is used to indicate the power management mode of a STA. The value of this field remains constant in each frame from a particular STA within a frame exchange sequence defined in 9.7. The value indicates the mode in which the station will be after the successful completion of the frame exchange sequence.

A value of 1 indicates that the STA will be in power-save mode. A value of 0 indicates that the STA will be in active mode. This field is always set to 0 in frames transmitted by an AP.

7.1.3.1.8 More Data field

The More Data field is 1 bit in length and is used to indicate to a STA in power-save mode that more MSDUs, or MMPDUs are buffered for that STA at the AP. The More Data field is valid in directed data or management type frames transmitted by an AP to an STA in power-save mode. A value of 1 indicates that at least one additional buffered MSDU, or MMPDU, is present for the same STA.

The More Data field may be set to 1 in directed data type frames transmitted by a contention-free (CF)-Pollable STA to the point coordinator (PC) in response to a CF-Poll to indicate that the STA has at least one additional buffered MSDU available for transmission in response to a subsequent CF-Poll.

The More Data field is set to 0 in all other directed frames.

The More Data field is set to 1 in broadcast/multicast frames transmitted by the AP, when additional broadcast/multicast MSDUs, or MMPDUs, remain to be transmitted by the AP during this beacon interval. The More Data field is set to 0 in broadcast/multicast frames transmitted by the AP when no more broadcast/multicast MSDUs, or MMPDUs, remain to be transmitted by the AP during this beacon interval and in all broadcast/multicast frames transmitted by non-AP stations.

7.1.3.1.9 WEP field

The WEP field is 1 bit in length. It is set to 1 if the Frame Body field contains information that has been processed by the WEP algorithm. The WEP field is only set to 1 within frames of type Data and frames of

type Management, subtype Authentication. The WEP field is set to 0 in all other frames. When the WEP bit is set to 1, the Frame Body field is expanded as defined in 8.2.5.

7.1.3.1.10 Order field

The Order field is 1 bit in length and is set to 1 in any data type frame that contains an MSDU, or fragment thereof, which is being transferred using the StrictlyOrdered service class. This field is set to 0 in all other frames.

7.1.3.2 Duration/ID field

The Duration/ID field is 16 bits in length. The contents of this field are as follows:

- a) In control type frames of subtype Power Save (PS)-Poll, the Duration/ID field carries the association identity (AID) of the station that transmitted the frame in the 14 least significant bits (lsb), with the 2 most significant bits (msb) both set to 1. The value of the AID is in the range 1–2007.
- b) In all other frames, the Duration/ID field contains a duration value as defined for each frame type in 7.2. For frames transmitted during the contention-free period (CFP), the duration field is set to 32 768.

Whenever the contents of the Duration/ID field are less than 32 768, the duration value is used to update the network allocation vector (NAV) according to the procedures defined in Clause 9.

The encoding of the Duration/ID field is given in Table 3.

Table 3—Duration/ID field encoding

Bit 15	Bit 14	Bits 13–0	Usage
0		0–32 767	Duration
1	0	0	Fixed value within frames transmitted during the CFP
1	0	1–16 383	Reserved
1	1	0	Reserved
1	1	1–2 007	AID in PS-Poll frames
1	1	2 008–16 383	Reserved

7.1.3.3 Address fields

There are four address fields in the MAC frame format. These fields are used to indicate the BSSID, source address, destination address, transmitting station address, and receiving station address. The usage of the four address fields in each frame type is indicated by the abbreviations BSSID, DA, SA, RA, and TA, indicating basic service set identifier (BSSID), Destination Address, Source Address, Receiver Address, and Transmitter Address, respectively. Certain frames may not contain some of the address fields.

Certain address field usage is specified by the relative position of the address field (1–4) within the MAC header, independent of the type of address present in that field. For example, receiver address matching is always performed on the contents of the Address 1 field in received frames, and the receiver address of CTS and ACK frames is always obtained from the Address 2 field in the corresponding RTS frame, or from the frame being acknowledged.

7.1.3.3.1 Address representation

Each Address field contains a 48-bit address as defined in 5.2 of IEEE Std 802-1990.

7.1.3.3.2 Address designation

A MAC sublayer address is one of the following two types:

- a) *Individual address.* The address associated with a particular station on the network.
- b) *Group address.* A multideestination address, associated with one or more stations on a given network. The two kinds of group addresses are as follows:
 - 1) *Multicast-group address.* An address associated by higher-level convention with a group of logically related stations.
 - 2) *Broadcast address.* A distinguished, predefined multicast address that always denotes the set of all stations on a given LAN. All 1s in the Destination Address field are interpreted to be the broadcast address. This group is predefined for each communication medium to consist of all stations actively connected to that medium; it is used to broadcast to all the active stations on that medium. All stations are able to recognize the broadcast address. It is not necessary that a station be capable of generating the broadcast address.

The address space is also partitioned into locally administered and universal (globally administered) addresses. The nature of a body and the procedures by which it administers these universal (globally administered) addresses is beyond the scope of this standard. See IEEE Std 802-1990 for more information.

7.1.3.3.3 BSSID field

The BSSID field is a 48-bit field of the same format as an IEEE 802 MAC address. This field uniquely identifies each BSS. The value of this field, in an infrastructure BSS, is the MAC address currently in use by the STA in the AP of the BSS.

The value of this field in an IBSS is a locally administered IEEE MAC address formed from a 46-bit random number generated according to the procedure defined in 11.1.3. The individual/group bit of the address is set to 0. The universal/local bit of the address is set to 1. This mechanism is used to provide a high probability of selecting a unique BSSID.

The value of all 1s is used to indicate the broadcast BSSID. A broadcast BSSID may only be used in the BSSID field of management frames of subtype probe request.

7.1.3.3.4 Destination Address (DA) field

The DA field contains an IEEE MAC individual or group address that identifies the MAC entity or entities intended as the final recipient(s) of the MSDU (or fragment thereof) contained in the frame body field.

7.1.3.3.5 Source Address (SA) field

The SA field contains an IEEE MAC individual address that identifies the MAC entity from which the transfer of the MSDU (or fragment thereof) contained in the frame body field was initiated. The individual/group bit is always transmitted as a zero in the source address.

7.1.3.3.6 Receiver Address (RA) field

The RA field contains an IEEE MAC individual or group address that identifies the intended immediate recipient STA(s), on the WM, for the information contained in the frame body field.

7.1.3.3.7 Transmitter Address (TA) field

The TA field contains an IEEE MAC individual address that identifies the STA that has transmitted, onto the WM, the MPDU contained in the frame body field. The Individual/Group bit is always transmitted as a zero in the transmitter address.

7.1.3.4 Sequence Control field

The Sequence Control field is 16 bits in length and consists of two subfields, the Sequence Number and the Fragment Number. The format of the Sequence Control field is illustrated in Figure 14.

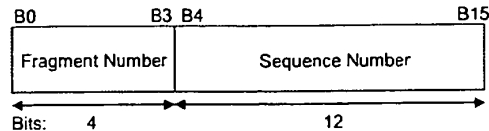


Figure 14—Sequence Control field

7.1.3.4.1 Sequence Number field

The Sequence Number field is a 12-bit field indicating the sequence number of an MSDU or MMPDU. Each MSDU or MMPDU transmitted by a STA is assigned a sequence number. Sequence numbers are assigned from a single modulo 4096 counter, starting at 0 and incrementing by 1 for each MSDU or MMPDU. Each fragment of an MSDU or MMPDU contains the assigned sequence number. The sequence number remains constant in all retransmissions of an MSDU, MMPDU, or fragment thereof.

7.1.3.4.2 Fragment Number field

The Fragment Number field is a 4-bit field indicating the number of each fragment of an MSDU or MMPDU. The fragment number is set to zero in the first or only fragment of an MSDU or MMPDU and is incremented by one for each successive fragment of that MSDU or MMPDU. The fragment number remains constant in all retransmissions of the fragment.

7.1.3.5 Frame Body field

The Frame Body is a variable length field that contains information specific to individual frame types and subtypes. The minimum frame body is 0 octets. The maximum length frame body is defined by the maximum length (MSDU + ICV + IV), where ICV and IV are the WEP fields defined in 8.2.5.

7.1.3.6 FCS field

The FCS field is a 32-bit field containing a 32-bit CRC. The FCS is calculated over all the fields of the MAC header and the Frame Body field. These are referred to as the *calculation fields*.

The FCS is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

The FCS is the 1's complement of the sum (modulo 2) of the following:

- a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \dots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the calculation fields, and

- b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by x^{32} and then division by $G(x)$.

The FCS field is transmitted commencing with the coefficient of the highest-order term.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all 1's and is then modified by division of the calculation fields by the generator polynomial $G(x)$. The 1's complement of this remainder is transmitted, with the highest-order bit first, as the FCS field.

At the receiver, the initial remainder is preset to all 1's and the serial incoming bits of the calculation fields and FCS, when divided by $G(x)$, results in the absence of transmission errors, in a unique nonzero remainder value. The unique remainder value is the polynomial:

$$x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^4 + x^3 + x + 1$$

7.2 Format of individual frame types

7.2.1 Control frames

In the following descriptions, "immediately previous" frame means a frame whose reception concluded within the prior short interframe space (SIFS) interval.

The subfields within the Frame Control field of control frames are set as illustrated in Figure 15.

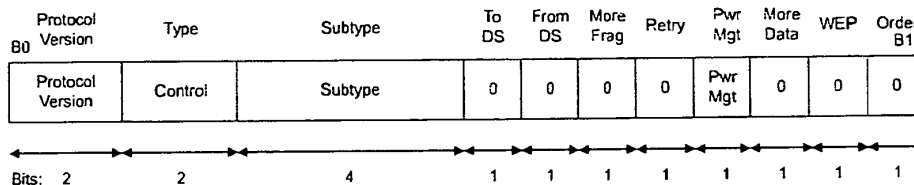


Figure 15—Frame Control field subfield values within control frames

7.2.1.1 Request To Send (RTS) frame format

The frame format for the RTS frame is as defined in Figure 16.

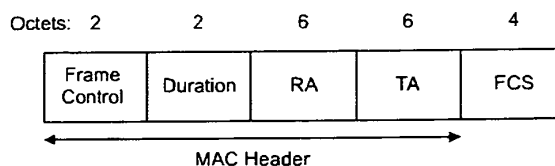


Figure 16—RTS frame

The RA of the RTS frame is the address of the STA, on the WM, that is the intended immediate recipient of the pending directed data or management frame.

The TA is the address of the STA transmitting the RTS frame.

The duration value is the time, in microseconds, required to transmit the pending data or management frame, plus one CTS frame, plus one ACK frame, plus three SIFS intervals. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.2 Clear To Send (CTS) frame format

The frame format for the CTS frame is as defined in Figure 17.

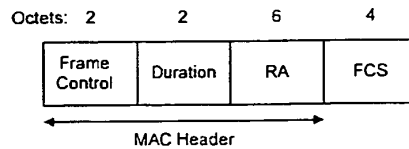


Figure 17—CTS frame

The RA of the CTS frame is copied from the TA field of the immediately previous RTS frame to which the CTS is a response.

The duration value is the value obtained from the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the CTS frame and its SIFS interval. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.3 Acknowledgment (ACK) frame format

The frame format for the ACK frame is as defined in Figure 18.

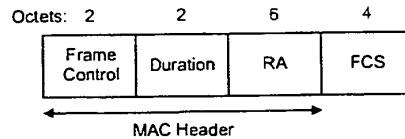


Figure 18—ACK frame

The RA of the ACK frame is copied from the Address 2 field of the immediately previous directed data, management, or PS-Poll control frame.

If the More Fragment bit was set to 0 in the Frame Control field of the immediately previous directed data or management frame, the duration value is set to 0. If the More Fragment bit was set to 1 in the Frame Control field of the immediately previous directed data or management frame, the duration value is the value obtained from the Duration field of the immediately previous data or management frame, minus the time, in microseconds, required to transmit the ACK frame and its SIFS interval. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.4 Power-Save Poll (PS-Poll) frame format

The frame format for the PS-Poll frame is as defined in Figure 19.

The BSSID is the address of the STA contained in the AP. The TA is the address of the STA transmitting the frame. The AID is the value assigned to the STA transmitting the frame by the AP in the association response frame that established that STA's current association.

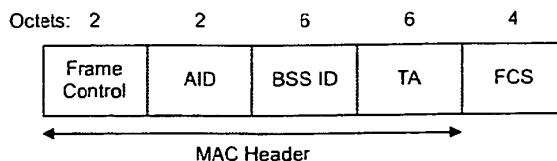


Figure 19—PS-Poll frame

The AID value always has its two most significant bits each set to 1. All STAs, upon receipt of a PS-Poll frame, update their NAV settings as appropriate under the coordination function rules using a duration value equal to the time, in microseconds, required to transmit one ACK frame plus one SIFS interval.

7.2.1.5 CF-End frame format

The frame format for the CF-End frame is as defined in Figure 20.

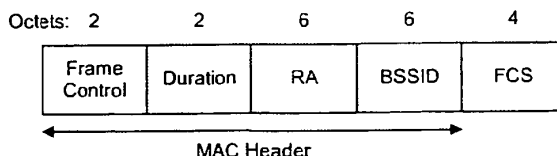


Figure 20—CF-End frame

The BSSID is the address of the STA contained in the AP. The RA is the broadcast group address.

The Duration field is set to 0.

7.2.1.6 CF-End + CF-Ack frame format

The frame format for the contention-free-end acknowledge (CF-End + CF-Ack) frame is as defined in Figure 21.

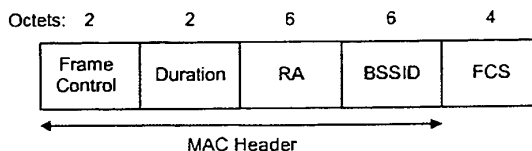


Figure 21—CF-End + CF-Ack Frame

The BSSID is the address of the STA contained in the AP. The RA is the broadcast group address.

The Duration field is set to 0.

7.2.2 Data frames

The frame format for a Data frame is independent of subtype and is as defined in Figure 22.

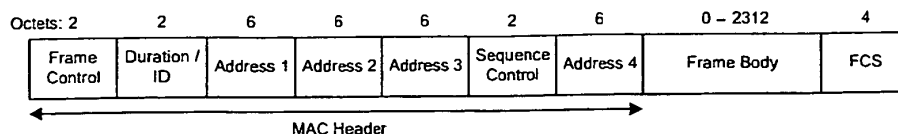


Figure 22—Data frame

The content of the Address fields of the data frame is dependent upon the values of the To DS and From DS bits and is defined in Table 4. Where the content of a field is shown as not applicable (N/A), the field is omitted. Note that Address 1 always holds the receiver address of the intended receiver (or, in the case of multicast frames, receivers), and that Address 2 always holds the address of the station that is transmitting the frame.

Table 4 —Address field contents

To DS	From DS	Address 1	Address 2	Address 3	Address 4
0	0	DA	SA	BSSID	N/A
0	1	DA	BSSID	SA	N/A
1	0	BSSID	SA	DA	N/A
1	1	RA	TA	DA	SA

A station uses the contents of the Address 1 field to perform address matching for receive decisions. In cases where the Address 1 field contains a group address, the BSSID also is validated to ensure that the broadcast or multicast originated in the same BSS.

A station uses the contents of the Address 2 field to direct the acknowledgment if an acknowledgment is necessary.

The DA is the destination of the MSDU (or fragment thereof) in the frame body field.

The SA is the address of the MAC entity that initiated the MSDU (or fragment thereof) in the frame body field.

The RA is the address of the STA contained in the AP in the wireless distribution system that is the next immediate intended recipient of the frame.

The TA is the address of the STA contained in the AP in the wireless distribution system that is transmitting the frame.

The BSSID of the Data frame is determined as follows:

- If the station is an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
- If the station is a member of an IBSS, the BSSID is the BSSID of the IBSS.

The frame body consists of the MSDU or a fragment thereof, and a WEP IV and ICV (if and only if the WEP subfield in the frame control field is set to 1). The frame body is null (0 octets in length) in data frames of Subtype Null function (no data), CF-Ack (no data), CF-Poll (no data), and CF-Ack+CF-Poll (no data).

Within all data type frames sent during the CFP, the Duration field is set to the value 32 768. Within all data type frames sent during the contention period, the Duration field is set according to the following rules:

- If the Address 1 field contains a group address, the duration value is set to 0.
- If the More Fragments bit is set to 0 in the Frame Control field of a frame and the Address 1 field contains an individual address, the duration value is set to the time, in microseconds, required to transmit one ACK frame, plus one SIFS interval.
- If the More Fragments bit is set to 1 in the Frame Control field of a frame, and the Address 1 field contains an individual address, the duration value is set to the time, in microseconds, required to transmit the next fragment of this data frame, plus two ACK frames, plus three SIFS intervals.

The duration value calculation for the data frame is based on the rules in 9.6 that determine the data rate at which the control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All stations process Duration field values less than or equal to 32 767 from valid data frames to update their NAV settings as appropriate under the coordination function rules.

7.2.3 Management frames

The frame format for a Management frame is independent of frame subtype and is as defined in Figure 23.

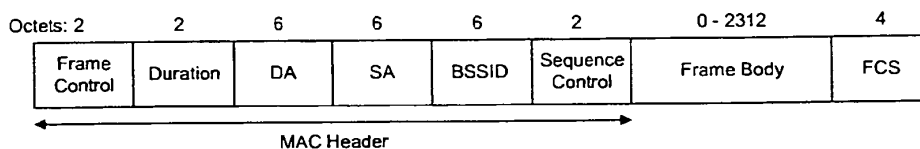


Figure 23—Management frame format

A STA uses the contents of the Address 1 field to perform the address matching for receive decisions. In the case where the Address 1 field contains a group address and the frame type is other than Beacon, the BSSID also is validated to ensure that the broadcast or multicast originated in the same BSS. If the frame type is Beacon, other address matching rules apply, as specified in 11.1.2.3.

The address fields for management frames do not vary by frame subtype.

The BSSID of the management frame is determined as follows:

- a) If the station is an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
- b) If the station is a member of an IBSS, the BSSID is the BSSID of the IBSS.
- c) In Management frames of subtype Probe Request, the BSSID is either a specific BSSID, or the broadcast BSSID as defined in the procedures specified in Clause 10.

The DA is the destination of the frame.

The SA is the address of the station transmitting the frame.

Within all management type frames sent during the CFP, the Duration field is set to the value 32 768. Within all management type frames sent during the contention period, the Duration field is set according to the following rules:

- If the DA field contains a group address, the duration value is set to 0.
- If the More Fragments bit is set to 0 in the Frame Control field of a frame and the DA contains an individual address, the duration value is set to the time, in microseconds, required to transmit one ACK frame, plus one SIFS interval.
- If the More Fragments bit is set to 1 in the Frame Control field of a frame, and the DA contains an individual address, the duration value is the time, in microseconds, required to transmit the next fragment of this management frame, plus two ACK frames, plus three SIFS intervals.

The duration value calculation for the management frame is based on the rules in 9.6 that determine the data rate at which the control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All stations process Duration field values less than or equal to 32 767 from valid management frames to update their NAV settings as appropriate under the coordination function rules.

The frame body consists of the fixed fields and information elements defined for each management frame subtype. All fixed fields and information elements are mandatory unless stated otherwise, and they can appear only in the specified order. Stations encountering an element type they do not understand ignore that element. Element type codes not explicitly defined in this standard are reserved, and do not appear in any frames.

7.2.3.1 Beacon frame format

The frame body of a management frame of subtype Beacon contains the information shown in Table 5.

Table 5—Beacon frame body

Order	Information	Notes
1	Timestamp	
2	Beacon interval	
3	Capability information	
4	SSID	
5	Supported rates	
6	FH Parameter Set	The FH Parameter Set information element is present within Beacon frames generated by STAs using frequency-hopping PHYs.
7	DS Parameter Set	The DS Parameter Set information element is present within Beacon frames generated by STAs using direct sequence PHYs.
8	CF Parameter Set	The CF Parameter Set information element is only present within Beacon frames generated by APs supporting a PCF.
9	IBSS Parameter Set	The IBSS Parameter Set information element is only present within Beacon frames generated by STAs in an IBSS.
10	TIM	The TIM information element is only present within Beacon frames generated by APs.

7.2.3.2 IBSS Announcement Traffic Indication Message (ATIM) frame format

The frame body of a management frame of subtype ATIM is null.

7.2.3.3 Disassociation frame format

The frame body of a management frame of subtype Disassociation contains the information shown in Table 6.

Table 6—Disassociation frame body

Order	Information
1	Reason code

7.2.3.4 Association Request frame format

The frame body of a management frame of subtype Association Request contains the information shown in Table 7.

Table 7 —Association Request frame body

Order	Information
1	Capability information
2	Listen interval
3	SSID
4	Supported rates

7.2.3.5 Association Response frame format

The frame body of a management frame of subtype Association Response contains the information shown in Table 8.

Table 8—Association Response frame body

Order	Information
1	Capability information
2	Status code
3	Association ID (AID)
4	Supported rates

7.2.3.6 Reassociation Request frame format

The frame body of a management frame of subtype Reassociation Request contains the information shown in Table 9.

Table 9—Reassociation Request frame body

Order	Information
1	Capability information
2	Listen interval
3	Current AP address
4	SSID
5	Supported rates

7.2.3.7 Reassociation Response frame format

The frame body of a management frame of subtype Reassociation Response contains the information shown in Table 10.

Table 10—Reassociation Response frame body

Order	Information
1	Capability information
2	Status code
3	Association ID (AID)
4	Supported rates

7.2.3.8 Probe Request frame format

The frame body of a management frame of subtype Probe Request contains the information shown in Table 11.

Table 11—Probe Request frame body

Order	Information
1	SSID
2	Supported rates

7.2.3.9 Probe Response frame format

The frame body of a management frame of subtype Probe Response contains the information shown in Table 12.

Table 12—Probe Response frame body

Order	Information	Notes
1	Timestamp	
2	Beacon interval	
3	Capability information	
4	SSID	
5	Supported rates	
6	FH Parameter Set	The FH Parameter Set information element is present within Probe Response frames generated by STAs using frequency-hopping PHYs.
7	DS Parameter Set	The DS Parameter Set information element is present within Probe Response frames generated by STAs using direct sequence PHYs.
8	CF Parameter Set	The CF Parameter Set information element is only present within Probe Response frames generated by APs supporting a PCF.
9	IBSS Parameter Set	The IBSS Parameter Set information element is only present within Probe Response frames generated by STAs in an IBSS.

7.2.3.10 Authentication frame format

The frame body of a management frame of subtype Authentication contains the information shown in Table 13.

Table 13—Authentication frame body

Order	Information	Notes
1	Authentication algorithm number	
2	Authentication transaction sequence number	
3	Status code	The status code information is reserved and set to 0 in certain Authentication frames as defined in Table 14.
4	Challenge text	The challenge text information is only present in certain Authentication frames as defined in Table 14.

Table 14—Presence of challenge text information

Authentication algorithm	Authentication transaction sequence no.	Status code	Challenge text
Open System	1	Reserved	Not present
Open System	2	Status	Not present
Shared Key	1	Reserved	Not present
Shared Key	2	Status	Present
Shared Key	3	Reserved	Present
Shared Key	4	Status	Not present

7.2.3.11 Deauthentication

The frame body of a management frame of subtype Deauthentication contains the information shown in Table 15.

Table 15—Deauthentication frame body

Order	Information
1	Reason code

7.3 Management frame body components

Within management frames, fixed-length mandatory frame body components are defined as fixed fields; variable length mandatory and all optional frame body components are defined as information elements.

7.3.1 Fixed fields

7.3.1.1 Authentication Algorithm Number field

The Authentication Algorithm Number field indicates a single authentication algorithm. The length of the Authentication Algorithm Number field is 2 octets. The Authentication Algorithm Number field is illustrated in Figure 24. The following values are defined for authentication algorithm number:

- Authentication algorithm number = 0: Open System
- Authentication algorithm number = 1: Shared Key
- All other values of authentication number are reserved.

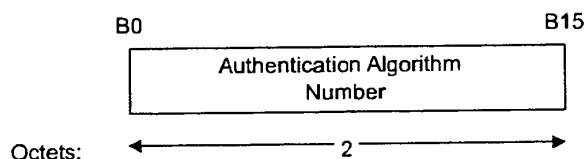


Figure 24—Authentication Algorithm Number fixed field

7.3.1.2 Authentication Transaction Sequence Number field

The Authentication Transaction Sequence Number field indicates the current state of progress through a multistep transaction. The length of the Authentication Transaction Sequence Number field is 2 octets. The Authentication Transaction Sequence Number field is illustrated in Figure 25.

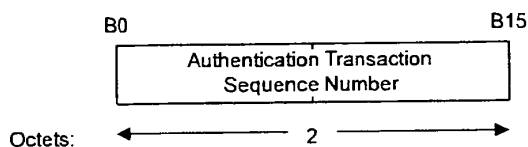


Figure 25—Authentication Transaction Sequence Number fixed field

7.3.1.3 Beacon Interval field

The Beacon Interval field represents the number of time units (TUs) between target beacon transmission times (TBTTs). The length of the Beacon Interval field is 2 octets. The Beacon Interval field is illustrated in Figure 26.

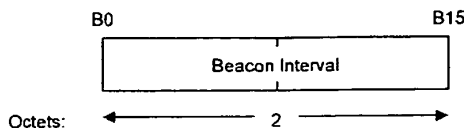


Figure 26—Beacon Interval fixed field

7.3.1.4 Capability Information field

The Capability Information field contains a number of subfields that are used to indicate requested or advertised capabilities. The length of the Capability Information field is 2 octets. The Capability Information field consists of the following subfields: ESS, IBSS, CF-Pollable, CF-Poll Request, and Privacy. The remaining part of the Capability Information field is reserved. The format of the Capability Information field is as illustrated in Figure 27.

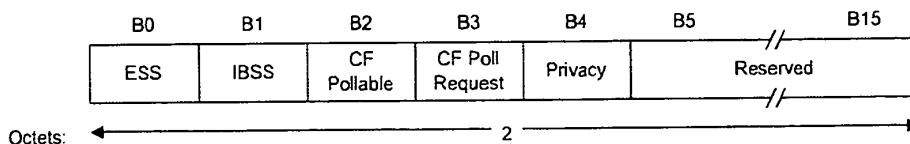


Figure 27—Capability Information fixed field

Each Capability Information subfield is interpreted only in the management frame subtypes for which the transmission rules are defined.

APs set the ESS subfield to 1 and the IBSS subfield to 0 within transmitted Beacon or Probe Response management frames. STAs within an IBSS set the ESS subfield to 0 and the IBSS subfield to 1 in transmitted Beacon or Probe Response management frames.

STAs set the CF-Pollable and CF-Poll Request subfields in Association and Reassociation Request management frames according to Table 16.

Table 16—STA usage of CF-Pollable and CF-Poll Request

CF-Pollable	CF-Poll request	Meaning
0	0	STA is not CF-Pollable
0	1	STA is CF-Pollable, not requesting to be placed on the CF-Polling list
1	0	STA is CF-Pollable, requesting to be placed on the CF-Polling list
1	1	STA is CF-Pollable, requesting never to be polled

APs set the CF-Pollable and CF-Poll Request subfields in Beacon, Probe Response, Association Response, and Reassociation Response management frames according to Table 17. An AP sets the CF-Pollable and CF-Poll Request subfield values in Association Response and Reassociation Response management frames equal to the values in the last Beacon or Probe Response frame that it transmitted.

Table 17—AP usage of CF-Pollable and CF-Poll Request

CF-Pollable	CF-Poll Request	Meaning
0	0	No point coordinator at AP
0	1	Point coordinator at AP for delivery only (no polling)
1	0	Point coordinator at AP for delivery and polling
1	1	Reserved

APs set the Privacy subfield to 1 within transmitted Beacon, Probe Response, Association Response, and Reassociation Response management frames if WEP encryption is required for all data type frames exchanged within the BSS. If WEP encryption is not required, the Privacy subfield is set to 0.

STAs within an IBSS set the Privacy subfield to 1 in transmitted Beacon or Probe Response management frames if WEP encryption is required for all data type frames exchanged within the IBSS. If WEP encryption is not required, the Privacy subfield is set to 0.

7.3.1.5 Current AP Address field

The Current AP Address field is the MAC address of the AP with which the station is currently associated. The length of the Current AP Address field is 6 octets. The Current AP Address field is illustrated in Figure 28.

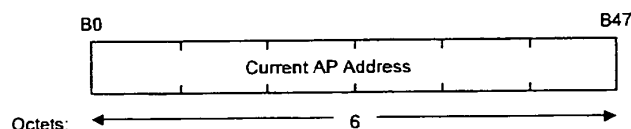


Figure 28—Current AP Address fixed field

7.3.1.6 Listen Interval field

The Listen Interval field is used to indicate to the AP how often an STA wakes to listen to Beacon management frames. The value of this parameter is the STA's Listen Interval parameter of the MLME-Associate.request primitive and is expressed in units of Beacon Interval. The length of the Listen Interval field is 2 octets. The Listen Interval field is illustrated in Figure 29.

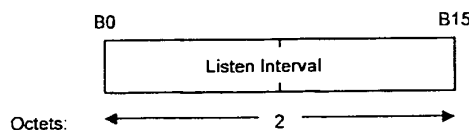


Figure 29—Listen Interval fixed field

An AP may use the Listen Interval information in determining the lifetime of frames that it buffers for an STA.

7.3.1.7 Reason Code field

This Reason Code field is used to indicate the reason that an unsolicited notification management frame of type Disassociation or Deauthentication was generated. The length of the Reason Code field is 2 octets. The Reason Code field is illustrated in Figure 30.

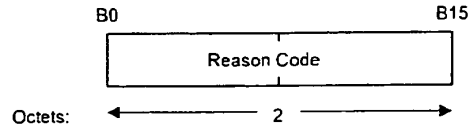


Figure 30—Reason Code fixed field

The reason codes are defined in Table 18.

Table 18—Reason codes

Reason code	Meaning
0	Reserved
1	Unspecified reason
2	Previous authentication no longer valid
3	Deauthenticated because sending station is leaving (or has left) IBSS or ESS
4	Disassociated due to inactivity
5	Disassociated because AP is unable to handle all currently associated stations
6	Class 2 frame received from nonauthenticated station
7	Class 3 frame received from nonassociated station
8	Disassociated because sending station is leaving (or has left) BSS
9	Station requesting (re)association is not authenticated with responding station
10–65 535	Reserved

7.3.1.8 Association ID (AID) field

The AID field is a value assigned by an AP during association that represents the 16-bit ID of a STA. The length of the AID field is 2 octets. The AID field is illustrated in Figure 31.

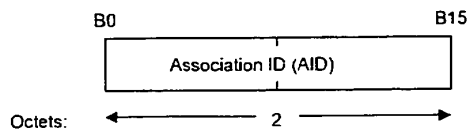


Figure 31—AID fixed field

The value assigned as the Association ID is in the range 1–2007 and is placed in the 14 least significant bits of the AID field, with the two most significant bits of the AID field each set to 1 (see 7.1.3.2).

7.3.1.9 Status Code field

The Status Code field is used in a response management frame to indicate the success or failure of a requested operation. The length of the Status Code field is 2 octets. The Status Code field is illustrated in Figure 32.

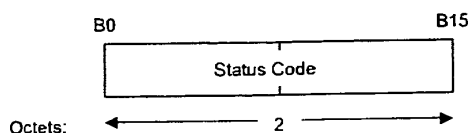


Figure 32—Status Code fixed field

If an operation is successful, then the status code is set to 0. If an operation results in failure, the status code indicates a failure cause. The failure cause codes are defined in Table 19.

Table 19—Status codes

Status code	Meaning
0	Successful
1	Unspecified failure
2–9	Reserved
10	Cannot support all requested capabilities in the Capability Information field
11	Reassociation denied due to inability to confirm that association exists
12	Association denied due to reason outside the scope of this standard
13	Responding station does not support the specified authentication algorithm
14	Received an Authentication frame with authentication transaction sequence number out of expected sequence
15	Authentication rejected because of challenge failure
16	Authentication rejected due to timeout waiting for next frame in sequence
17	Association denied because AP is unable to handle additional associated stations
18	Association denied due to requesting station not supporting all of the data rates in the BSSBasicRateSet parameter
19–65 535	Reserved

7.3.1.10 Timestamp field

This field represents the value of the TSFTIMER (see 11.1) of a frame's source. The length of the Timestamp field is 8 octets. The Timestamp field is illustrated in Figure 33.

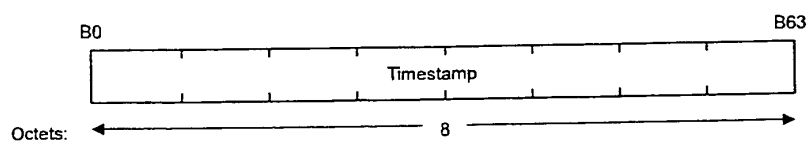


Figure 33—Timestamp fixed field

7.3.2 Information elements

Elements are defined to have a common general format consisting of a 1 octet Element ID field, a 1 octet length field, and a variable-length element-specific information field. Each element is assigned a unique Element ID as defined in this standard. The Length field specifies the number of octets in the Information field. See Figure 34.

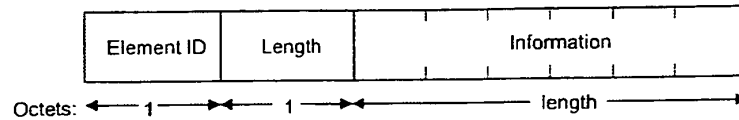


Figure 34—Element format

The set of valid elements is defined in Table 20.

Table 20—Element IDs

Information element	Element ID
SSID	0
Supported rates	1
FH Parameter Set	2
DS Parameter Set	3
CF Parameter Set	4
TIM	5
IBSS Parameter Set	6
Reserved	7–15
Challenge text	16
Reserved for challenge text extension	17–31
Reserved	32–255

7.3.2.1 Service Set Identity (SSID) element

The SSID element indicates the identity of an ESS or IBSS. See Figure 35.

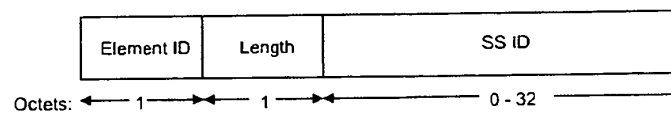


Figure 35—SSID element format

The length of the SSID information field is between 0 and 32 octets. A 0 length information field indicates the broadcast SSID.

7.3.2.2 Supported Rates element

The Supported Rates element specifies the rates in the Operational Rate Set as described in the MLME_Join.request and MLME_Start.request primitives. The information field is encoded as 1 to 8 octets where each octet describes a single supported rate in units of 500 kbit/s.

Within Beacon, Probe Response, Association Response, and Reassociation Response management frames, each supported rate belonging to the BSSBasicRateSet, as defined in 10.3.10.1, is encoded as an octet with the msb (bit 7) set to 1 (e.g., a 1 Mbit/s rate belonging to the BSSBasicRateSet is encoded as X'82'). Rates not belonging to the BSSBasicRateSet are encoded with the msb set to 0 (e.g., a 2 Mbit/s rate not belonging to the BSSBasicRateSet is encoded as X'04'). The msb of each Supported Rate octet in other management frame types is ignored by receiving STAs.

BSSBasicRateSet information in Beacon and Probe Response management frames is used by STAs in order to avoid associating with a BSS if they do not support all the data rates in the BSSBasicRateSet. See Figure 36.

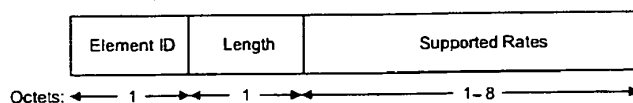


Figure 36—Supported rates element format

7.3.2.3 FH Parameter Set element

The FH Parameter Set element contains the set of parameters necessary to allow synchronization for STAs using a frequency-hopping (FH) PHY. The information field contains Dwell Time, Hop Set, Hop Pattern, and Hop Index parameters. The total length of the information field is 5 octets. See Figure 37.

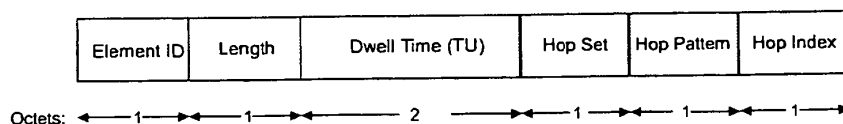


Figure 37—FH Parameter Set element format

The Dwell Time field is 2 octets in length and contains the dwell time in TU.

The Hop Set field identifies the current set (dot11CurrentSet) of hop patterns and is a single octet.

The Hop Pattern field identifies the current pattern (dot11CurrentPattern) within a set of hop patterns and is a single octet.

The Hop Index field selects the current index (dot11CurrentIndex) within a pattern and is a single octet.

The description of the attributes used in this subclause can be found in 14.8.2.1.

7.3.2.4 DS Parameter Set element

The DS Parameter Set element contains information to allow channel number identification for STAs using a direct sequence spread spectrum (DSSS) PHY. The information field contains a single parameter containing the dot11CurrentChannelNumber (see 15.4.6.2 for values). The length of the dot11CurrentChannelNumber parameter is 1 octet. See Figure 38.

7.3.2.5 CF Parameter Set element

The CF Parameter Set element contains the set of parameters necessary to support the PCF. The information field contains the CFPCount, CFPPeriod, CFPMaDuration, and CFPDurRemaining fields. The total length of the information field is 6 octets. See Figure 39.

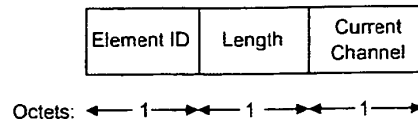


Figure 38—DS Parameter Set element format

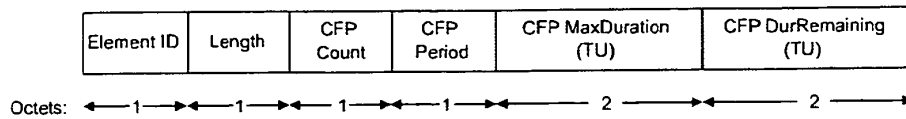


Figure 39—CF Parameter Set element format

CFPCount indicates how many DTIMs (including the current frame) appear before the next CFP start. A CFPCount of 0 indicates that the current DTIM marks the start of the CFP.

CFPPeriod indicates the number of DTIM intervals between the start of CFPs. The value is an integral number of DTIM intervals.

CFPMaxDuration indicates the maximum duration, in TU, of the CFP that may be generated by this PCF. This value is used by STAs to set their NAV at the TBTT of beacons that begin CFPs.

CFPDurRemaining indicates the maximum time, in TU, remaining in the present CFP, and is set to zero in CFP Parameter elements of beacons transmitted during the contention period. The value of CFPDurRemaining is referenced to the immediately previous TBTT. This value is used by all STAs to update their NAVs during CFPs.

7.3.2.6 TIM

The TIM element contains four fields: DTIM Count, DTIM Period, Bitmap Control, and Partial Virtual Bitmap. See Figure 40.

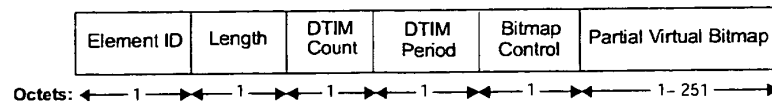


Figure 40—TIM element format

The Length field for this element indicates the length of the information field, which is constrained as described below.

The DTIM Count field indicates how many beacons (including the current frame) appear before the next DTIM. A DTIM Count of 0 indicates that the current TIM is a DTIM. The DTIM count field is a single octet.

The DTIM Period field indicates the number of Beacon intervals between successive DTIMs. If all TIMs are DTIMs, the DTIM Period field has the value 1. The DTIM Period value 0 is reserved. The DTIM period field is a single octet.

The Bitmap Control field is a single octet. Bit 0 of the field contains the Traffic Indicator bit associated with Association ID 0. This bit is set to 1 in TIM elements with a value of 0 in the DTIM Count field when one or

more broadcast or multicast frames are buffered at the AP. The remaining 7 bits of the field form the Bitmap Offset.

The traffic-indication virtual bitmap, maintained by the AP that generates a TIM, consists of 2008 bits, and is organized into 251 octets such that bit number N ($0 \leq N \leq 2007$) in the bitmap corresponds to bit number $(N \bmod 8)$ in octet number $\lfloor N/8 \rfloor$ where the low-order bit of each octet is bit number 0, and the high order bit is bit number 7. Each bit in the traffic-indication virtual bitmap corresponds to traffic buffered for a specific station within the BSS that the AP is prepared to deliver at the time the beacon frame is transmitted. Bit number N is 0 if there are no directed frames buffered for the station whose Association ID is N . If any directed frames for that station are buffered and the AP is prepared to deliver them, bit number N in the traffic-indication virtual bitmap is 1. A PC may decline to set bits in the TIM for CF-Pollable stations it does not intend to poll (see 11.2.1.5).

The Partial Virtual Bitmap field consists of octets numbered $N1$ through $N2$ of the traffic indication virtual bitmap, where $N1$ is the largest even number such that bits numbered 1 through $(N1 \times 8) - 1$ in the bitmap are all 0 and $N2$ is the smallest number such that bits numbered $(N2 + 1) \times 8$ through 2007 in the bitmap are all 0. In this case, the Bitmap Offset subfield value contains the number $\lfloor N1/2 \rfloor$, and the Length field will be set to $(N2 - N1) + 4$.

In the event that all bits other than bit 0 in the virtual bitmap are 0, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, and the Bitmap Offset subfield is 0.

7.3.2.7 IBSS Parameter Set element

The IBSS Parameter Set element contains the set of parameters necessary to support an IBSS. The information field contains the ATIM Window parameter. See Figure 41.

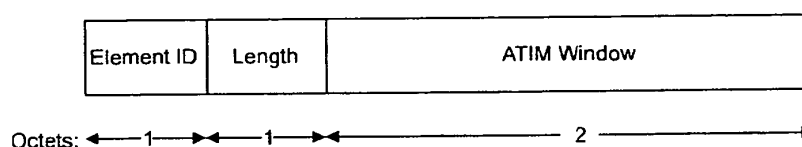


Figure 41—IBSS Parameter Set element format

The ATIM Window field is 2 octets in length and contains the ATIM Window length in TU.

7.3.2.8 Challenge Text element

The Challenge Text element contains the challenge text within Authentication exchanges. The element information field length is dependent upon the authentication algorithm and the transaction sequence number as specified in 8.1. See Figure 42.

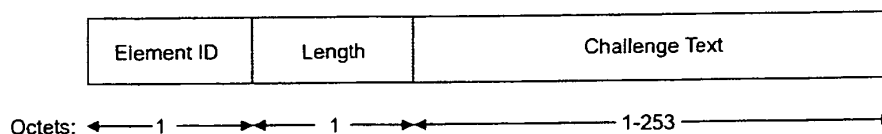


Figure 42—Challenge Text element format

8. Authentication and privacy

8.1 Authentication services

IEEE 802.11 defines two subtypes of authentication service: *Open System* and *Shared Key*. The subtype invoked is indicated in the body of authentication management frames. Thus authentication frames are self-identifying with respect to authentication algorithm. All management frames of subtype Authentication shall be unicast frames as authentication is performed between pairs of stations (i.e., multicast authentication is not allowed). Management frames of subtype Deauthentication are advisory, and may therefore be sent as group-addressed frames.

A mutual authentication relationship shall exist between two stations following a successful authentication exchange as described below. Authentication shall be used between stations and the AP in an infrastructure BSS. Authentication may be used between two STAs in an IBSS.

8.1.1 Open System authentication

Open System authentication is the simplest of the available authentication algorithms. Essentially it is a null authentication algorithm. Any STA that requests authentication with this algorithm may become authenticated if `dot11AuthenticationType` at the recipient station is set to Open System authentication. Open System authentication is not required to be successful as a STA may decline to authenticate with any particular other STA. Open System authentication is the default authentication algorithm.

Open System authentication involves a two-step authentication transaction sequence. The first step in the sequence is the identity assertion and request for authentication. The second step in the sequence is the authentication result. If the result is "successful," the STAs shall be mutually authenticated.

8.1.1.1 Open System authentication (first frame)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication Algorithm Identification = "Open System"
 - Station Identity Assertion (in SA field of header)
 - Authentication transaction sequence number = 1
 - Authentication algorithm dependent information (none)
- Direction of message: From authentication initiating STA to authenticating STA

8.1.1.2 Open System authentication (final frame)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication Algorithm Identification = "Open System"
 - Authentication transaction sequence number = 2
 - Authentication algorithm dependent information (none)
 - The result of the requested authentication as defined in 7.3.1.9
- Direction of message: From authenticating STA to initiating STA

If `dot11AuthenticationType` does not include the value "Open System," the result code shall not take the value "successful."

8.1.2 Shared Key authentication

Shared Key authentication supports authentication of STAs as either a member of those who know a shared secret key or a member of those who do not. IEEE 802.11 Shared Key authentication accomplishes this without the need to transmit the secret key in the clear; however, it does require the use of the WEP privacy mechanism. Therefore, this authentication scheme is only available if the WEP option is implemented. Additionally, the Shared Key authentication algorithm shall be implemented as one of the `dot11AuthenticationAlgorithms` at any STA where WEP is implemented.

The required secret, shared key is presumed to have been delivered to participating STAs via a secure channel that is independent of IEEE 802.11. This shared key is contained in a write-only MIB attribute via the MAC management path. The attribute is write-only so that the key value remains internal to the MAC.

During the Shared Key authentication exchange, both the challenge and the encrypted challenge are transmitted. This facilitates unauthorized discovery of the pseudorandom number (PRN) sequence for the key/IV pair used for the exchange. Implementations should therefore avoid using the same key/IV pair for subsequent frames.

A STA shall not initiate a Shared Key authentication exchange unless its `dot11PrivacyOptionImplemented` attribute is "true."

In the following description, the STA initiating the authentication exchange is referred to as the *requester*, and the STA to which the initial frame in the exchange is addressed is referred to as the *responder*.

8.1.2.1 Shared Key authentication (first frame)

- Message type: Management
- Message subtype: Authentication
- Information Items:
 - Station Identity Assertion (in SA field of header)
 - Authentication Algorithm Identification = "Shared Key"
 - Authentication transaction sequence number = 1
 - Authentication algorithm dependent information (none)
- Direction of message: From requester to responder

8.1.2.2 Shared Key authentication (second frame)

Before sending the second frame in the Shared Key authentication sequence, the responder shall use WEP to generate a string of octets that shall be used as the authentication challenge text.

- Message type: Management
- Message subtype: Authentication
- Information Items:
 - Authentication Algorithm Identification = "Shared Key"
 - Authentication transaction sequence number = 2
 - Authentication algorithm dependent information = the authentication result.
 - The result of the requested authentication as defined in 7.3.1.9

If the status code is not "successful," this shall be the last frame of the transaction sequence. If the status code is not "successful," the content of the challenge text field is unspecified.

If the status code is "successful," the following additional information items shall have valid contents:

Authentication algorithm dependent information = challenge text.

This field shall be of fixed length of 128 octets. The field shall be filled with octets generated by the WEP pseudo-random number generator (PRNG). The actual value of the challenge field is unimportant, but the value shall not be a single static value. The key and IV used when generating the challenge text are unspecified because this key/IV value does not have to be shared and does not affect interoperability.

- Direction of message: From responder to requester

8.1.2.3 Shared Key authentication (third frame)

The requester shall copy the challenge text from the second frame into the third frame. The third frame shall be transmitted after encryption by WEP, as defined in 8.2.3, using the shared secret key.

- Message type: Management
- Message subtype: Authentication
- Information Items:
 - Authentication Algorithm Identification = "Shared Key"
 - Authentication transaction sequence number = 3
 - Authentication algorithm dependent information = challenge text from sequence two frame
- Direction of message: From requester to responder

This frame shall be encrypted as described below.

8.1.2.4 Shared Key authentication (final frame)

The responder shall attempt to decrypt the contents of the third frame in the authentication sequence as described below. If the WEP ICV check is successful, the responder shall then compare the decrypted contents of the Challenge Text field to the challenge text that was sent in Frame 2 of the sequence. If they are the same, then the responder shall respond with a successful status code in Frame 4 of the sequence. If the WEP ICV check fails, the responder shall respond with an unsuccessful status code in Frame 4 of the sequence as described below.

- Message type: Management
- Message subtype: Authentication
- Information Items:
 - Authentication Algorithm Identification = "Shared Key"
 - Authentication transaction sequence number = 4
 - Authentication algorithm dependent information = the authentication result
The result of the requested authentication.
This is a fixed length item with values "successful" and "unsuccessful."
- Direction of message: From responder to requester

8.2 The Wired Equivalent Privacy (WEP) algorithm

8.2.1 Introduction

Eavesdropping is a familiar problem to users of other types of wireless technology. IEEE 802.11 specifies a wired LAN equivalent data confidentiality algorithm. *Wired equivalent privacy* is defined as protecting authorized users of a wireless LAN from casual eavesdropping. This service is intended to provide functionality for the wireless LAN equivalent to that provided by the physical security attributes inherent to a wired medium.

Data confidentiality depends on an external key management service to distribute data enciphering/deciphering keys. The IEEE 802.11 standards committee specifically recommends against running an IEEE 802.11

LAN with privacy but without authentication. While this combination is possible, it leaves the system open to significant security threats.

8.2.2 Properties of the WEP algorithm

The WEP algorithm has the following properties:

- *It is reasonably strong*: The security afforded by the algorithm relies on the difficulty of discovering the secret key through a brute-force attack. This in turn is related to the length of the secret key and the frequency of changing keys. WEP allows for the changing of the key (k) and frequent changing of the IV.
- *It is self-synchronizing*: WEP is self-synchronizing for each message. This property is critical for a data-link level encryption algorithm, where “best effort” delivery is assumed and packet loss rates may be high.
- *It is efficient*: The WEP algorithm is efficient and may be implemented in either hardware or software.
- *It may be exportable*: Every effort has been made to design the WEP system operation so as to maximize the chances of approval, by the U.S. Department of Commerce, of export from the U.S. of products containing a WEP implementation. However, due to the legal and political climate toward cryptography at the time of publication, no guarantee can be made that any specific IEEE 802.11 implementations that use WEP will be exportable from the USA.
- *It is optional*: The implementation and use of WEP is an IEEE 802.11 option.

8.2.3 WEP theory of operation

The process of disguising (binary) data in order to hide its information content is called *encryption* (denoted by E) (see [B4]). Data that is not enciphered is called *plaintext* (denoted by P) and data that is enciphered is called *ciphertext* (denoted by C). The process of turning ciphertext back into plaintext is called *decryption* (denoted by D). A *cryptographic algorithm*, or cipher, is a mathematical function used for enciphering or deciphering data. Modern cryptographic algorithms use a key sequence (denoted by k) to modify their output. The encryption function E operates on P to produce C :

$$E_k(P) = C$$

In the reverse process, the decryption function D operates on C to produce P :

$$D_k(C) = P$$

As illustrated in Figure 43, note that if the same key can be used for encryption and decryption then

$$D_k(E_k(P)) = P$$

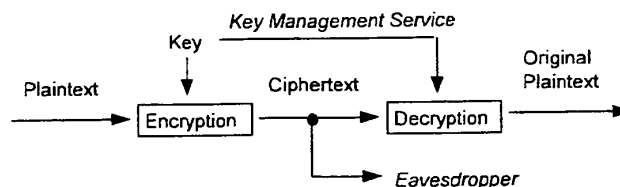


Figure 43—A confidential data channel

The WEP algorithm is a form of electronic code book in which a block of plaintext is bitwise XORed with a pseudorandom key sequence of equal length. The key sequence is generated by the WEP algorithm.

Referring to Figure 44 and viewing from left to right, encipherment begins with a *secret key* that has been distributed to cooperating STAs by an external key management service. WEP is a symmetric algorithm in which the same key is used for encipherment and decipherment.

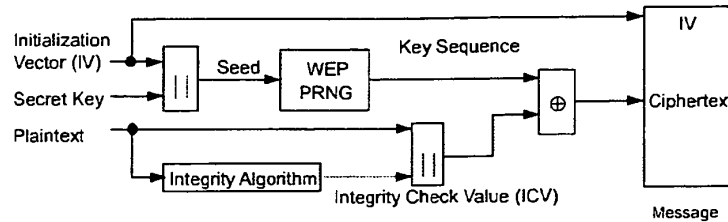


Figure 44—WEP encipherment block diagram

The secret key is concatenated with an *initialization vector* (IV) and the resulting *seed* is input to a PRNG. The PRNG outputs a *key sequence* k of pseudorandom octets equal in length to the number of data octets that are to be transmitted in the expanded MPDU plus 4 [since the key sequence is used to protect the *integrity check value* (ICV) as well as the data]. Two processes are applied to the plaintext MPDU. To protect against unauthorized data modification, an integrity algorithm operates on P to produce an ICV. Encipherment is then accomplished by mathematically combining the key sequence with the plaintext concatenated with the ICV. The output of the process is a *message* containing the IV and ciphertext.

The WEP PRNG is the critical component of this process, since it transforms a relatively short secret key into an arbitrarily long key sequence. This greatly simplifies the task of key distribution, as only the secret key needs to be communicated between STAs. The IV extends the useful lifetime of the secret key and provides the self-synchronous property of the algorithm. The secret key remains constant while the IV changes periodically. Each new IV results in a new seed and key sequence, thus there is a one-to-one correspondence between the IV and k . The IV may be changed as frequently as every MPDU and, since it travels with the message, the receiver will always be able to decipher any message. The IV is transmitted in the clear since it does not provide an attacker with any information about the secret key, and since its value must be known by the recipient in order to perform the decryption.

When choosing how often to change IV values, implementors should consider that the contents of some fields in higher-layer protocol headers, as well as certain other higher-layer information, is constant or highly predictable. When such information is transmitted while encrypting with a particular key and IV, an eavesdropper can readily determine portions of the key sequence generated by that (key, IV) pair. If the same (key, IV) pair is used for successive MPDUs, this effect may substantially reduce the degree of privacy conferred by the WEP algorithm, allowing an eavesdropper to recover a subset of the user data without any knowledge of the secret key. Changing the IV after each MPDU is a simple method of preserving the effectiveness of WEP in this situation.

The WEP algorithm is applied to the frame body of an MPDU. The (IV, frame body, ICV) triplet forms the actual data to be sent in the data frame.

For WEP protected frames, the first four octets of the frame body contain the IV field for the MPDU. This field is defined in 8.2.5. The PRNG seed is 64 bits. Bits 0 through 23 of the IV correspond to bits 0 through 23 of the PRNG seed, respectively. Bits 0 through 39 of the secret key correspond to bits 24 through 63 of the PRNG seed, respectively. The bit and octet numbering conventions in 7.1.1 apply to the PRNG seed, secret key, and IV. The numbering of the octets of the PRNG seed corresponds to that of the RC4 key. The IV is followed by the MPDU, which is followed by the ICV. The WEP ICV is 32 bits. The WEP Integrity Check algorithm is CRC-32, as defined in 7.1.3.6.

As stated previously, WEP combines k with P using bitwise XOR.

Referring to Figure 45 and viewing from left to right, decipherment begins with the arrival of a message. The IV of the incoming message shall be used to generate the key sequence necessary to decipher the incoming message. Combining the ciphertext with the proper key sequence yields the original plaintext and ICV. Correct decipherment shall be verified by performing the integrity check algorithm on the recovered plaintext and comparing the output ICV' to the ICV transmitted with the message. If ICV' is not equal to ICV, the received MPDU is in error and an error indication is sent to MAC management. MSDUs with erroneous MPDUs (due to inability to decrypt) shall not be passed to LLC.

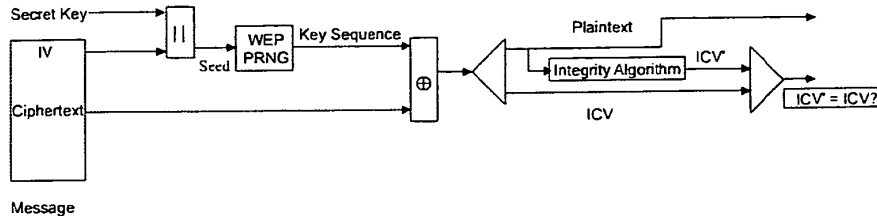


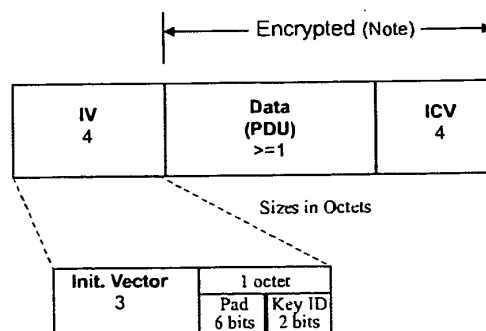
Figure 45—WEP decipherment block diagram

8.2.4 WEP algorithm specification

WEP uses the RC4 PRNG algorithm from RSA Data Security, Inc.⁶

8.2.5 WEP Frame Body expansion

Figure 46 shows the encrypted Frame Body as constructed by the WEP algorithm.



NOTE – The encypherment process has expanded the original Frame Body by 8 octets, 4 for the IV field and 4 for the ICV. The ICV is calculated on the data field only.

Figure 46—Construction of expanded WEP Frame Body

The WEP ICV shall be a 32-bit field containing the CRC-32, as defined in 7.1.3.6 calculated over the Data (PDU) field as depicted in Figure 46. The expanded Frame Body shall include a 32-bit IV field immediately preceding the original Frame Body. This field shall contain three subfields: a three-octet field that contains the initialization vector, a 2-bit key ID field, and a 6-bit pad field. The ordering conventions defined in 7.1.1 apply to the IV fields and its subfields and to the ICV field. The key ID subfield contents select one of four

⁶Details of the RC4 algorithm are available from RSA. Please contact RSA for algorithm details and the uniform RC4 license terms that RSA offers to anyone wishing to use RC4 for the purpose of implementing the IEEE 802.11 WEP option. If necessary, contact the IEEE Standards Department Intellectual Property Rights Administrator for details on how to communicate with RSA.

possible secret key values for use in decrypting this Frame Body. Interpretation of these bits is discussed further in 8.3.2. The contents of the pad subfield shall be zero. The key ID occupies the two msb of the last octet of the IV field, while the pad occupies the six lsb of this octet.

The WEP mechanism is invisible to entities outside the IEEE 802.11 MAC data path.

8.3 Security-Related MIB attributes

The IEEE 802.11 security mechanisms are controlled via the MAC management path and related MIB attributes. This subclause gives an overview of the security-related MIB attributes and how they are used. For details of the MIB attribute definitions, refer to 11.4.

8.3.1 Authentication-Related MIB attributes

The type of authentication invoked when authentication is attempted is controlled by the AuthenticationType parameter to the MLME-AUTHENTICATE.request primitive. The type of authentication request that may be accepted by a STA is controlled by the MIB attribute dot11AuthenticationType. The type of authentication is selected from the following set of values:

- Open System
- Shared Key

All other values are reserved. The numeric encoding of these values is given in 7.3.1.1.

8.3.2 Privacy-Related MIB attributes

WEP invocation is controlled by the parameters passed to the MLME-AUTHENTICATE.request primitive as well as a number of MIB attributes. An overview of the attributes and their usage is given in this subclause. All MIB attributes that hold WEP keys are externally write-only; the contents shall not be readable via MAC management SAPs. See 11.4 for the formal MIB attribute definitions.

The boolean variable dot11PrivacyInvoked shall be set to “false” to prevent the STA from transmitting MPDUs of type Data with the WEP subfield of the Frame Control field set to 1. It does not affect MPDU or MMPDU reception.

The default value for all WEP keys shall be null. Note that encrypting a frame using WEP with a null key is not the same as failing to encrypt the frame. Any request to encrypt a frame with a null key shall result in the MSDU being discarded and an MA-UNIDATA-STATUS.indication with a transmission status indicating that the frame may not be encrypted with a null key. Decrypting a frame whose WEP subfield is set to 1 involves stripping the IV, and checking the ICV against the calculated ICV' value computed over the data contained in the MPDU.

To support shared key configurations, the MIB contains a four-element vector called “dot11WEPPDefaultKeys.” The default value for each element of this vector is null. These elements contain the default keys to be used with WEP.

An additional attribute called “dot11WEPPDefaultKeyID” is an integer. When set to a value of 0, 1, 2, or 3, MPDUs transmitted with the WEP subfield of the Frame Control field set to 1 shall be encrypted using the first, second, third, or fourth element, respectively, from dot11WEPPDefaultKeys, unless the frame has an individual RA and a key mapping exists for the RA of the frame. On receive, the incoming MPDU shall be decrypted using the element from dot11WEPPDefaultKeys specified by the received key ID field, unless the frame has an individual RA and a key mapping exists for the TA of the frame. The value in the transmitted key ID field shall be zero in all cases except when dot11WEPPDefaultKeyID is used to encrypt a frame and is

set to a value of 1, 2, or 3, in which case the transmitted key ID field shall contain the value of `dot11WEPDefaultKeyID`.

When the boolean attribute `aExcludeUnencrypted` is set to True, MPDUs of type Data received by the STA with the WEP subfield of the Frame Control field equal to zero shall not be indicated at the MAC service interface. When `aExcludeUnencrypted` is set to True, only MSDUs that have been decrypted successfully shall be indicated at the MAC service interface.

IEEE 802.11 does not require that the same WEP key be used for all STAs. The MIB supports the ability to share a separate WEP key for each RA/TA pair. Key mapping is supported by a MIB attribute that is an array called "`dot11WEPKeyMappings`." `dot11WEPKeyMappings` contains zero or one entry for each MAC address, up to an implementation-defined maximum number of entries identified by `dot11WEPKeyMappingLength`, and contains two fields for each entry: a boolean "`WEPOn`" and the corresponding WEPKey. In an infrastructure BSS, the AP's `WEPOn` value in the entry in its `dot11WEPKeyMapping` table corresponding to a STA's MAC address shall not be set to True for a STA if that STA has not successfully initiated and completed an authentication sequence using an authentication type other than "Open System." The default value for all `WEPOn` fields is False. `dot11WEPKeyMappings` shall be indexed by either RA or TA addresses (since WEP is applied only to the wireless link), as described below. When an entry in the table exists for a particular MAC address, the values in the `dot11WEPKeyMappings` attribute shall be used instead of the `dot11WEPDefaultKeyID` and `dot11WEPDefaultKeys` variables.

The minimal value of `dot11WEPKeyMappingLength` shall be 10. This value represents a minimum capability that may be assumed for any STA implementing the WEP option.

When transmitting a frame of type Data, the values of `dot11PrivacyInvoked`, `dot11WEPKeyMappings`, `dot11WEPDefaultKeys`, and `dot11WEPDefaultKeyID` in effect at an unspecified time between receipt by the MAC of the `MAUNITDATA.request` primitive and the time of transmission of that frame shall be used according to the following decision tree:

```
if dot11PrivacyInvoked is "false"
    the MPDU is transmitted without encryption
else
    if (the MPDU has an individual RA and
        there is an entry in dot11WEPKeyMappings for that RA)
        if that entry has WEPOn set to "false"
            the MPDU is transmitted without encryption
        else
            if that entry contains a key that is null
                discard the entire MSDU and generate an
                MA-UNITDATA-STATUS.indication primitive to
                notify LLC that the MSDU was undeliverable due to
                a null WEP key
            else
                encrypt the MPDU using that entry's key, setting the keyID
                subfield of the IV field to zero
    else
        if (the MPDU has a group RA and the Privacy subfield
            of the Capability Information field in this BSS is set to 0)
            the MPDU is transmitted without encryption
        else
            if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null
                discard the MSDU and generate an
                MA-UNITDATA-STATUS.indication primitive to
```

```

        notify LLC that the entire MSDU was undeliverable
        due to a null WEP key
    else
        encrypt the MPDU using
        dot11WEPDefaultKeys[dot11WEPDefaultKeyID],
        setting the KeyID subfield of the IV field to
        dot11WEPDefaultKeyID

```

When receiving a frame of type Data, the values of dot11PrivacyOptionImplemented, dot11WEPKeyMappings, dot11WEPDefaultKeys, dot11WEPDefaultKeyID, and aExcludeUnencrypted in effect at the time the PHY-RXSTART.indication primitive is received by the MAC shall be used according to the following decision tree:

```

    if the WEP subfield of the Frame Control Field is zero
        if aExcludeUnencrypted is "true"
            discard the frame body without indication to LLC and increment
            dot11WEPExcludedCount
        else
            receive the frame without decryption
    else
        if dot11PrivacyOptionImplemented is "true"
            if (the MPDU has individual RA and
                there is an entry in dot11WEPKeyMappings matching the MPDU's TA)
                if that entry has WEPOn set to "false"
                    discard the frame body and increment
                    dot11WEPUndecryptableCount
                else
                    if that entry contains a key that is null
                        discard the frame body and increment
                        dot11WEPUndecryptableCount
                    else
                        attempt to decrypt with that key, incrementing
                        dot11WEPICVErrorCount if the ICV check fails
            else
                if dot11WEPDefaultKeys[keyID] is null
                    discard the frame body and increment
                    dot11WEPUndecryptableCount
                else
                    attempt to decrypt with dot11WEPDefaultKeys[keyID],
                    incrementing dot11WEPICVErrorCount if the ICV check fails
        else
            discard the frame body and increment dot11WEPUndecryptableCount

```

When transmitting a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

```

    if dot11PrivacyOptionImplemented is "false"
        the MMPDU is transmitted with a sequence
        of zero octets in the Challenge Text field and a Status Code value of 13
    else
        the MMPDU is transmitted with a sequence of 128 octets generated using the
        WEP PRNG and a key whose value is unspecified and beyond the scope of this
        standard and a randomly chosen IV value (note that this will typically be selected
        by the same mechanism for choosing IV values for transmitted data MPDUs)

```

in the Challenge Text field and a status code value of 0 (the IV used is immaterial and is not transmitted). Note that there are cryptographic issues involved in the choice of key/IV for this process as the challenge text is sent unencrypted and therefore provides a known output sequence from the PRNG.

When receiving a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

```
if the WEP subfield of the Frame Control field is 1
    respond with a status code value of 15
else
    if dot11PrivacyOptionImplemented is "true"
        if there is a mapping in dot11WEPKeyMappings matching the MSDU's TA
            if that key is null
                respond with a frame whose Authentication Transaction
                Sequence Number field is 3 that contains the appropriate
                Authentication Algorithm Number, a status code value of
                15 and no Challenge Text field, without encrypting the
                contents of the frame
            else
                respond with a frame whose Authentication Transaction
                Sequence Number field is 3 that contains the appropriate
                Authentication Algorithm Number, a status code value of
                0 and the identical Challenge Text field, encrypted using
                that key, and setting the key ID subfield in the IV field to 0
        else
            if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null
                respond with a frame whose Authentication Transaction
                Sequence Number field is 3 that contains the appropriate
                Authentication Algorithm Number, a status code value of
                15 and no Challenge Text field, without encrypting the
                contents of the frame
            else
                respond with a frame whose Authentication Transaction
                Sequence Number field is 3 that contains the appropriate
                Authentication Algorithm Number, a status code value of 0
                and the identical Challenge Text field, encrypted using
                dot11WEPDefaultKeys[dot11WEPDefaultKeyID], setting the
                key ID subfield in the IV field to dot11WEPDefaultKeyID
    else
        respond with a frame whose Authentication Transaction
        Sequence Number field is 3 that contains the appropriate Authentication
        Algorithm Number, a status code value of 13 and no Challenge Text
        field, without encrypting the contents of the frame
```

When receiving a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 3, the MAC shall operate according to the following decision tree:

```
if the WEP subfield of the Frame Control field is zero
    respond with a status code value of 15
else
    if dot11PrivacyOptionImplemented is "true"
        if there is a mapping in dot11WEPKeyMappings matching the MSDU's TA
```

```

        if that key is null
            respond with a frame whose Authentication Transaction
            Sequence Number field is 4 that contains the appropriate
            Authentication Algorithm Number, and a status code value
            of 15 without encrypting the contents of the frame
        else
            attempt to decrypt with that key, incrementing
            dot11WEPICVErrorCount and responding with a status code value
            of 15 if the ICV check fails
    else
        if dot11WEPDefaultKeys[keyID] is null
            respond with a frame whose Authentication Transaction
            Sequence Number field is 4 that contains the appropriate
            Authentication Algorithm Number, and a status code value
            of 15 without encrypting the contents of the frame
        else
            attempt to decrypt with dot11WEPDefaultKeys[keyID],
            incrementing dot11WEPICVErrorCount and responding with
            a status code value of 15 if the ICV check fails
    else
        respond with a frame whose Authentication Transaction Sequence Number
        field is 4 that contains the appropriate Authentication Algorithm Number,
        and a status code value of 15

```

The attribute dot11PrivacyInvoked shall not take the value "true" if the attribute dot11PrivacyOptionImplemented is "false." Setting the attribute dot11WEPKeyMappings to a value that includes more than dot11WEPKeyMappingLength entries is illegal and shall have an implementation-specific effect on the operation of the privacy service. Note that dot11WEPKeyMappings may contain between zero and dot11WEPKeyMappingLength entries, inclusive.

It is recommended that the values of the attributes in the aPrivacygrp not be changed during the authentication sequence as unintended operation may result.

9. MAC sublayer functional description

The MAC functional description is presented in this clause. The architecture of the MAC sublayer, including the distributed coordination function (DCF), the point coordination function (PCF), and their coexistence in an IEEE 802.11 LAN are introduced in 9.1. These functions are expanded on in 9.2 and 9.3, and a complete functional description of each is provided. Fragmentation and defragmentation are covered in 9.4 and 9.5. Multirate support is addressed in 9.6. The allowable frame exchange sequences are listed in 9.7. Finally, a number of additional restrictions to limit the cases in which MSDUs are reordered or discarded are described in 9.8.

9.1 MAC architecture

The MAC architecture can be described as shown in Figure 47 as providing the PCF through the services of the DCF.

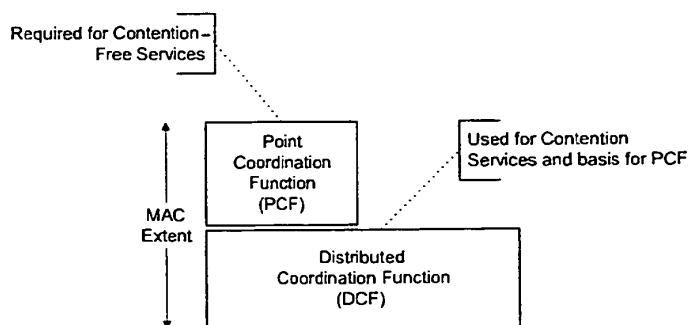


Figure 47—MAC architecture

9.1.1 Distributed coordination function (DCF)

The fundamental access method of the IEEE 802.11 MAC is a DCF known as *carrier sense multiple access with collision avoidance* (CSMA/CA). The DCF shall be implemented in all STAs, for use within both IBSS and infrastructure network configurations.

For a STA to transmit, it shall sense the medium to determine if another STA is transmitting. If the medium is not determined to be busy (see 9.2.1), the transmission may proceed. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exist between contiguous frame sequences. A transmitting STA shall ensure that the medium is idle for this required duration before attempting to transmit. If the medium is determined to be busy, the STA shall defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the STA shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions—here the transmitting and receiving STA exchange short control frames [request to send (RTS) and clear to send (CTS) frames] after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission. The details of CSMA/CA, deferrals, and backoffs are described in 9.2. RTS/CTS exchanges are also presented in 9.2.

9.1.2 Point coordination function (PCF)

The IEEE 802.11 MAC may also incorporate an optional access method called a PCF, which is only usable on infrastructure network configurations. This access method uses a point coordinator (PC), which shall

operate at the access point of the BSS, to determine which STA currently has the right to transmit. The operation is essentially that of polling, with the PC performing the role of the polling master. The operation of the PCF may require additional coordination, not specified in this standard, to permit efficient operation in cases where multiple point-coordinated BSSs are operating on the same channel, in overlapping physical space.

The PCF uses a virtual carrier-sense mechanism aided by an access priority mechanism. The PCF shall distribute information within Beacon management frames to gain control of the medium by setting the network allocation vector (NAV) in STAs. In addition, all frame transmissions under the PCF may use an interframe space (IFS) that is smaller than the IFS for frames transmitted via the DCF. The use of a smaller IFS implies that point-coordinated traffic shall have priority access to the medium over STAs in overlapping BSSs operating under the DCF access method.

The access priority provided by a PCF may be utilized to create a *contention-free* (CF) access method. The PC controls the frame transmissions of the STAs so as to eliminate contention for a limited period of time.

9.1.3 Coexistence of DCF and PCF

The DCF and the PCF shall coexist in a manner that permits both to operate concurrently within the same BSS. When a PC is operating in a BSS, the two access methods alternate, with a contention-free period (CFP) followed by a contention period (CP). This is described in greater detail in 9.3.

9.1.4 Fragmentation/defragmentation overview

The process of partitioning a MAC service data unit (MSDU) or a MAC management protocol data unit (MMPDU) into smaller MAC level frames, MAC protocol data units (MPDUs), is called fragmentation. Fragmentation creates MPDUs smaller than the original MSDU or MMPDU length to increase reliability, by increasing the probability of successful transmission of the MSDU or MMPDU in cases where channel characteristics limit reception reliability for longer frames. Fragmentation is accomplished at each immediate transmitter. The process of recombining MPDUs into a single MSDU or MMPDU is defined as defragmentation. Defragmentation is accomplished at each immediate recipient.

Only MPDUs with a unicast receiver address shall be fragmented. Broadcast/multicast frames shall not be fragmented even if their length exceeds aFragmentationThreshold.

When a directed MSDU is received from the LLC or a directed MMPDU is received from the MAC sublayer management entity (MLME) with a length greater than aFragmentationThreshold, the MSDU or MMPDU shall be fragmented. The MSDU or MMPDU is divided into MPDUs. Each fragment is a frame no larger than aFragmentationThreshold. It is possible that any fragment may be a frame smaller than aFragmentationThreshold. An illustration of fragmentation is shown in Figure 48.

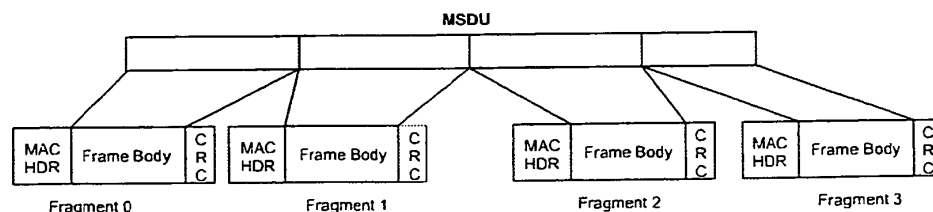


Figure 48—Fragmentation

The MPDUs resulting from the fragmentation of an MSDU or MMPDU are sent as independent transmissions, each of which is separately acknowledged. This permits transmission retries to occur per fragment,

rather than per MSDU or MMPDU. Unless interrupted due to medium occupancy limitations for a given PHY, the fragments of a single MSDU or MMPDU are sent as a burst during the CP, using a single invocation of the DCF medium access procedure. The fragments of a single MSDU or MMPDU are sent during a CFP as individual frames obeying the rules of the PC medium access procedure.

9.1.5 MAC data service

The MAC data service shall translate MAC service requests from LLC into input signals utilized by the MAC state machines. The MAC data service shall also translate output signals from the MAC state machines into service indications to LLC. The translations are given in the MAC data service state machine defined in Annex C.

9.2 DCF

The basic medium access protocol is a DCF that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff time following a busy medium condition. In addition, all directed traffic uses immediate positive acknowledgment (ACK frame) where retransmission is scheduled by the sender if no ACK is received.

The CSMA/CA protocol is designed to reduce the collision probability between multiple STAs accessing a medium, at the point where collisions would most likely occur. Just after the medium becomes idle following a busy medium (as indicated by the CS function) is when the highest probability of a collision exists. This is because multiple STAs could have been waiting for the medium to become available again. This is the situation that necessitates a random backoff procedure to resolve medium contention conflicts.

Carrier sense shall be performed both through physical and virtual mechanisms.

The virtual carrier-sense mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration/ID field that defines the period of time that the medium is to be reserved to transmit the actual data frame and the returning ACK frame. All STAs within the reception range of either the originating STA (which transmits the RTS) or the destination STA (which transmits the CTS) shall learn of the medium reservation. Thus a STA can be unable to receive from the originating STA, yet still know about the impending use of the medium to transmit a data frame.

Another means of distributing the medium reservation information is the Duration/ID field in directed frames. This field gives the time that the medium is reserved, either to the end of the immediately following ACK, or in the case of a fragment sequence, to the end of the ACK following the next fragment.

The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long data frame had been transmitted and a return ACK frame had not been detected.

Another advantage of the RTS/CTS mechanism occurs where multiple BSSs utilizing the same channel overlap. The medium reservation mechanism works across the BSA boundaries. The RTS/CTS mechanism may also improve operation in a typical situation where all STAs can receive from the AP, but cannot receive from all other STAs in the BSA.

The RTS/CTS mechanism cannot be used for MPDUs with broadcast and multicast immediate address because there are multiple destinations for the RTS, and thus potentially multiple concurrent senders of the CTS in response. The RTS/CTS mechanism need not be used for every data frame transmission. Because the

additional RTS and CTS frames add overhead inefficiency, the mechanism is not always justified, especially for short data frames.

The use of the RTS/CTS mechanism is under control of the `dot11RTSThreshold` attribute. This attribute may be set on a per-STA basis. This mechanism allows STAs to be configured to use RTS/CTS either always, never, or only on frames longer than a specified length.

A STA configured not to initiate the RTS/CTS mechanism shall still update its virtual carrier-sense mechanism with the duration information contained in a received RTS or CTS frame, and shall always respond to an RTS addressed to it with a CTS.

The medium access protocol allows for STAs to support different sets of data rates. All STAs shall receive all the data rates in `aBasicRateSet` and transmit at one or more of the `aBasicRateSet` data rates. To support the proper operation of the RTS/CTS and the virtual carrier-sense mechanism, all STAs shall be able to detect the RTS and CTS frames. For this reason the RTS and CTS frames shall be transmitted at one of the `aBasicRateSet` rates. (See 9.6 for a description of multirate operation.)

Data frames sent under the DCF shall use the frame type Data and subtype Data or Null Function. STAs receiving Data type frames shall only consider the frame body as the basis of a possible indication to LLC.

9.2.1 Carrier-sense mechanism

Physical and virtual carrier-sense functions are used to determine the state of the medium. When either function indicates a busy medium, the medium shall be considered busy; otherwise, it shall be considered idle.

A physical carrier-sense mechanism shall be provided by the PHY. See Clause 12 for how this information is conveyed to the MAC. The details of physical carrier sense are provided in the individual PHY specifications.

A virtual carrier-sense mechanism shall be provided by the MAC. This mechanism is referred to as the network allocation vector (NAV). The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames prior to the actual exchange of data. The duration information is also available in the MAC headers of all frames sent during the CP other than PS-Poll Control frames. The mechanism for setting the NAV using RTS/CTS in the DCF is described in 9.2.5.4, and use of the NAV in PCF is described in 9.3.2.2.

The carrier-sense mechanism combines the NAV state and the STA's transmitter status with physical carrier sense to determine the busy/idle state of the medium. The NAV may be thought of as a counter, which counts down to zero at a uniform rate. When the counter is zero, the virtual carrier-sense indication is that the medium is idle; when nonzero, the indication is busy. The medium shall be determined to be busy whenever the STA is transmitting.

9.2.2 MAC-Level acknowledgments

The reception of some frames, as described in 9.7, 9.2.8, and 9.3.3.4, requires the receiving STA to respond with an acknowledgment, generally an ACK frame, if the FCS of the received frame is correct. This technique is known as positive acknowledgment.

Lack of reception of an expected ACK frame indicates to the source STA that an error has occurred. Note, however, that the destination STA may have received the frame correctly, and that the error may have occurred in the reception of the ACK frame. To the initiator of the frame exchange, this condition is indistinguishable from an error occurring in the initial frame.

9.2.3 Interframe space (IFS)

The time interval between frames is called the IFS. A STA shall determine that the medium is idle through the use of the carrier-sense function for the interval specified. Four different IFSs are defined to provide priority levels for access to the wireless media; they are listed in order, from the shortest to the longest. Figure 49 shows some of these relationships.

- a) SIFS short interframe space
- b) PIFS PCF interframe space
- c) DIFS DCF interframe space
- d) EIFS extended interframe space

The different IFSs shall be independent of the STA bit rate. The IFS timings shall be defined as time gaps on the medium, and shall be fixed for each PHY (even in multirate-capable PHYs). The IFS values are determined from attributes specified by the PHY.

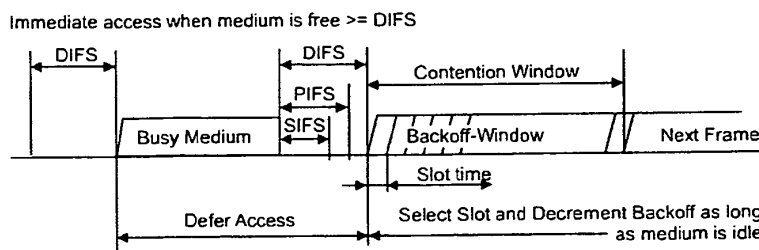


Figure 49—Some IFS relationships

9.2.3.1 Short IFS (SIFS)

The SIFS shall be used for an ACK frame, a CTS frame, the second or subsequent MPDU of a fragment burst, and by a STA responding to any polling by the PCF. It may also be used by a PC for any types of frames during the CFP (see 9.3). The SIFS is the time from the end of the last symbol of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen at the air interface. The valid cases where the SIFS may or shall be used are listed in the frame exchange sequences in 9.7.

The SIFS timing shall be achieved when the transmission of the subsequent frame is started at the TxSIFS Slot boundary as specified in 9.2.10. An IEEE 802.11 implementation shall not allow the space between frames that are defined to be separated by a SIFS time, as measured on the medium, to vary from the nominal SIFS value by more than $\pm 10\%$ of aSlotTime for the PHY in use.

SIFS is the shortest of the interframe spaces. SIFS shall be used when STAs have seized the medium and need to keep it for the duration of the frame exchange sequence to be performed. Using the smallest gap between transmissions within the frame exchange sequence prevents other STAs, which are required to wait for the medium to be idle for a longer gap, from attempting to use the medium, thus giving priority to completion of the frame exchange sequence in progress.

9.2.3.2 PCF IFS (PIFS)

The PIFS shall be used only by STAs operating under the PCF to gain priority access to the medium at the start of the CFP. A STA using the PCF shall be allowed to transmit contention-free traffic after its carrier-sense mechanism (see 9.2.1) determines that the medium is idle at the TxPIFS slot boundary as defined in 9.2.10. Subclause 9.3 describes the use of the PIFS by STAs operating under the PCF.

9.2.3.3 DCF IFS (DIFS)

The DIFS shall be used by STAs operating under the DCF to transmit data frames (MPDUs) and management frames (MMPDUs). A STA using the DCF shall be allowed to transmit if its carrier-sense mechanism (see 9.2.1) determines that the medium is idle at the TxDIFS slot boundary as defined in 9.2.10 after a correctly received frame, and its backoff time has expired. A STA using the DCF shall not transmit within an EIFS after it determines that the medium is idle following reception of a frame for which the PHYRX-END.indication primitive contained an error or a frame for which the MAC FCS value was not correct. A STA may transmit after subsequent reception of an error-free frame, resynchronizing the STA. This allows the STA to transmit using the DIFS following that frame.

9.2.3.4 Extended IFS (EIFS)

The EIFS shall be used by the DCF whenever the PHY has indicated to the MAC that a frame transmission was begun that did not result in the correct reception of a complete MAC frame with a correct FCS value. The duration of an EIFS is defined in 9.2.10. The EIFS interval shall begin following indication by the PHY that the medium is idle after detection of the erroneous frame, without regard to the virtual carrier-sense mechanism. The EIFS is defined to provide enough time for another STA to acknowledge what was, to this STA, an incorrectly received frame before this STA commences transmission. Reception of an error-free frame during the EIFS resynchronizes the STA to the actual busy/idle state of the medium, so the EIFS is terminated and normal medium access (using DIFS and, if necessary, backoff) continues following reception of that frame.

9.2.4 Random backoff time

A STA desiring to initiate transfer of data MPDUs and/or management MMPDUs shall invoke the carrier-sense mechanism (see 9.2.1) to determine the busy/idle state of the medium. If the medium is busy, the STA shall defer until the medium is determined to be idle without interruption for a period of time equal to DIFS when the last frame detected on the medium was received correctly, or after the medium is determined to be idle without interruption for a period of time equal to EIFS when the last frame detected on the medium was not received correctly. After this DIFS or EIFS medium idle time, the STA shall then generate a random backoff period for an additional deferral time before transmitting, unless the backoff timer already contains a nonzero value, in which case the selection of a random number is not needed and not performed. This process minimizes collisions during contention between multiple STAs that have been deferring to the same event.

$$\text{Backoff Time} = \text{Random}() \times \text{aSlotTime}$$

where

$\text{Random}()$ = Pseudorandom integer drawn from a uniform distribution over the interval $[0, CW]$, where CW is an integer within the range of values of the PHY characteristics $aCW_{\min}$ and $aCW_{\max}$, $aCW_{\min} \leq CW \leq aCW_{\max}$. It is important that designers recognize the need for statistical independence among the random number streams among STAs.

$aSlotTime$ = The value of the correspondingly named PHY characteristic.

The contention window (CW) parameter shall take an initial value of $aCW_{\min}$. Every STA shall maintain a STA short retry count (SSRC) as well as a STA long retry count (SLRC), both of which shall take an initial value of zero. The SSRC shall be incremented whenever any short retry count associated with any MSDU is incremented. The SLRC shall be incremented whenever any long retry count associated with any MSDU is incremented. The CW shall take the next value in the series every time an unsuccessful attempt to transmit an MPDU causes either STA retry counter to increment, until the CW reaches the value of $aCW_{\max}$. A retry is defined as the entire sequence of frames sent, separated by SIFS intervals, in an attempt to deliver an MPDU, as described in 9.7. Once it reaches $aCW_{\max}$, the CW shall remain at the value of $aCW_{\max}$ until it is reset. This improves the stability of the access protocol under high-load conditions. See Figure 50.

The CW shall be reset to aCWmin after every successful attempt to transmit an MSDU or MMPDU, when SLRC reaches aLongRetryLimit, or when SSRC reaches dot11ShortRetryLimit. The SSRC shall be reset to 0 whenever a CTS frame is received in response to an RTS frame, whenever an ACK frame is received in response to an MPDU or MMPDU transmission, or whenever a frame with a group address in the Address1 field is transmitted. The SLRC shall be reset to 0 whenever an ACK frame is received in response to transmission of an MPDU or MMPDU of length greater than dot11RTSThreshold, or whenever a frame with a group address in the Address1 field is transmitted.

The set of CW values shall be sequentially ascending integer powers of 2, minus 1, beginning with a PHY-specific aCWmin value, and continuing up to and including a PHY-specific aCWmax value.

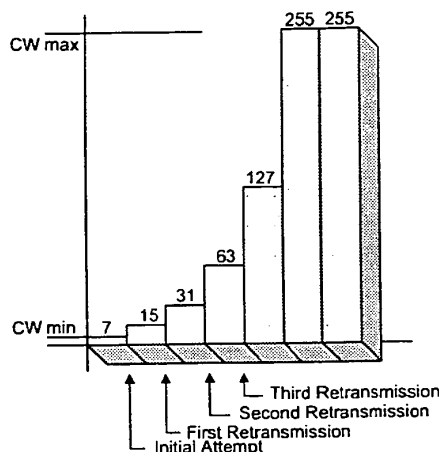


Figure 50—An example of exponential increase of CW

9.2.5 DCF access procedure

The CSMA/CA access method is the foundation of the DCF. The operational rules vary slightly between the DCF and the PCF.

9.2.5.1 Basic access

Basic access refers to the core mechanism a STA uses to determine whether it may transmit.

In general, a STA may transmit a pending MPDU when it is operating under the DCF access method, either in the absence of a PC, or in the CP of the PCF access method, when the STA determines that the medium is idle for greater than or equal to a DIFS period, or an EIFS period if the immediately preceding medium-busy event was caused by detection of a frame that was not received at this STA with a correct MAC FCS value. If, under these conditions, the medium is determined by the carrier-sense mechanism to be busy when a STA desires to initiate the initial frame of one of the frame exchanges described in 9.7, exclusive of the CF period, the random backoff algorithm described in 9.2.5.2 shall be followed. There are conditions, specified in 9.2.5.2 and 9.2.5.5, where the random backoff algorithm shall be followed even for the first attempt to initiate a frame exchange sequence.

In a STA having an FH PHY, control of the channel is lost at the dwell time boundary and the STA shall have to contend for the channel after that dwell boundary. It is required that STAs having an FH PHY complete transmission of the entire MPDU and associated acknowledgment (if required) before the dwell time bound-

ary. If, when transmitting or retransmitting an MPDU, there is not enough time remaining in the dwell to allow transmission of the MPDU plus the acknowledgment (if required), the STA shall defer the transmission by selecting a random backoff time, using the present CW (without advancing to the next value in the series). The short retry counter and long retry counter for the MSDU are not affected.

The basic access mechanism is illustrated in Figure 51.

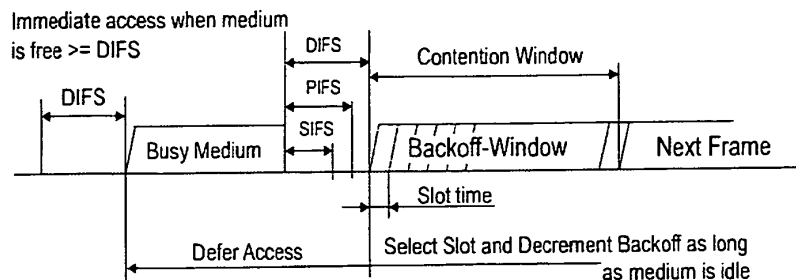


Figure 51—Basic access method

9.2.5.2 Backoff procedure

The backoff procedure shall be invoked for a STA to transfer a frame when finding the medium busy as indicated by either the physical or virtual carrier-sense mechanism (see Figure 52). The backoff procedure shall also be invoked when a transmitting STA infers a failed transmission as defined in 9.2.5.7 or 9.2.8.

To begin the backoff procedure, the STA shall set its Backoff Timer to a random backoff time using the equation in 9.2.4. All backoff slots occur following a DIFS period during which the medium is determined to be idle for the duration of the DIFS period, or following an EIFS period during which the medium is determined to be idle for the duration of the EIFS period following detection of a frame that was not received correctly.

A STA performing the backoff procedure shall use the carrier-sense mechanism (9.2.1) to determine whether there is activity during each backoff slot. If no medium activity is indicated for the duration of a particular backoff slot, then the backoff procedure shall decrement its backoff time by aSlotTime.

If the medium is determined to be busy at any time during a backoff slot, then the backoff procedure is suspended; that is, the backoff timer shall not decrement for that slot. The medium shall be determined to be idle for the duration of a DIFS period or EIFS, as appropriate (see 9.2.3), before the backoff procedure is allowed to resume. Transmission shall commence whenever the Backoff Timer reaches zero.

A backoff procedure shall be performed immediately after the end of every transmission with the More Fragments bit set to 0 of an MPDU of type Data, Management, or Control with subtype PS-Poll, even if no additional transmissions are currently queued. In the case of successful acknowledged transmissions, this backoff procedure shall begin at the end of the received ACK frame. In the case of unsuccessful transmissions requiring acknowledgment, this backoff procedure shall begin at the end of the ACK timeout interval. If the transmission is successful, the CW value reverts to aCWmin before the random backoff interval is chosen, and the STA short retry count and/or STA long retry count are updated as described in 9.2.4. This assures that transmitted frames from a STA are always separated by at least one backoff interval.

The effect of this procedure is that when multiple STAs are deferring and go into random backoff, then the STA selecting the smallest backoff time using the random function will win the contention.

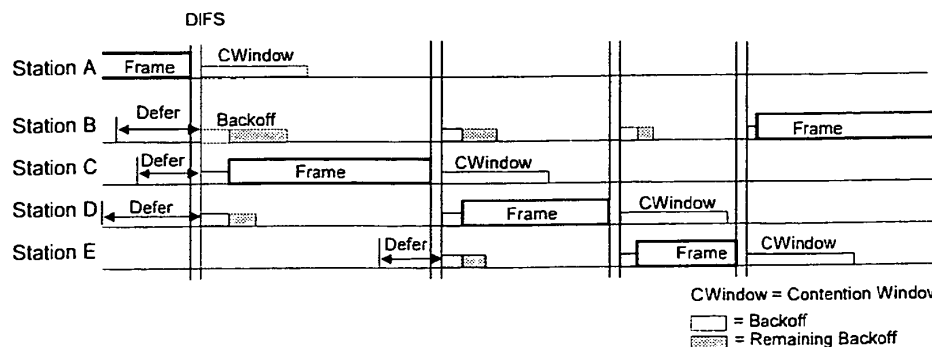


Figure 52—Backoff procedure

In an IBSS, the backoff time for a pending non-beacon or non-ATIM transmission shall not decrement in the period from the target beacon transmission time (TBTT) until the expiration of the ATIM window, and the backoff time for a pending ATIM management frame shall decrement only within the ATIM window. (See Clause 11.) Within an IBSS, a separate backoff interval shall be generated to precede the transmission of a beacon, as described in 11.1.2.2.

9.2.5.3 Recovery procedures and retransmit limits

Error recovery is always the responsibility of the STA that initiates a frame exchange sequence, as defined in 9.7. Many circumstances may cause an error to occur that requires recovery. For example, the CTS frame may not be returned after an RTS frame is transmitted. This may happen due to a collision with another transmission, due to interference in the channel during the RTS or CTS frame, or because the STA receiving the RTS frame has an active virtual carrier-sense condition (indicating a busy medium time period).

Error recovery shall be attempted by retrying transmissions for frame exchange sequences that the initiating STA infers have failed. Retries shall continue, for each failing frame exchange sequence, until the transmission is successful, or until the relevant retry limit is reached, whichever occurs first. STAs shall maintain a short retry count and a long retry count for each MSDU or MMPDU awaiting transmission. These counts are incremented and reset independently of each other.

After an RTS frame is transmitted, the STA shall perform the CTS procedure, as defined in 9.2.5.7. If the RTS transmission fails, the short retry count for the MSDU or MMPDU and the STA short retry count are incremented. This process shall continue until the number of attempts to transmit that MSDU or MMPDU reaches `dot11ShortRetryLimit`.

After transmitting a frame that requires acknowledgment, the STA shall perform the ACK procedure, as defined in 9.2.8. The short retry count for an MSDU or MMPDU and the STA short retry count shall be incremented every time transmission of a MAC frame of length less than or equal to `dot11RTSThreshold` fails for that MSDU or MMPDU. This short retry count and the STA short retry count shall be reset when a MAC frame of length less than or equal to `dot11RTSThreshold` succeeds for that MSDU or MMPDU. The long retry count for an MSDU or MMPDU and the STA long retry count shall be incremented every time transmission of a MAC frame of length greater than `dot11RTSThreshold` fails for that MSDU or MMPDU. This long retry count and the STA long retry count shall be reset when a MAC frame of length greater than `dot11RTSThreshold` succeeds for that MSDU or MMPDU. All retransmission attempts for an MSDU or MMPDU that has failed the ACK procedure one or more times shall be made with the Retry field set to 1 in the Data or Management type frame.

Retries for failed transmission attempts shall continue until the short retry count for the MSDU or MMPDU is equal to `dot11ShortRetryLimit` or until the long retry count for the MSDU or MMPDU is equal to `aLongRetryLimit`. When either of these limits is reached, retry attempts shall cease, and the MSDU or MMPDU shall be discarded.

A STA in power-save mode, in an ESS, initiates a frame exchange sequence by transmitting a PS-Poll frame to request data from an AP. In the event that neither an ACK frame nor a data frame is received from the AP in response to a PS-Poll frame, then the STA shall retry the sequence, by transmitting another PS-Poll frame, at its convenience. If the AP sends a data frame in response to a PS-Poll frame, but fails to receive the ACK frame acknowledging this data frame, the next PS-Poll frame from the same STA may cause a retransmission of the last MSDU. This duplicate MSDU shall be filtered at the receiving STA using the normal duplicate frame filtering mechanism. If the AP responds to a PS-Poll by transmitting an ACK frame, then responsibility for the data frame delivery error recovery shifts to the AP because the data is transferred in a subsequent frame exchange sequence, which is initiated by the AP. The AP shall attempt to deliver one MSDU to the STA that transmitted the PS-Poll, using any frame exchange sequence valid for a directed MSDU. If the power save STA that transmitted the PS-Poll returns to Doze state after transmitting the ACK frame in response to successful receipt of this MSDU, but the AP fails to receive this ACK frame, the AP will retry transmission of this MSDU until the relevant retry limit is reached. See Clause 11 for details on filtering of extra PS-Poll frames.

9.2.5.4 Setting and resetting the NAV

STAs receiving a valid frame shall update their NAV with the information received in the Duration/ID field, but only when the new NAV value is greater than the current NAV value and only when the frame is not addressed to the receiving STA. Various additional conditions may set or reset the NAV, as described in 9.3.2.2. When the NAV is reset, a `PHY-CCARESET.request` shall be issued.

Figure 53 indicates the NAV for STAs that may receive the RTS frame, while other STAs may only receive the CTS frame, resulting in the lower NAV bar as shown (with the exception of the STA to which the RTS was addressed).

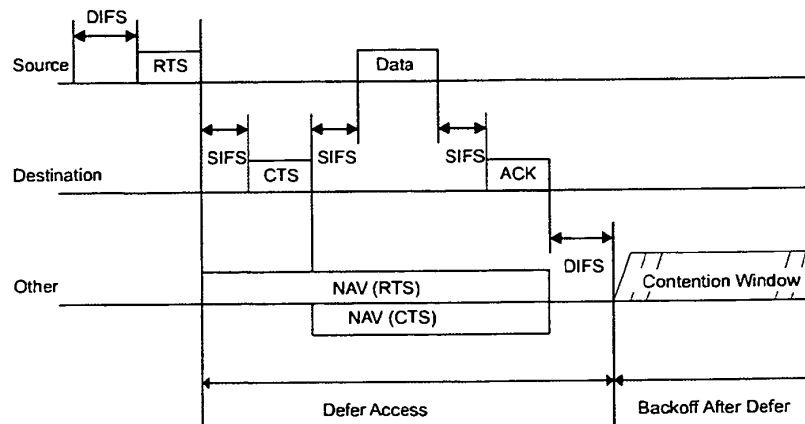


Figure 53—RTS/CTS/data/ACK and NAV setting

A STA that used information from an RTS frame as the most recent basis to update its NAV setting is permitted to reset its NAV if no `PHY-RXSTART.indication` is detected from the PHY during a period with a duration of $(2 \times \text{aSIFSTime}) + (\text{CTS\_Time}) + (2 \times \text{aSlotTime})$ starting at the `PHY-RXEND.indication` corresponding to the detection of the RTS frame. The “CTS_Time” shall be calculated using the length of the CTS frame and the data rate at which the RTS frame used for the most recent NAV update was received.

- The source STA has received an acknowledgment for a previous fragment, has more fragment(s) for the same MSDU to transmit, and there is enough time before the next dwell boundary to send the next fragment and receive its acknowledgment.

The following rules shall also apply:

- When a STA has transmitted a frame other than an initial or intermediate fragment, that STA shall not transmit on the channel following the acknowledgment for that frame, without performing the backoff procedure.
- When an MSDU has been successfully delivered or all retransmission attempts have been exhausted, and the STA has a subsequent MSDU to transmit, then that STA shall perform a backoff procedure.
- Only unacknowledged fragments shall be retransmitted.

9.2.5.6 RTS/CTS usage with fragmentation

The following is a description of using RTS/CTS for a fragmented MSDU or MMPDU. The RTS/CTS frames define the duration of the following frame and acknowledgment. The Duration/ID field in the data and acknowledgment (ACK) frames specifies the total duration of the next fragment and acknowledgment. This is illustrated in Figure 55.

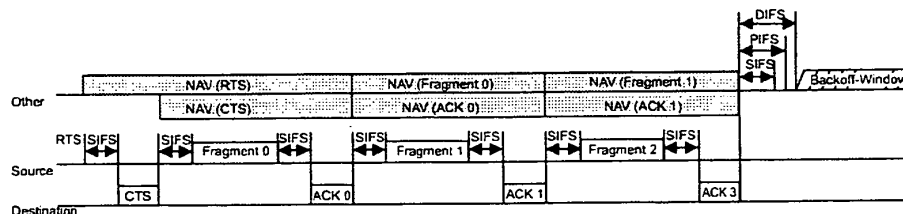


Figure 55—RTS/CTS with fragmented MSDU

Each frame contains information that defines the duration of the next transmission. The duration information from RTS frames shall be used to update the NAV to indicate busy until the end of ACK 0. The duration information from the CTS frame shall also be used to update the NAV to indicate busy until the end of ACK 0. Both Fragment 0 and ACK 0 shall contain duration information to update the NAV to indicate busy until the end of ACK 1. This shall be done by using the Duration/ID field in the Data and ACK frames. This shall continue until the last fragment, which shall have a duration of one ACK time plus one SIFS time, and its ACK, which shall have its Duration/ID field set to zero. Each fragment and ACK acts as a virtual RTS and CTS; therefore no further RTS/CTS frames need to be generated after the RTS/CTS that began the frame exchange sequence even though subsequent fragments may be larger than dot11RTSThreshold. At STAs using a frequency-hopping PHY, when there is insufficient time before the next dwell boundary to transmit the subsequent fragment, the STA initiating the frame exchange sequence may set the Duration/ID field in the last data or management frame to be transmitted before the dwell boundary to the duration of one ACK time plus one SIFS time.

In the case where an acknowledgment is sent but not received by the source STA, STAs that heard the fragment, or ACK, will mark the channel busy for the next frame exchange due to the NAV having been updated from these frames. This is the worst-case situation, and it is shown in Figure 56. If an acknowledgment is not sent by the destination STA, STAs that can only hear the destination STA will not update their NAV and may attempt to access the channel when their NAV updated from the previously received frame reaches zero. All STAs that hear the source will be free to access the channel after their NAV updated from the transmitted fragment has expired.

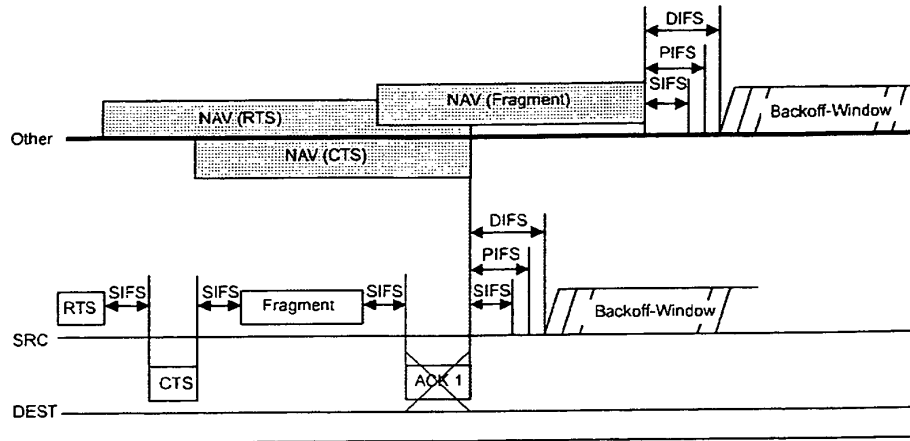


Figure 56—RTS/CTS with transmitter priority and missed acknowledgment

9.2.5.7 CTS procedure

A STA that is addressed by an RTS frame shall transmit a CTS frame after a SIFS period if the NAV at the STA receiving the RTS frame indicates that the medium is idle. If the NAV at the STA receiving the RTS frame indicates the medium is not idle, that STA shall not respond to the RTS frame. The RA field of the CTS frame shall be the value obtained from the TA field of the RTS frame to which this CTS frame is a response. The Duration/ID field in the CTS frame shall be the duration field from the received RTS frame, adjusted by subtraction of aSIFSTime and the number of microseconds required to transmit a CTS frame at the data rate used for the RTS frame to which this CTS frame is a response.

After transmitting an RTS frame, the STA shall wait for a CTSTimeout interval, starting at the PHY-TXEND.confirm. If a PHY-RXSTART.indication does not occur during the CTSTimeout interval, the STA shall conclude that the transmission of the RTS has failed, and this STA shall invoke its backoff procedure upon expiration of the CTSTimeout interval. If a PHY-RXSTART.indication does occur during the CTSTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication to determine whether the RTS transmission was successful. The recognition of a valid CTS frame sent by the recipient of the RTS frame, corresponding to this PHY-RXEND.indication, shall be interpreted as successful response, permitting the frame sequence to continue (see 9.7). The recognition of anything else, including any other valid frame, shall be interpreted as failure of the RTS transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication and may process the received frame.

9.2.6 Directed MPDU transfer procedure

A STA shall use an RTS/CTS exchange for directed frames only when the length of the MPDU is greater than the length threshold indicated by the dot11RTSThreshold attribute.

The dot11RTSThreshold attribute shall be a managed object within the MAC MIB, and its value may be set and retrieved by the MAC LME. The value 0 shall be used to indicate that all MPDUs shall be delivered with the use of RTS/CTS. Values of dot11RTSThreshold larger than the maximum MSDU length shall indicate that all MPDUs shall be delivered without RTS/CTS exchanges.

When an RTS/CTS exchange is used, the asynchronous data frame shall be transmitted after the end of the CTS frame and a SIFS period. No regard shall be given to the busy or idle status of the medium when transmitting this data frame.

When an RTS/CTS exchange is not used, the asynchronous data frame shall be transmitted following the success of the basic access procedure. With or without the use of the RTS/CTS exchange procedure, the STA that is the destination of an asynchronous data frame shall follow the ACK procedure.

9.2.7 Broadcast and multicast MPDU transfer procedure

In the absence of a PCF, when broadcast or multicast MPDUs are transferred from a STA with the ToDS bit clear, only the basic access procedure shall be used. Regardless of the length of the frame, no RTS/CTS exchange shall be used. In addition, no ACK shall be transmitted by any of the recipients of the frame. Any broadcast or multicast MPDUs transferred from a STA with a ToDS bit set shall, in addition to conforming to the basic access procedure of CSMA/CA, obey the rules for RTS/CTS exchange, because the MPDU is directed to the AP. The broadcast/multicast message shall be distributed into the BSS. The STA originating the message shall receive the message as a broadcast/multicast message. Therefore, all STAs shall filter out broadcast/multicast messages that contain their address as the source address. Broadcast and multicast MSDUs shall be propagated throughout the ESS.

There is no MAC-level recovery on broadcast or multicast frames, except for those frames sent with the ToDS bit set. As a result, the reliability of this traffic is reduced, relative to the reliability of directed traffic, due to the increased probability of lost frames from interference, collisions, or time-varying channel properties.

9.2.8 ACK procedure

An ACK frame shall be generated as shown in the frame exchange sequences listed in 9.7.

Upon successful reception of a frame of a type that requires acknowledgment with the ToDS bit set, an AP shall generate an ACK frame. An ACK frame shall be transmitted by the destination STA that is not an AP, whenever it successfully receives a unicast frame of a type that requires acknowledgment, but not if it receives a broadcast or multicast frame of such type. After a successful reception of a frame requiring acknowledgment, transmission of the ACK frame shall commence after a SIFS period, without regard to the busy/idle state of the medium.

The source STA shall wait ACKTimeout amount of time without receiving an ACK frame before concluding that the MPDU failed. (See Figure 57.)

After transmitting an MPDU that requires an ACK frame as a response (see 9.7), the STA shall wait for an ACK-Timeout interval, starting at the PHY-TXEND.confirm. If a PHY-RXSTART.indication does not occur during the ACKTimeout interval, the STA concludes that the transmission of the MPDU has failed, and this STA shall invoke its backoff procedure upon expiration of the ACKTimeout interval. If a PHY-RXSTART.indication does occur during the ACKTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication to determine whether the MPDU transmission was successful. The recognition of a valid ACK frame sent by the recipient of the MPDU requiring acknowledgment, corresponding to this PHY-RXEND.indication, shall be interpreted as successful acknowledgment, permitting the frame sequence to continue, or to end without retries, as appropriate for the particular frame sequence in progress. The recognition of anything else, including any other valid frame, shall be interpreted as failure of the MPDU transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication and may process the received frame. The sole exception is that recognition of a valid data frame sent by the recipient of a PS-Poll frame shall also be accepted as successful acknowledgment of the PS-Poll frame.

9.2.9 Duplicate detection and recovery

Since MAC-level acknowledgments and retransmissions are incorporated into the protocol, there is the possibility that a frame may be received more than once. Such duplicate frames shall be filtered out within the destination MAC.

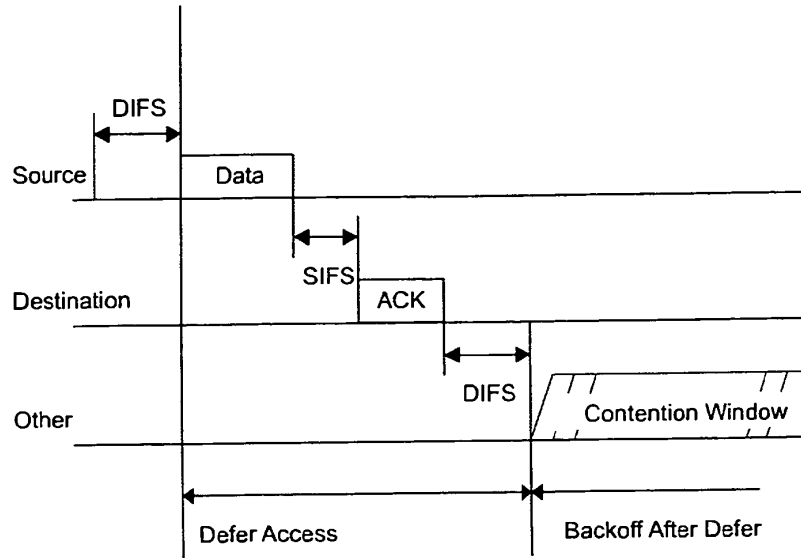


Figure 57—Directed data/ACK MPDU

Duplicate frame filtering is facilitated through the inclusion of a Sequence Control field (consisting of a sequence number and fragment number) within data and management frames. MPDUs that are part of the same MSDU shall have the same sequence number, and different MSDUs shall (with a high probability) have a different sequence number.

The sequence number is generated by the transmitting STA as an incrementing sequence of integers.

The receiving STA shall keep a cache of recently received <Address 2, sequence-number, fragment-number> tuples. A receiving STA is required to keep only the most recent cache entry per Address 2-sequence-number pair, storing only the most recently received fragment number for that pair. A receiving STA may omit tuples obtained from broadcast/multicast or ATIM frames from the cache.

A destination STA shall reject as a duplicate frame any frame that has the Retry bit set in the Frame Control field and that matches an <Address 2, sequence-number, and fragment-number> tuple of an entry in the cache.

There is a small possibility that a frame may be improperly rejected due to such a match; however, this occurrence would be rare and simply results in a lost frame (similar to an FCS error in other LAN protocols).

The destination STA shall perform the ACK procedure on all successfully received frames requiring acknowledgment, even if the frame is discarded due to duplicate filtering.

9.2.10 DCF timing relations

The relationships between the IFS specifications are defined as time gaps on the medium. The associated attributes are provided by the specific PHY. (See Figure 58.)

All timings that are referenced from the end of the transmission are referenced from the end of the last symbol of a frame on the medium. The beginning of transmission refers to the first symbol of the next frame on the medium.

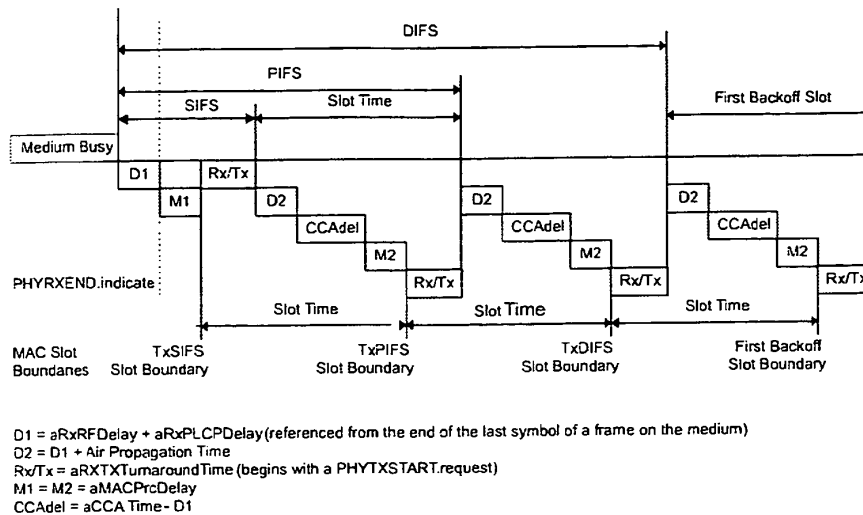


Figure 58—DCF timing relationships

aSIFSTime and aSlotTime are fixed per PHY.

aSIFSTime is: $aRxRFDelay + aRxPLCPDelay + aMACProcessingDelay + aRxTxTurnaroundTime$.

aSlotTime is: $aCCATime + aRxTxTurnaroundTime + aAirPropagationTime + aMACProcessingDelay$.

The PIFS and DIFS are derived by the following equations, as illustrated in Figure 58.

$$PIFS = aSIFSTime + aSlotTime$$

$$DIFS = aSIFSTime + 2 \times aSlotTime$$

The EIFS is derived from the SIFS and the DIFS and the length of time it takes to transmit an ACK Control frame at 1 Mbit/s by the following equation:

$$EIFS = aSIFSTime + (8 \times ACKSize) + aPreambleLength + aPLCPHeaderLngth + DIFS$$

where

ACKSize is the length, in bytes, of an ACK frame; and
 $(8 \times ACKSize) + aPreambleLength + aPLCPHeaderLngth$ is expressed in microseconds required to transmit at the PHY's lowest mandatory rate.

Figure 58 illustrates the relation between the SIFS, PIFS, and DIFS as they are measured on the medium and the different MAC slot boundaries TxSIFS, TxPIFS, and TxDIFS. These slot boundaries define when the transmitter shall be turned on by the MAC to meet the different IFS timings on the medium, after subsequent detection of the CCA result of the previous slot time.

The following equations define the MAC Slot Boundaries, using attributes provided by the PHY, which are such that they compensate for implementation timing variations. The starting reference of these slot boundaries is again the end of the last symbol of the previous frame on the medium.

$$TxSIFS = SIFS - aRxTxTurnaroundTime$$

$$TxPIFS = TxSIFS + aSlotTime$$

$$TxDIFS = TxSIFS + 2 \times aSlotTime.$$

The tolerances are specified in the PLME SAP Interface Specification (10.4), and shall only apply to the SIFS specification, so that tolerances shall not accumulate.

9.3 PCF

The PCF provides contention-free frame transfer. The PC shall reside in the AP. It is an option for an AP to be able to become the PC. All STAs inherently obey the medium access rules of the PCF, because these rules are based on the DCF, and they set their NAV at the beginning of each CFP. The operating characteristics of the PCF are such that all STAs are able to operate properly in the presence of a BSS in which a PC is operating, and, if associated with a point-coordinated BSS, are able to receive all frames sent under PCF control. It is also an option for a STA to be able to respond to a contention-free poll (CF-Poll) received from a PC. A STA that is able to respond to CF-Polls is referred to as being CF-Pollable, and may request to be polled by an active PC. CF-Pollable STAs and the PC do not use RTS/CTS in the CFP. When polled by the PC, a CF-Pollable STA may transmit only one MPDU, which can be to any destination (not just to the PC), and may “piggyback” the acknowledgment of a frame received from the PC using particular data frame subtypes for this transmission. If the data frame is not in turn acknowledged, the CF-Pollable STA shall not retransmit the frame unless it is polled again by the PC, or it decides to retransmit during the CP. If the addressed recipient of a CF transmission is not CF-Pollable, that STA acknowledges the transmission using the DCF acknowledgment rules, and the PC retains control of the medium. A PC may use contention-free frame transfer solely for delivery of frames to STAs, and never to poll non-CF-Pollable STAs.

A PC may perform a backoff on retransmission of an unacknowledged frame during the CFP. A PC that is maintaining a polling list may retry the unacknowledged frame the next time the particular AID is at the top of the polling list.

A PC may retransmit an unacknowledged frame during the CFP after a PIFS time.

When more than one point-coordinated BSS is operating on the same PHY channel in overlapping space, the potential exists for collisions between PCF transfer activities by the independent PCs. The rules under which multiple, overlapping point-coordinated BSSs may coexist are presented in 9.3.3.2. As shown in Figure 47, the PCF is built on top of the CSMA/CA-based DCF, by utilizing the access priority provisions provided by this scheme. An active PC shall be located at an AP, which restricts PCF operation to infrastructure networks. PCF is activated at a PC-capable AP by setting the CFPMaDuration parameter in the CF Parameter Set of the MLMEStart.request to a non-zero value.

Data frames sent during under the DCF shall use the data subtypes Data or Null Function. Data frames sent by, or in response to polling by, the PC during the CFP shall use the appropriate data subtypes based upon the following usage rules:

- Data+CF-Poll, Data+CF-Ack+CF-Poll, CF-Poll, and CF-Ack+CF-Poll shall only be sent by a PC.
- Data, Data+CF-Ack, Null Function, and CF-Ack may be sent by a PC or by any CF-Pollable STA.

STAs receiving Data type frames shall only consider the frame body as the basis of a possible indication to LLC, if the frame is of subtype Data, Data+CF-Ack, Data+CF-Poll, or Data+CF-Ack+CF-Poll. CF-Pollable STAs shall interpret all subtype bits of received Data type frames for CF purposes, but shall only inspect the frame body if the frame is of subtype Data, Data+CF-Ack, Data+CF-Poll, or Data+CF-Ack+CF-Poll.

9.3.1 CFP structure and timing

The PCF controls frame transfers during a CFP. The CFP shall alternate with a CP, when the DCF controls frame transfers, as shown in Figure 59. Each CFP shall begin with a Beacon frame that contains a DTIM element (hereafter referred to as a "DTIM"). The CFPs shall occur at a defined repetition rate, which shall be synchronized with the beacon interval as specified in the following paragraphs.

The PC generates CFPs at the *contention-free repetition rate* (CFPRate), which is defined as a number of DTIM intervals. The PC shall determine the CFPRate (depicted as a repetition interval in the illustrations in Figure 59 and Figure 60) to use from the CFPRate parameter in the CF Parameter Set. This value, in units of DTIM intervals, shall be communicated to other STAs in the BSS in the CFPeriod field of the CF Parameter Set element of Beacon frames. The CF Parameter Set element shall only be present in Beacon and Probe Response frames transmitted by STAs containing an active PC.

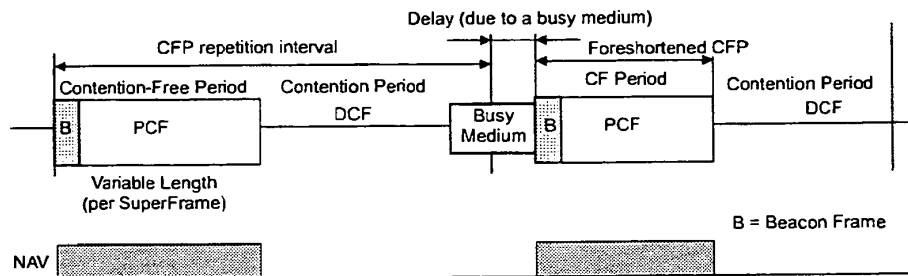


Figure 59—CFP/CP alternation

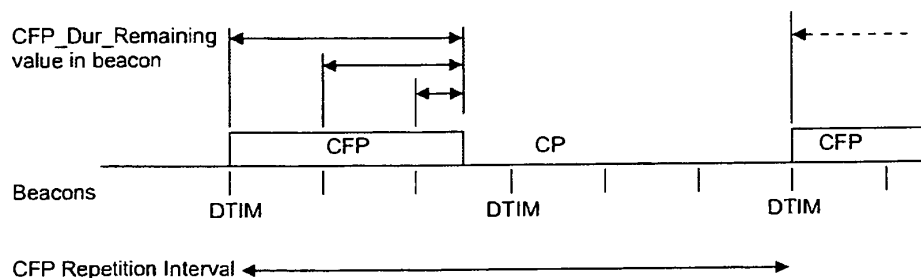


Figure 60—Beacons and CFPs

The length of the CFP is controlled by the PC, with maximum duration specified by the value of the CFP-MaxDuration Parameter in the CF Parameter Set at the PC. Neither the maximum duration nor the actual duration (signaled by transmission of a Control frame of subtype CF-End or CF-End+ACK by the PC) is

constrained to be a multiple of the beacon interval. If the CFP duration is greater than the beacon interval, the PC shall transmit beacons at the appropriate times during the CFP (subject to delay due to traffic at the nominal times, as with all beacons). The CF Parameter Set element in all beacons at the start of, or within, a CFP shall contain a nonzero value in the CFPDurRemaining field. This value, in units of TU, shall specify the maximum time from the transmission of this beacon to the end of this CFP. The value of the CFPDurRemaining field shall be zero in beacons sent during the CP. An example of these relationships is illustrated in Figure 60, which shows a case where the CFP is two DTIM intervals, the DTIM interval is three beacon intervals, and the aCFPMaxDuration value is approximately 2.5 beacon intervals.

The PC may terminate any CFP at or before the aCFPMaxDuration, based on available traffic and size of the polling list. Because the transmission of any beacon may be delayed due to a medium busy condition at the nominal beacon transmission time, a CFP may be foreshortened by the amount of the delay. In the case of a busy medium due to DCF traffic, the beacon shall be delayed for the time required to complete the current DCF frame exchange. In cases where the beacon transmission is delayed, the CFPDurRemaining value in the beacon at the beginning of the CFP shall specify a time that causes the CFP to end no later than TBTT plus the value of aCFPMaxDuration. This is illustrated in Figure 61.

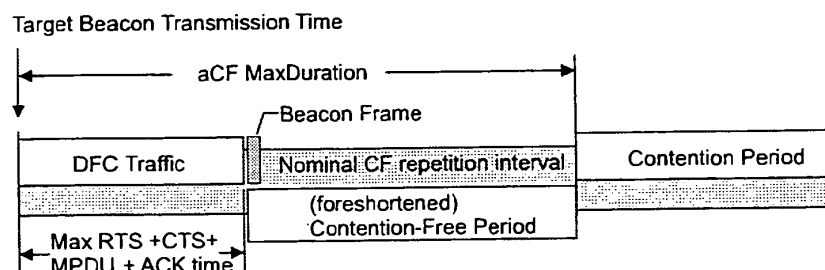


Figure 61—Example of delayed beacon and foreshortened CFP

9.3.2 PCF access procedure

The contention-free transfer protocol is based on a polling scheme controlled by a PC operating at the AP of the BSS. The PC gains control of the medium at the beginning of the CFP and attempts to maintain control for the entire CFP by waiting a shorter time between transmissions than the STAs using the DCF access procedure. All STAs in the BSS (other than the PC) set their NAVs to the CFPMaxDuration value at the nominal start time of each CFP. This prevents most contention by preventing non-pollled transmissions by STAs whether or not they are CF-Pollable. Acknowledgment of frames sent during the CFP may be accomplished using Data+CF-ACK, CF-ACK, Data+CF-ACK+CF-Poll (only on frames transmitted by the PC), or CF-ACK+CF-Poll (only on frames transmitted by the PC) frames in cases where a Data (or Null) frame immediately follows the frame being acknowledged, thereby avoiding the overhead of separate ACK Control frames. Non-CF-Pollable or unpollled CF-Pollable STAs acknowledge frames during the CFP using the DCF ACK procedure.

9.3.2.1 Fundamental access

At the nominal beginning of each CFP, the PC shall sense the medium. When the medium is determined to be idle for one PIFS period, the PC shall transmit a Beacon frame containing the CF Parameter Set element and a DTIM element.

After the initial beacon frame, the PC shall wait for at least one SIFS period, and then transmit one of the following: a data frame, a CF-Poll frame, a Data+CF-Poll frame, or a CF-End frame. If the CFP is null, i.e.,

there is no traffic buffered and no polls to send at the PC, a CF-End frame shall be transmitted immediately after the initial beacon.

STAs receiving directed, error-free frames from the PC are expected to respond after a SIFS period, in accordance with the transfer procedures defined in 9.3.3. If the recipient STA is not CF-Pollable, the response to receipt of an error-free data frame shall always be an ACK frame.

9.3.2.2 NAV operation during the CFP

The mechanism for handling the NAV during the CFP is designed to facilitate the operation of overlapping CFP coordinated infrastructure BSSs. The mechanism by which infrastructure BSSs coordinate their CFPs is beyond the scope of this standard.

Each STA, except the STA with the PC, shall preset its NAV to the CFPMaxDuration value (obtained from the CF Parameter Set element in beacons from this PC) at each target beacon transmission time (TBTT) (see Clause 11) at which a CFP is scheduled to start (based on the CFPPeriod field in the CF Parameter Set element of the Beacon frames from this PC). Each non-PC STA shall update its NAV using the CFPDurRemaining value in any error-free CF Parameter Set element of the Beacon frame that the STA receives. This includes CFPDurRemaining values in CF Parameter Set elements from Beacon frames received from other (overlapping) BSSs.

These actions prevent STAs from taking control of the medium during the CFP, which is especially important in cases where the CFP spans multiple medium-occupancy intervals, such as dwell periods of an FH PHY. This setting of the NAV also reduces the risk of hidden STAs determining the medium to be idle for a DIFS period during the CFP and possibly corrupting a transmission in progress.

A STA joining a BSS operating with a PC shall use the information in the CFPDurRemaining element of the CF parameter set of any received Beacon or Probe Response frames to update its NAV prior to initiating any transmissions.

The PC shall transmit a CF-End or CF-End+ACK frame at the end of each CFP. A STA that receives either of these frames, from any BSS, shall reset its NAV.

9.3.3 PCF transfer procedure

Frame transfers under the PCF typically consist of frames alternately sent from the AP/PC and sent to the AP/PC. During the CFP, the ordering of these transmissions, and the STA allowed to transmit frames to the PC at any given point in time, shall be controlled by the PC. Figure 62 depicts a frame transfer during a typical CFP. The rules under which this frame transfer takes place are detailed in the following subclauses.

In a STA having an FH PHY, control of the channel is lost at a dwell time boundary. It is required that the current MPDU transmission and the accompanying acknowledgment of the MPDU be transmitted before the dwell time boundary. After having been polled by the PC, if there is not enough time remaining in the dwell to allow transmission of the MPDU plus the acknowledgment, the STA shall defer the transmission of the MPDU and shall transmit a Null frame or CF-ACK frame. The short retry counter and long retry counter for the MSDU shall not be affected.

MaxMPDUTime is the time to transmit the maximum-sized MAC frame, expanded by WEP, plus the time to transmit the PHY preamble, header, trailer, and expansion bits, if any. In a STA having an FH PHY, the PC shall not transmit a CF-Poll to a STA if there is insufficient time remaining before the dwell boundary for the STA to respond with a Null frame or CF-ACK frame.

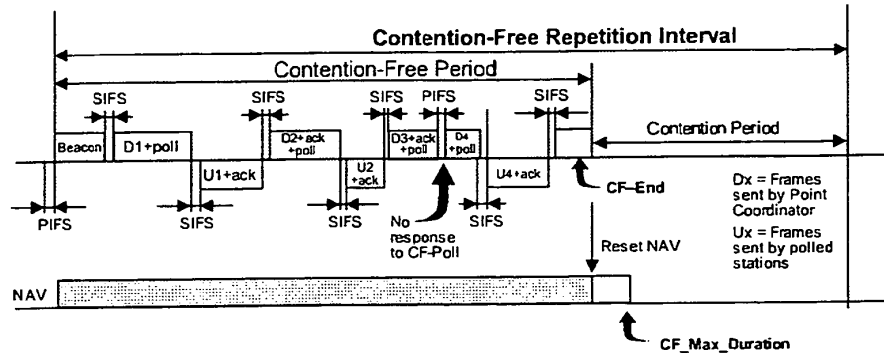


Figure 62—Example of PCF frame transfer

9.3.3.1 PCF transfers when the PCF STA is transmitter or recipient

The PC shall transmit frames between the Beacon that starts the CFP and the CF-End using the SIFS except in cases where a transmission by another STA is expected by the PC and a SIFS period elapses without the receipt of the expected transmission. In such cases the PC may send its next pending transmission as soon as one PIFS after the end of its last transmission. This permits the PC to retain control of the medium in the presence of an overlapping BSS. The PC may transmit any of the following frame types to CF-Pollable STAs:

- Data, used to send data from the PC when the addressed recipient is not being polled and there is no previous frame to acknowledge;
- Data+CF-ACK, used to send data from the PC when the addressed recipient is not being polled and the PC needs to acknowledge the receipt of a frame received from a CF-Pollable STA a SIFS period before starting this transmission;
- Data+CF-Poll, used to send data from the PC when the addressed recipient is the next STA to be permitted to transmit during this CFP and there is no previous frame to acknowledge;
- Data+CF-ACK+CF-Poll, used to send data from the PC when the addressed recipient is the next STA to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame received from a CF-Pollable STA a SIFS period before starting this transmission;
- CF-Poll, used when the PC is not sending data to the addressed recipient, but the addressed recipient is the next STA to be permitted to transmit during this CFP and there is no previous frame to acknowledge;
- CF-ACK+CF-Poll, used when the PC is not sending data to the addressed recipient but the addressed recipient is the next STA to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame from a CF-Pollable STA a SIFS period before starting this transmission;
- CF-ACK, used when the PC is not sending data to, or polling, the addressed recipient, but the PC needs to acknowledge receipt of a frame from a CF-Pollable STA a SIFS period before starting this transmission (useful when the next transmission by the PC is a management frame, such as a beacon); or
- Any management frame that is appropriate for the AP to send under the rules for that frame type.

The PC may transmit data or management frames to non-CF-Pollable, non-power-save STAs during the CFP. These STAs shall acknowledge receipt with ACK frames after a SIFS, as with the DCF. The PC may also transmit broadcast or multicast frames during the CFP. Because the Beacon frame that initiates the CFP

contains a DTIM element, if there are associated STAs using power-save mode, the broadcasts and multicasts buffered shall be sent immediately after any beacon containing a TIM element with a DTIM count field with a value of 0.

A CF-Pollable STA that receives a directed data frame of any subtype that includes CF-Poll may transmit one data frame a SIFS period after receiving the CF-Poll. CF-Pollable STAs shall ignore, but not reset, their NAV when performing transmissions in response to a CF-Poll.

Non-CF-Pollable STAs that receive a directed frame during the CFP shall transmit an ACK, but shall not reset their NAV.

For frames that require MAC-level acknowledgment, CF-Pollable STAs that received a CF-Poll (of any type) may perform this acknowledgment using the Data+CF-ACK subtype in the response to the CF-Poll. For example, the U1 frame in Figure 62 contains the acknowledgment to the preceding D1 frame. The D2 frame contains the acknowledgment to the preceding U1 frame. The PC may use the CF-ACK subtypes to acknowledge a received frame even if the data frame sent with the CF-ACK subtype is addressed to a different STA than the one being acknowledged. CF-Pollable STAs that are expecting an acknowledgment shall interpret the subtype of the frame (if any) sent by the PC a SIFS period after that STA's transmission to the PC. If a frame that requires MAC-level acknowledgment is received by a non-CF-Pollable STA, that STA shall not interpret the CF-Poll indication (if any), and shall acknowledge the frame by sending an ACK Control frame after a SIFS period.

The lengths of the frames may be variable, only bounded by the frame and/or fragment length limitations that apply for the BSS. If a CF-Pollable STA does not respond to a CF-Poll (of any type) within the SIFS period following a transmission from the PC, or a non-CF-Pollable STA does not return the ACK frame within a SIFS period following a transmission from the PC that requires acknowledgment, then the PC shall resume control and may transmit its next frame after a PIFS period from the end of the PC's last transmission.

A CF-Pollable STA shall always respond to a CF-Poll directed to its MAC address and received without error. If the STA has no frame to send when polled, the response shall be a Null frame. If the STA has no frame to send when polled, but an acknowledgment is required for the frame that conveyed the CF-Poll, the response shall be a CF-ACK (no data) frame. The null response is required to permit a "no-traffic" situation to be distinguished from a collision between overlapping PCs.

The CFP shall end when the CFP_{DurRemaining} time has elapsed since the Beacon frame originating the CFP or when the PC has no further frames to transmit nor STAs to poll. In either case, the end of the CFP shall be signaled by the transmission of a CF-End by the PC. If there is a received frame that requires acknowledgment at the time the CF-End is to be transmitted, the PC shall transmit a CF-End+ACK frame instead. All STAs of the BSS receiving a CF-End or CF-End+ACK shall reset their NAVs so they may attempt to transmit during the CP.

9.3.3.2 Operation with overlapping point-coordinated BSSs

Because the PCF operates without the CSMA/CA contention window randomization and backoff of the DCF, there is a risk of repeated collisions if multiple, overlapping, point-coordinated BSSs are operating on the same PHY channel, and their CFP Rates and beacon intervals are approximately equal. To minimize the risk of significant frame loss due to CF collisions, the PC shall use a DIFS plus a random backoff delay (with CW in the range of 1 to aCW_{min}) to start a CFP when the initial beacon is delayed because of deferral due to a busy medium. The PC may optionally use this backoff during the CFP prior to retransmitting an unacknowledged, directed data or management frame.

To further reduce the susceptibility to inter-PC collisions, the PC shall require that the medium be determined as being idle for a DIFS period plus a random (over a range of 1 to aCW_{min}) number of slot times once every aMediumOccupancyLimit TU during the CFP. This results in loss of control of the medium to

overlapping BSS or hidden STA traffic, because the STAs in this BSS are prevented from transmitting by their NAV setting to $CFP_{MaxDuration}$ or $CFP_{DurRemaining}$. For operation of the PCF in conjunction with an FH PHY, $aMediumOccupancyLimit$ shall be set equal to the dwell time. For operation in conjunction with other PHY types, $aMediumOccupancyLimit$ may be set equal to $CFP_{MaxDuration}$, unless extra protection against PCF collisions is desired. The $aMediumOccupancyLimit$ is also useful for compliance in regulatory domains that impose limits on continuous transmission time by a single STA as part of a spectrum etiquette.

9.3.3.3 $CFP_{MaxDuration}$ limit

The value of $CFP_{MaxDuration}$ shall be limited to allow coexistence between contention and contention-free traffic.

The minimum value for $CFP_{MaxDuration}$ is two times $MaxMPDUTime$ plus the time required to send the initial Beacon frame and the CF-End frame of the CFP. This may allow sufficient time for the AP to send one data frame to a STA, while polling that STA, and for the polled STA to respond with one data frame.

The maximum value for $CFP_{MaxDuration}$ is the duration of $(BeaconPeriod \times DTIMPeriod \times CFP_{Rate})$ minus $[MaxMPDUTime + (2 \times aSIFSTime) + (2 \times aSlotTime) + (8 \times ACKSize)]$, expressed in microseconds, when operating with a contention window of $aCWmin$. $MaxMPDUTime$ is the time to transmit the maximum-sized MAC frame, expanded by WEP, plus the time to transmit the PHY preamble, header, trailer, and expansion bits, if any. This allows sufficient time to send at least one data frame during the CP.

9.3.3.4 Contention-Free usage rules

A PC may send broadcast or multicast frames, and directed data or management frames to any active STA, as well as to CF-Pollable power save STAs. During the CFP, CF-Pollable STAs shall acknowledge after a SIFS period, the receipt of each Data+CF-Poll frame or Data+CF-ACK+CF-Poll frame using Data+CF-Ack or CF-Ack (no data) frames, the receipt of each CF-Poll (no data) using Data or Null (no data), and the receipt of all other data and management frames using ACK Control frames. Non-CF-Pollable STAs shall acknowledge receipt of data and management frames using ACK Control frames sent after a SIFS period. This non-CF-Pollable operation is the same as that already employed by such STAs for DCF operation.

When polled by the PCF (Data+CF-Poll, Data+CF-ACK+CF-Poll, CF-Poll, or CF-ACK+CF-Poll) a CF-Pollable STA may send one data frame to any destination. Such a frame directed to or through the PC STA shall be acknowledged by the PC, using the CF-ACK indication (Data+CF-ACK, Data+CF-ACK+CF-Poll, CF-ACK, CF-ACK+CF-Poll, or CF-End+ACK) sent after a SIFS. Such a frame directed to a non-CF-Pollable STA shall be acknowledged using an ACK Control frame sent after a SIFS period. A polled CF-Pollable STA with neither a data frame nor an acknowledgment to send shall respond by transmitting a Null frame after a SIFS period. A polled CF-Pollable STA with insufficient time before the end of the CFP or current medium occupancy limit, to send its queued MPDU and receive an acknowledgment, shall respond by transmitting a Null frame, or a CF-ACK frame if polled using Data+CF-Poll or Data+CF-ACK+CF-Poll, after a SIFS period. The CF-Pollable STA may set the More Data bit in its response to permit the PC to distinguish between an empty STA queue and a response due to insufficient time to transfer an MPDU.

The PC shall not issue frames with a subtype that includes CF-Polls if insufficient time remains in the current CFP to permit the polled STA to transmit a data frame containing a minimum length MPDU.

9.3.4 Contention-Free polling list

If the PC supports use of the CFP for inbound frame transfer as well as for frame delivery, the PC shall maintain a "polling list" for use in selecting STAs that are eligible to receive CF-Polls during CFPs. The polling list functional characteristics are defined below. If the PC supports the use of the CFP solely for frame delivery, the PC does not require a polling list, and shall never generate data frames with a subtype that includes

CF-Poll. The form of contention-free support provided by the PC is identified in the Capability Information field of Beacon, Association Response, Reassociation Response, and Probe Response management frames, which are sent from APs. Any such frames sent by STAs, as in noninfrastructure networks, shall always have these bits set to zero.

The polling list is used to force the polling of CF-Pollable STAs, whether or not the PC has pending traffic to transmit to those STAs. The polling list may be used to control the use of Data+CF-Poll and Data+CF-ACK+CF-Poll types for transmission of data frames being sent to CF-Pollable STAs by the PC. The polling list is a *logical* construct, which is not exposed outside of the PC. A minimum set of polling list maintenance techniques are required to ensure interoperability of arbitrary CF-Pollable STAs in BSSs controlled by arbitrary access points with active PCs. APs may also implement additional polling list maintenance techniques that are outside the scope of this standard.

9.3.4.1 Polling list processing

The PC shall send a CF-Poll to at least one STA during each CFP when there are entries in the polling list. During each CFP, the PC shall issue polls to a subset of the STAs on the polling list in order by ascending AID value.

While time remains in the CFP, all CF frames have been delivered, and all STAs on the polling list have been polled, the PC may generate one or more CF-Polls to *any* STAs on the polling list. While time remains in the CFP, all CF frames have been delivered, and all STAs on the polling list have been polled, the PC *may* send data or management frames to *any* STAs.

In order to gain maximum efficiency from the CFP, and the ability to piggyback acknowledgments on successor data frames in the opposite direction, the PC should generally use Data+CF-Poll and Data+CF-ACK+CF-Poll types for each data frame transmitted while sufficient time for the potential response to the CF-Poll remains in the CFP.

9.3.4.2 Polling list update procedure

A STA indicates its CF-Pollability using the CF-Pollable subfield of the Capability Information field of Association Request and Reassociation Request frames. If a STA desires to change the PC's record of CF-Pollability, that STA shall perform a reassociation. During association, a CF-Pollable STA may also request to be placed on the polling list for the duration of its association, or by setting the CF-Poll Request subfield in the Capability Information field. If a CF-Pollable STA desires never to be placed on the polling list, that STA shall perform Association with both the CF-Pollable subfield false and the CF-Poll Request subfield true. Never being polled is useful for CF-Pollable STAs that normally use power-save mode, permitting them to receive buffered traffic during the CFP (since they have to be awake to receive the DTIM that initiated the CFP), but not requiring them to stay awake to receive CF-Polls when they have no traffic to send. If a STA desires to be removed from the polling list, that STA shall perform a reassociation.

CF-Pollable STAs that are not on the polling list, but did not request never to be polled during their most recent association, may be dynamically placed on the polling list by the PC to handle bursts of frame transfer activity by that STA.

9.4 Fragmentation

The MAC may fragment and reassemble directed MSDUs or MMPDUs. The fragmentation and defragmentation mechanisms allow for fragment retransmission.

The length of a fragment MPDU shall be an equal number of octets for all fragments except the last, which may be smaller. The length of a fragment MPDU shall always be an even number of octets, except for the

last fragment of an MSDU or MMPDU, which may be either an even or an odd number of octets. The length of a fragment shall never be larger than `aFragmentationThreshold` unless WEP is invoked for the MPDU. If WEP is active for the MPDU, then the MPDU shall be expanded by IV and ICV (see 8.2.5); this may result in a fragment larger than `aFragmentationThreshold`.

When data is to be transmitted, the number of octets in the fragment (before WEP processing) shall be determined by `aFragmentationThreshold` and the number of octets in the MPDU that have yet to be assigned to a fragment at the instant the fragment is constructed for the first time. Once a fragment is transmitted for the first time, its frame body content and length shall be fixed until it is successfully delivered to the immediate receiving STA. A STA shall be capable of receiving fragments of arbitrary length.

If a fragment requires retransmission, its frame body content and length shall remain fixed for the lifetime of the MSDU or MMPDU at that STA. After a fragment is transmitted once, contents and length of that fragment are not allowed to fluctuate to accommodate the dwell time boundaries. Each fragment shall contain a Sequence Control field, which is comprised of a sequence number and fragment number. When a STA is transmitting an MSDU or MMPDU, the sequence number shall remain the same for all fragments of that MSDU or MMPDU. The fragments shall be sent in order of lowest fragment number to highest fragment number, where the fragment number value starts at zero, and increases by one for each successive fragment. The Frame Control field also contains a bit, the More Fragments bit, that is equal to zero to indicate the last (or only) fragment of the MSDU or MMPDU.

The source STA shall maintain a transmit MSDU timer for each MSDU being transmitted. The attribute `aMaxTransmitMSDULifetime` specifies the maximum amount of time allowed to transmit an MSDU. The timer starts on the attempt to transmit the first fragment of the MSDU. If the timer exceeds `aMaxTransmitMSDULifetime`, then all remaining fragments are discarded by the source STA and no attempt is made to complete transmission of the MSDU.

9.5 Defragmentation

Each fragment contains information to allow the complete MSDU or MMPDU to be reassembled from its constituent fragments. The header of each fragment contains the following information that is used by the destination STA to reassemble the MSDU or MMPDU:

- Frame type
- Address of the sender, obtained from the `Address2` field
- Destination address
- *Sequence Control field*: This field allows the destination STA to check that all incoming fragments belong to the same MSDU or MMPDU, and the sequence in which the fragments should be reassembled. The sequence number within the Sequence Control field remains the same for all fragments of an MSDU or MMPDU, while the fragment number within the Sequence Control field increments for each fragment.
- *More Fragments indicator*: Indicates to the destination STA that this is not the last fragment of the MSDU or MMPDU. Only the last or sole fragment of the MSDU or MMPDU shall have this bit set to zero. All other fragments of the MSDU or MMPDU shall have this bit set to one.

The destination STA shall reconstruct the MSDU or MMPDU by combining the fragments in order of fragment number subfield of the Sequence Control field. If WEP has been applied to the fragment, it shall be decrypted before the fragment is used for defragmentation of the MSDU or MMPDU. If the fragment with the More Fragments bit set to zero has not yet been received, then the destination STA knows that the MSDU or MMPDU is not yet complete. As soon as the STA receives the fragment with the More Fragments bit set to zero, the STA knows that no more fragments may be received for the MSDU or MMPDU.

All STAs shall support the concurrent reception of fragments of at least three MSDUs or MMPDUs. Note that a STA receiving more than three fragmented MSDUs or MMPDUs concurrently may experience a significant increase in the number of frames discarded.

The destination STA shall maintain a Receive Timer for each MSDU or MMPDU being received, for a minimum of three MSDUs or MMPDUs. The STA may implement additional timers to be able to receive additional concurrent MSDUs or MMPDUs. The receiving STA shall discard all fragments that are part of an MSDU or MMPDU for which a timer is not maintained. There is also an attribute, `aMaxReceiveLifetime`, that specifies the maximum amount of time allowed to receive an MSDU. The receive MSDU or MMPDU timer starts on the reception of the first fragment of the MSDU or MMPDU. If the receive MSDU timer exceeds `aMaxReceiveLifetime`, then all received fragments of this MSDU or MMPDU are discarded by the destination STA. If additional fragments of a directed MSDU or MMPDU are received after its `aMaxReceiveLifetime` is exceeded, those fragments shall be acknowledged and discarded.

To properly reassemble MPDUs into an MSDU or MMPDU, a destination STA shall discard any duplicated fragments received. A STA shall discard duplicate fragments as described in 9.2.9. However, an acknowledgment shall be sent in response to a duplicate fragment of a directed MSDU.

9.6 Multirate support

Some PHYs have multiple data transfer rate capabilities that allow implementations to perform dynamic rate switching with the objective of improving performance. The algorithm for performing rate switching is beyond the scope of this standard, but in order to ensure coexistence and interoperability on multirate-capable PHYs, this standard defines a set of rules that shall be followed by all STAs.

All Control frames shall be transmitted at one of the rates in the `BSSBasicRateSet` (see 10.3.10.1), or at one of the rates in the PHY mandatory rate set so they will be understood by all STAs.

All frames with multicast and broadcast RA shall be transmitted at one of the rates included in the `BSSBasicRateSet`, regardless of their type.

Data and/or management MPDUs with a unicast immediate address shall be sent on any supported data rate selected by the rate switching mechanism (whose output is an internal MAC variable called `MACCurrentRate`, defined in units of 500 kbit/s, which is used for calculating the Duration/ID field of each frame). A STA shall not transmit at a rate that is known not to be supported by the destination STA, as reported in the supported rates element in the management frames. For frames of type Data+CF-ACK, Data+CF-Poll+CF-ACK, and CF-Poll+CF-ACK, the rate chosen to transmit the frame must be supported by both the addressed recipient STA and the STA to which the ACK is intended.

Under no circumstances shall a STA initiate transmission of a data or management frame at a data rate higher than the greatest rate in the `OperationalRateSet`, a parameter of the `MLME-JOIN.request` primitive.

In order to allow the transmitting STA to calculate the contents of the Duration/ID field, the responding STA shall transmit its Control Response frame (either CTS or ACK) at the same rate as the immediately previous frame in the frame exchange sequence (as defined in 9.7), if this rate belongs to the PHY mandatory rates, or else at the highest possible rate belonging to the PHY rates in the `BSSBasicRateSet`.

9.7 Frame exchange sequences

The allowable frame exchange sequences are summarized in Table 21 and Table 22. A legend applicable to both tables follows Table 22.

Table 21—Frame sequences

Sequence	Frames in sequence	Usage
Data(bc/mc)	1	Broadcast or multicast MSDU
Mgmt(bc)	1	Broadcast MMPDU
{RTS – CTS –} {Frag – ACK –} Last – ACK	2	Directed MSDU or MMPDU
PS-Poll – ACK	2	Deferred PS-POLL response
PS-Poll – {Frag – ACK –} Last – ACK	3	Immediate PS-POLL response
DTIM(CF) – [≤CF-Sequence> –] {CF-End}	2 or more	Start of CFP
[<CF-Sequence> –] {CF-End}	2 or more	Continuation of CFP after missing ACK or medium occupancy boundary

Table 22—CF frame sequences

CF frame sequence	Frames in sequence	Usage
Beacon(CF)	1	Beacon during CFP
Data(bc/mc)	1	Broadcast or multicast MSDU
Mgmt(bc)	1 or 2	Broadcast MMPDU
Mgmt(dir) – ACK	2 or 3	Directed MMPDU
Data(dir)+CF-Poll {+CF-Ack} – Data(dir)+CF-Ack – {CF-Ack(no data)}	2	Poll and ACK sent with MPDUs
Data(dir)+CF-Poll {+CF-Ack} – CF-Ack(no data)	2	Poll of STA with empty queue, insufficient time for queued MPDU, or too little time remaining before a dwell or medium occupancy boundary to send a queued frame
CF-Poll(no data) {+CF-Ack} – Data(dir) – {CF-Ack(no data)}	2	Separate poll, ACK sent with MPDU
CF-Poll(no data) {+CF-Ack} – Data(dir) – ACK	3	Polled STA sends to STA in BSS
CF-Poll(no data) {+CF-Ack} – Null(no data)	2	Separate poll, STA queue empty, or insufficient time for queued MPDU or too little time remaining before a dwell or medium occupancy boundary to send a queued frame
Data(dir){+CF-Ack} – ACK	2	ACK if not CF-Pollable or not polled

LEGEND (For Table 21 and Table 22)

1—Items enclosed in brackets “[...]” may occur zero or more times in the sequence.

2—Items enclosed in braces “{...}” may occur zero or one time in the sequence.

3—An isolated hyphen “-” represents a SIFS interval separating the pair of frames.

4—“Data(bc/mc)” represents any frame of type Data with a broadcast or multicast address in the Address1 field.

5—“Mgmt(bc)” represents any Management type frame with a broadcast address in the DA field.

6—“RTS” represents a Control frame of subtype RTS.

7—“CTS” represents a Control frame of subtype CTS.

LEGEND (Continued)

- 8—"ACK" represents a Control frame of subtype ACK.
- 9—"Frag" represents an MPDU of type Data or an MMPDU of type Management with an individual address in the Address1 field that has the More Fragments field set to "1."
- 10—"Last" represents an MPDU of type Data or an MMPDU of type Management with an individual address in the Address1 field that has the More Fragments field set to "0."
- 11—"PS-Poll" represents a Control frame of subtype PS-Poll.
- 12—"DTIM(CF)" represents a management frame of subtype Beacon that contains a DTIM information element with a nonzero value in the CFDurationRemaining field of its Parameter Set element.
- 13—"CF-End" represents a Control frame of type CF-End, or (if the final frame of the immediately preceding <CF-Sequence> was a directed data or management frame requiring acknowledgment by the AP) of type CF-End+Ack.
- 14—"Beacon(CF)" represents a management frame of subtype Beacon with a nonzero value in the CFDurationRemaining field of its CF Parameter Set element.
- 15—"Data(dir)" represents any MPDU of type Data with an individual address in the Address1 field.
- 16—"Mgmt(dir)" represents any MMPDU of type Management with an individual address in the Address1 field.
- 17—"CF-Ack(no data)" represents a data frame of subtype CF-ACK (no data).
- 18—"CF-Poll(no data)" represents a data frame of subtype CF-Poll (no data).
- 19—"Null(no data)" represents a data frame of subtype Null Function (no data).
- 20—" {+CF-Ack} " indicates that the frame may or may not include a contention-free acknowledgment.
- 21—" +CF-Ack " indicates that the frame includes a contention-free acknowledgment.
- 22—" +CF-Poll " indicates that the frame includes a contention-free poll.
- 23—<CF-Sequence> represents a sequence of one or more frames sent during a CFP. A valid <CF-Sequence> shall consist of one of the frame sequences shown in Table 22. The collection of sequences of frame exchanges corresponding to [<CF-Sequence>] may occur in any order within the CFP.

Individual frames within each of these sequences are separated by a SIFS.

9.8 MSDU transmission restrictions

To avoid reordering MSDUs between pairs of LLC entities and/or unnecessarily discarding MSDUs, the following restrictions shall be observed by any STA that is able to concurrently process multiple outstanding MSDUs for transmission. Note that here the term "outstanding" refers to an MSDU or MMPDU that is eligible to be transmitted at a particular time. A STA may have any number (greater than or equal to one) of eligible MSDUs outstanding concurrently, subject to the restrictions below.

The STA shall ensure that no more than one MSDU or MMPDU from a particular SA to a particular individual RA is outstanding at a time. Note that a simpler, more restrictive invariant to maintain is that no more than one MSDU with a particular individual RA may be outstanding at a time.

In a STA where the optional StrictlyOrdered service class has been implemented, that STA shall ensure that there is no group-addressed (multidestination) MSDU of the StrictlyOrdered service class outstanding from the SA of any other outstanding MSDU (either directed or group-addressed). This is because a group-addressed MSDU is implicitly addressed to a collection of peer STAs that could include any individual RA.

It is recommended that the STA select a value of aMaxMSDUTransmitLifetime that is sufficiently large that the STA does not discard MSDUs due to excessive Transmit MSDU timeouts under normal operating conditions.

10. Layer management

10.1 Overview of management model

Both MAC and PHY layers conceptually include management entities, called MAC sublayer management and PHY layer management entities (MLME and PLME, respectively). These entities provide the layer management service interfaces through which layer management functions may be invoked.

In order to provide correct MAC operation, a station management entity (SME) shall be present within each STA. The SME is a layer-independent entity that may be viewed as residing in a separate management plane or as residing "off to the side." The exact functions of the SME are not specified in this standard, but in general this entity may be viewed as being responsible for such functions as the gathering of layer-dependent status from the various layer management entities, and similarly setting the value of layer-specific parameters. SME would typically perform such functions on behalf of general system management entities and would implement standard management protocols. Figure 11 depicts the relationship among management entities.

The various entities within this model interact in various ways. Certain of these interactions are defined explicitly within this standard, via a service access point (SAP) across which defined primitives are exchanged. Other interactions are not defined explicitly within this standard, such as the interfaces between MAC and MLME and between PLCP and PLME, represented as double arrows within Figure 63. The specific manner in which these MAC and PHY management entities are integrated into the overall MAC and PHY layers is not specified within this standard.

The management SAPs within this model are the following:

- SME-MLME SAP
- SME-PLME SAP
- MLME-PLME SAP

The latter two SAPs support identical primitives, and in fact may be viewed as a single SAP (called the PLME SAP) that may be used either directly by MLME or by SME. In this fashion, the model reflects what is anticipated to be a common implementation approach in which PLME functions are controlled by the MLME (on behalf of SME). In particular, PHY implementations are not required to have separate interfaces defined other than their interfaces with the MAC and MLME.

10.2 Generic management primitives

The management information specific to each layer is represented as a management information base (MIB) for that layer. The MAC and PHY layer management entities are viewed as "containing" the MIB for that layer. The generic model of MIB-related management primitives exchanged across the management SAPs is to allow the SAP user-entity to either GET the value of a MIB attribute, or to SET the value of a MIB attribute. The invocation of a SET.request primitive may require that the layer entity perform certain defined actions.

Figure 63 depicts these generic primitives.

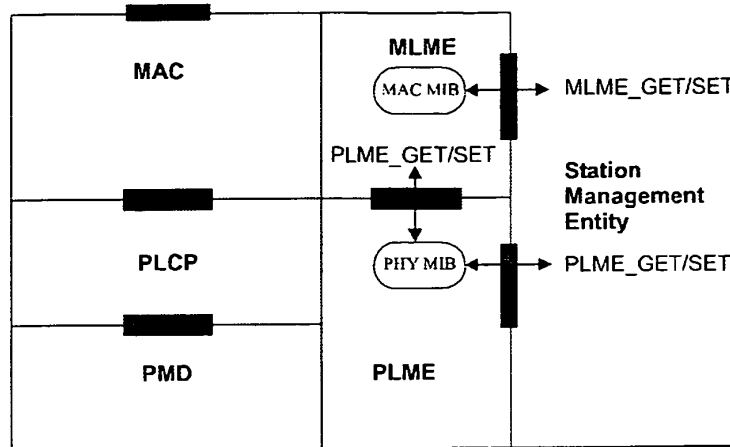


Figure 63—GET and SET operations

The GET and SET primitives are represented as REQUESTs with associated CONFIRM primitives. These primitives are prefixed by MLME or PLME depending upon whether the MAC or PHY layer management SAP is involved. In the following, XX denotes MLME or PLME:

XX-GET.request (MIBattribute)

Requests the value of the given MIBattribute.

XX-GET.confirm (status, MIBattribute, MIBattributevalue)

Returns the appropriate MIB attribute value if status = "success," otherwise returns an error indication in the Status field. Possible error status values include "invalid MIB attribute" and "attempt to get write-only MIB attribute."

XX-SET.request (MIBattribute, MIBattributevalue)

Requests that the indicated MIB attribute be set to the given value. If this MIBattribute implies a specific action, then this requests that the action be performed.

XX-SET.confirm (status, MIBattribute)

If status = "success," this confirms that the indicated MIB attribute was set to the requested value, otherwise it returns an error condition in status field. If this MIBattribute implies a specific action, then this confirms that the action was performed. Possible error status values include "invalid MIB attribute" and "attempt to set read-only MIB attribute."

Additionally, there are certain requests (with associated confirms) that may be invoked across a given SAP that do not involve the setting or getting of a specific MIB attribute. One of these is supported by each SAP, as follows:

- XX-RESET.request: where XX is MLME or PLME as appropriate
- XX-RESET.confirm

This service is used to initialize the management entities, the MIBs, and the datapath entities. It may include a list of attributes for items to be initialized to non-default values. The corresponding .confirm indicates success or failure of the request.

Other SAP-specific primitives are identified in 10.3.

10.3 MLME SAP interface

The services provided by the MLME to the SME are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface. MLME SAP primitives are of the general form ACTION.request followed by ACTION.confirm. The SME uses the services provided by the MLME through the MLME SAP.

10.3.1 Power management

This mechanism supports the process of establishment and maintenance of the power management mode of a STA.

10.3.1.1 MLME-POWERMGT.request

10.3.1.1.1 Function

This primitive requests a change in the power management mode.

10.3.1.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-POWERMGT.request    (
                           PowerManagementMode,
                           WakeUp,
                           ReceiveDTIMs
                           )
```

Name	Type	Valid range	Description
PowerManagementMode	Enumeration	ACTIVE, POWER_SAVE	An enumerated type that describes the desired power management mode of the STA.
WakeUp	Boolean	True, false	When true, the MAC is forced immediately into the Awake state. This parameter has no effect if the current power management mode is ACTIVE.
ReceiveDTIMs	Boolean	True, false	When true, this parameter causes the STA to awaken to receive all DTIM frames. When false, the STA is not required to awaken for every DTIM frame.

10.3.1.1.3 When generated

This primitive is generated by the SME to implement the power-saving strategy of an implementation.

10.3.1.1.4 Effect of receipt

This request sets the STA's power management parameters. The MLME subsequently issues a MLME-POWERMGT.confirm that reflects the results of the power management change request.

10.3.1.2 MLME-POWERMGT.confirm

10.3.1.2.1 Function

This primitive confirms the change in power management mode.

10.3.1.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```

MLME-POWERMGT.confirm    (
                           ResultCode
                           )
    
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-POWERMGT.request

10.3.1.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-POWERMGT.request to establish a new power management mode. It is not generated until the change has completed.

10.3.1.2.4 Effect of receipt

The SME is notified of the change of power management mode.

10.3.2 Scan

This mechanism supports the process of determining the characteristics of the available BSSs.

10.3.2.1 MLME-SCAN.request

10.3.2.1.1 Function

This primitive requests a survey of potential BSSs that the STA may later elect to try to join.

10.3.2.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```

MLME-SCAN.request        (
                           BSSType,
                           BSSID,
                           SSID,
                           ScanType,
                           ProbeDelay,
                           ChannelList,
                           MinChannelTime,
                           MaxChannelTime
                           )
    
```


Name	Type	Valid range	Description
BSSType	Enumeration	INFRASTRUCTURE, INDEPENDENT, ANY_BSS	Determines whether Infrastructure BSS, Independent BSS, or both, are included in the scan
BSSID	MACAddress	Any valid individual or broadcast MAC address	Identifies a specific or broadcast BSSID
SSID	Octet string	0–32 octets	Specifies the desired SSID or the broadcast SSID
ScanType	Enumeration	ACTIVE, PASSIVE	Indicates either active or passive scanning
ProbeDelay	Integer	N/A	Delay (in μ s) to be used prior to transmitting a Probe frame during active scanning
ChannelList	Ordered set of integers	Each channel will be selected from the valid channel range for the appropriate PHY and carrier set.	Specifies a list of channels that are examined when scanning for a BSS
MinChannelTime	Integer	$\geq$ ProbeDelay	The minimum time (in TU) to spend on each channel when scanning
MaxChannelTime	Integer	$\geq$ MinChannelTime	The maximum time (in TU) to spend on each channel when scanning

10.3.2.1.3 When generated

This primitive is generated by the SME for a STA to determine if there are other BSSs that it may join.

10.3.2.1.4 Effect of receipt

This request initiates the scan process when the current frame exchange sequence is completed.

10.3.2.2 MLME-SCAN.confirm

10.3.2.2.1 Function

This primitive returns the descriptions of the set of BSSs detected by the scan process.

10.3.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```

MLME-SCAN.confirm      (
                        BSSDescriptionSet,
                        ResultCode
                        )

```

Name	Type	Valid range	Description
BSSDescriptionSet	Set of BSSDescriptions	N/A	The BSSDescriptionSet is returned to indicate the results of the scan request. It is a set containing zero or more instances of a BSSDescription.
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS	Indicates the result of the MLME-SCAN.confirm

Each BSSDescription consists of the following elements:

Name	Type	Valid range	Description
BSSID	MACAddress	N/A	The BSSID of the found BSS
SSID	Octet string	1–32 octets	The SSID of the found BSS
BSSType	Enumeration	INFRASTRUCTURE, INDEPENDENT	The type of the found BSS
Beacon Period	Integer	N/A	The Beacon period of the found BSS (in TU)
DTIM Period	Integer	As defined in frame format	The DTIM period of the BSS (in beacon periods)
Timestamp	Integer	N/A	The timestamp of the received frame (probe response/beacon) from the found BSS
Local Time	Integer	N/A	The value of the STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame (probe response or beacon) from the found BSS
PHY parameter set	As defined in frame format	As defined in frame format	The parameter set relevant to the PHY
CF parameter set	As defined in frame format	As defined in frame format	The parameter set for the CF periods, if found BSS supports CF mode
IBSS parameter set	As defined in frame format	As defined in frame format	The parameter set for the IBSS, if found BSS is an IBSS
CapabilityInformation	As defined in frame format	As defined in frame format	The advertised capabilities of the BSS
BSSBasicRateSet	Set of integers	2–127 inclusive (for each integer in the set)	The set of data rates (in units of 500 kb/s) that must be supported by all STAs that desire to join this BSS. The STAs must be able to receive at each of the data rates listed in the set.

10.3.2.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-SCAN.request to ascertain the operating environment of the STA.

10.3.2.2.4 Effect of receipt

The SME is notified of the results of the scan procedure.

10.3.3 Synchronization

This mechanism supports the process of selection of a peer in the authentication process.

10.3.3.1 MLME-JOIN.request

10.3.3.1.1 Function

This primitive requests synchronization with a BSS.

10.3.3.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-JOIN.request      (
                        BSSDescription,
                        JoinFailureTimeout,
                        ProbeDelay,
                        OperationalRateSet
                        )
```

Name	Type	Valid range	Description
BSSDescription	BSSDescription	N/A	The BSSDescription of the BSS to join. The BSSDescription is a member of the set of descriptions that was returned as a result of a MLME-SCAN.request.
JoinFailureTimeout	Integer	≥ 1	The time limit, in units of beacon intervals, after which the join procedure will be terminated
ProbeDelay	Integer	N/A	Delay (in μ s) to be used prior to transmitting a Probe frame during active scanning
OperationalRateSet	Set of integers	2–127 inclusive (for each integer in the set)	The set of data rates (in units of 500 kbit/s) that the STA may use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. The OperationalRateSet is a superset of the BSSBasicRateSet advertised by the BSS.

10.3.3.1.3 When generated

This primitive is generated by the SME for a STA to establish synchronization with a BSS.

10.3.3.1.4 Effect of receipt

This primitive initiates a synchronization procedure once the current frame exchange sequence is complete. The MLME synchronizes its timing with the specified BSS based on the elements provided in the BSSDescription parameter. The MLME subsequently issues a MLME-JOIN.confirm that reflects the results.

10.3.3.2 MLME-JOIN.confirm

10.3.3.2.1 Function

This primitive confirms synchronization with a BSS.

10.3.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-JOIN.confirm      (
                        ResultCode
                        )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TIMEOUT	Indicates the result of the MLME-JOIN.request

10.3.3.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-JOIN.request to establish synchronization with a BSS.

10.3.3.2.4 Effect of receipt

The SME is notified of the results of the synchronization procedure.

10.3.4 Authenticate

This mechanism supports the process of establishing an authentication relationship with a peer MAC entity.

10.3.4.1 MLME-AUTHENTICATE.request

10.3.4.1.1 Function

This primitive requests authentication with a specified peer MAC entity.

10.3.4.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.request (
    PeerSTAAddress,
    AuthenticationType,
    AuthenticateFailureTimeout
)
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the authentication process
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm to use during the authentication process
AuthenticateFailureTimeout	Integer	≥1	Specifies a time limit (in TU) after which the authentication procedure will be terminated

10.3.4.1.3 When generated

This primitive is generated by the SME for a STA to establish authentication with a specified peer MAC entity in order to permit Class 2 frames to be exchanged between the two STAs. During the authentication procedure, the SME may generate additional MLME-AUTHENTICATE.request primitives.

10.3.4.1.4 Effect of receipt

This primitive initiates an authentication procedure. The MLME subsequently issues a MLME-AUTHENTICATE.confirm that reflects the results.

10.3.4.2 MLME-AUTHENTICATE.confirm

10.3.4.2.1 Function

This primitive reports the results of an authentication attempt with a specified peer MAC entity.

10.3.4.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.confirm (
    PeerSTAAAddress,
    AuthenticationType,
    ResultCode
)
```

Name	Type	Valid range	Description
PeerSTAAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication process was attempted. This value must match the peer-STAAAddress parameter specified in the corresponding MLME-AUTHENTICATE.request.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm that was used during the authentication process. This value must match the authenticationType parameter specified in the corresponding MLME-AUTHENTICATE.request.
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TIMEOUT, TOO_MANY_SIMULTANEOUS_REQUESTS, REFUSED	Indicates the result of the MLME-AUTHENTICATE.request.

10.3.4.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-AUTHENTICATE.request to authenticate with a specified peer MAC entity.

10.3.4.2.4 Effect of receipt

The SME is notified of the results of the authentication procedure.

10.3.4.3 MLME-AUTHENTICATE.indication

10.3.4.3.1 Function

This primitive reports the establishment of an authentication relationship with a specific peer MAC entity.

10.3.4.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.indication (
    PeerSTAAAddress,
    AuthenticationType
)
```

Name	Type	Valid range	Description
PeerSTAAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was established
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm that was used during the authentication process

10.3.4.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of an authentication relationship with a specific peer MAC entity that resulted from an authentication procedure that was initiated by that specific peer MAC entity.

10.3.4.3.4 Effect of receipt

The SME is notified of the establishment of the authentication relationship.

10.3.5 De-authenticate

This mechanism supports the process of invalidating an authentication relationship with a peer MAC entity.

10.3.5.1 MLME-DEAUTHENTICATE.request

10.3.5.1.1 Function

This primitive requests that the authentication relationship with a specified peer MAC entity be invalidated.

10.3.5.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEAUTHENTICATE.request    (
                                PeerSTAAAddress,
                                ReasonCode
                                )
```

Name	Type	Valid range	Description
PeerSTAAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the deauthentication process
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason for initiating the deauthentication procedure

10.3.5.1.3 When generated

This primitive is generated by the SME for a STA to invalidate authentication with a specified peer MAC entity in order to prevent the exchange of Class 2 frames between the two STAs. During the deauthentication procedure, the SME may generate additional MLME-DEAUTHENTICATE.request primitives.

10.3.5.1.4 Effect of receipt

This primitive initiates a deauthentication procedure. The MLME subsequently issues a MLME-DEAUTHENTICATE.confirm that reflects the results.

10.3.5.2 MLME-DEAUTHENTICATE.confirm

10.3.5.2.1 Function

This primitive reports the results of a deauthentication attempt with a specified peer MAC entity.

10.3.5.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.confirm (PeerSTAAddress, ResultCode)

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the deauthentication process was attempted
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TOO_MANY_SIMULTANEOUS_REQUESTS	Indicates the result of the MLME-DEAUTHENTICATE.request

10.3.5.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DEAUTHENTICATE.request to invalidate the authentication relationship with a specified peer MAC entity.

10.3.5.2.4 Effect of receipt

The SME is notified of the results of the deauthentication procedure.

10.3.5.3 MLME-DEAUTHENTICATE.indication

10.3.5.3.1 Function

This primitive reports the invalidation of an authentication relationship with a specific peer MAC entity.

10.3.5.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.indication (PeerSTAAddress, ReasonCode)

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was invalidated
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason the deauthentication procedure was initiated

10.3.5.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an authentication relationship with a specific peer MAC entity.

10.3.5.3.4 Effect of receipt

The SME is notified of the invalidation of the specific authentication relationship.

10.3.6 Associate

The following primitives describe how a STA becomes associated with an access point (AP).

10.3.6.1 MLME-ASSOCIATE.request

10.3.6.1.1 Function

This primitive requests association with a specified peer MAC entity that is acting as an AP.

10.3.6.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.request (
    PeerSTAAddress,
    AssociateFailureTimeout,
    CapabilityInformation,
    ListenInterval
)
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the association process
AssociateFailureTimeout	Integer	≥ 1	Specifies a time limit (in TU) after which the associate procedure will be terminated
CapabilityInformation	As defined in frame format	As defined in frame format	Specifies the operational capability definitions to be used by the MAC entity
ListenInterval	Integer	≥ 0	Specifies the number of beacon intervals that may pass before the STA awakens and listens for the next beacon

10.3.6.1.3 When generated

This primitive is generated by the SME when a STA wishes to establish association with an AP.

10.3.6.1.4 Effect of receipt

This primitive initiates an association procedure. The MLME subsequently issues an MLME-ASSOCIATE.confirm that reflects the results.

10.3.6.2 MLME-ASSOCIATE.confirm

10.3.6.2.1 Function

This primitive reports the results of an association attempt with a specified peer MAC entity that is acting as an AP.

10.3.6.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.confirm    (  
    ResultCode  
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-ASSOCIATE.request

10.3.6.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-ASSOCIATE.request to associate with a specified peer MAC entity that is acting as an AP.

10.3.6.2.4 Effect of receipt

The SME is notified of the results of the association procedure.

10.3.6.3 MLME-ASSOCIATE.indication

10.3.6.3.1 Function

This primitive reports the establishment of an association with a specific peer MAC entity.

10.3.6.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.indication (  
    PeerSTAAddress  
)
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the association was established

10.3.6.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of an association with a specific peer MAC entity that resulted from an association procedure that was initiated by that specific peer MAC entity.

10.3.6.3.4 Effect of receipt

The SME is notified of the establishment of the association.

10.3.7 Reassociate

The following primitives describe how a STA becomes associated with another AP.

10.3.7.1 MLME-REASSOCIATE.request

10.3.7.1.1 Function

This primitive requests a change in association to a specified new peer MAC entity that is acting as an AP.

10.3.7.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.request (
    NewAPAddress,
    ReassociateFailureTimeout,
    CapabilityInformation,
    ListenInterval
)
```

Name	Type	Valid range	Description
NewAPAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the reassociation process
ReassociateFailureTimeout	Integer	≥ 1	Specifies a time limit (in TU) after which the reassociate procedure will be terminated
CapabilityInformation	As defined in frame format	As defined in frame format	Specifies the operational capability definitions to be used by the MAC entity
ListenInterval	Integer	≥ 0	Specifies the number of beacon intervals that may pass before the STA awakens and listens for the next beacon.

10.3.7.1.3 When generated

This primitive is generated by the SME for a STA to change association to a specified new peer MAC entity that is acting as an AP.

10.3.7.1.4 Effect of receipt

This primitive initiates a reassociation procedure. The MLME subsequently issues a MLME-REASSOCIATE.confirm that reflects the results.

10.3.7.2 MLME-REASSOCIATE.confirm

10.3.7.2.1 Function

This primitive reports the results of a reassociation attempt with a specified peer MAC entity that is acting as an AP.

10.3.7.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.confirm  (
    ResultCode
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-REASSOCIATE.request

10.3.7.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-REASSOCIATE.request to reassociate with a specified peer MAC entity that is acting as an AP.

10.3.7.2.4 Effect of receipt

The SME is notified of the results of the reassociation procedure.

10.3.7.3 MLME-REASSOCIATE.indication

10.3.7.3.1 Function

This primitive reports the establishment of a reassociation with a specified peer MAC entity.

10.3.7.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.indication (
    PeerSTAAddress
)
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the reassociation was established

10.3.7.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of a reassociation with a specific peer MAC entity that resulted from a reassociation procedure that was initiated by that specific peer MAC entity.

10.3.7.3.4 Effect of receipt

The SME is notified of the establishment of the reassociation.

10.3.8 Disassociate

10.3.8.1 MLME-DISASSOCIATE.request

10.3.8.1.1 Function

This primitive requests disassociation with a specified peer MAC entity that is acting as an AP.

10.3.8.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.request  (
                              PeerSTAAAddress,
                              ReasonCode
                              )
```

Name	Type	Valid range	Description
PeerSTAAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the disassociation process
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason for initiating the disassociation procedure

10.3.8.1.3 When generated

This primitive is generated by the SME for a STA to establish disassociation with an AP.

10.3.8.1.4 Effect of receipt

This primitive initiates a disassociation procedure. The MLME subsequently issues an MLME-DISASSOCIATE.confirm that reflects the results.

10.3.8.2 MLME-DISASSOCIATE.confirm

10.3.8.2.1 Function

This primitive reports the results of a disassociation procedure with a specific peer MAC entity that is acting as an AP.

10.3.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.confirm  (
                              ResultCode
                              )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-DISASSOCIATE.request

10.3.8.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DISASSOCIATE.request to disassociate with a specified peer MAC entity that is acting as an AP.

10.3.8.2.4 Effect of receipt

The SME is notified of the results of the disassociation procedure.

10.3.8.3 MLME-DISASSOCIATE.indication

10.3.8.3.1 Function

This primitive reports disassociation with a specific peer MAC entity.

10.3.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.indication (
    PeerSTAAddress,
    ReasonCode
)
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the association relationship was invalidated
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason the disassociation procedure was initiated

10.3.8.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an association relationship with a specific peer MAC entity.

10.3.8.3.4 Effect of receipt

The SME is notified of the invalidation of the specific association relationship.

10.3.9 Reset

This mechanism supports the process of resetting the MAC.

10.3.9.1 MLME-RESET.request

10.3.9.1.1 Function

This primitive requests that the MAC entity be reset.

10.3.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESET.request      (
                          STAAddress,
                          SetDefaultMIB
                          )
```

Name	Type	Valid range	Description
STAAddress	MACAddress	Any valid MAC address	Specifies the MAC address that is to be used by the MAC entity that is being reset. This value may be used to provide a locally administered STA address.
SetDefaultMIB	Boolean	True, false	If true, all MIB attributes are set to their default values. The default values are implementation dependent. If false, the MAC is reset, but all MIB attributes retain the values that were in place prior to the generation of the MLME-RESET.request primitive.

10.3.9.1.3 When generated

This primitive is generated by the SME to reset the MAC to initial conditions. The MLME-RESET.request primitive must be used prior to use of the MLME-START.request primitive.

10.3.9.1.4 Effect of receipt

This primitive sets the MAC to initial conditions, clearing all internal variables to the default values. MIB attributes may be reset to their implementation-dependent default values by setting the SetDefaultMIB flag to true. The MLME subsequently issues a MLME-RESET.confirm that reflects the results.

10.3.9.2 MLME-RESET.confirm

10.3.9.2.1 Function

This primitive reports the results of a reset procedure.

10.3.9.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESET.confirm      (
                          ResultCode
                          )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS	Indicates the result of the MLME-RESET.request

10.3.9.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-RESET.request to reset the MAC entity.

10.3.9.2.4 Effect of receipt

The SME is notified of the results of the reset procedure.

10.3.10 Start

This mechanism supports the process of creating a new BSS.

10.3.10.1 MLME-START.request

10.3.10.1.1 Function

This primitive requests that the MAC entity start a new BSS.

10.3.10.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-START.request      (
                          SSID,
                          BSSType,
                          BeaconPeriod,
                          DTIMPeriod,
                          CF parameter set,
                          PHY parameter set,
                          IBSS parameter set,
                          ProbeDelay,
                          CapabilityInformation,
                          BSSBasicRateSet,
                          OperationalRateSet
                          )
```

Name	Type	Valid range	Description
SSID	Octet string	1–32 octets	The SSID of the BSS
BSSType	Enumeration	INFRA- STRUCTURE, INDEPEN- DENT	The type of the BSS
Beacon Period	Integer	≥1	The Beacon period of the BSS (in TU)
DTIM Period	Integer	As defined in frame format	The DTIM Period of the BSS (in beacon periods)
CF parameter set	As defined in frame format	As defined in frame format	The parameter set for CF periods, if the BSS supports CF mode. aCFPPeriod is modified as a side effect of the issuance of an MLME-START.request primitive.
PHY parameter set	As defined in frame format	As defined in frame format	The parameter set relevant to the PHY
IBSS parameter set	As defined in frame format	As defined in frame format	The parameter set for the IBSS, if BSS is an IBSS

Name	Type	Valid range	Description
ProbeDelay	Integer	N/A	Delay (in μ s) to be used prior to transmitting a Probe frame during active scanning
CapabilityInformation	As defined in frame format	As defined in frame format	The capabilities to be advertised for the BSS
BSSBasicRateSet	Set of integers	2–127 inclusive (for each integer in the set)	The set of data rates (in units of 500 kbit/s) that must be supported by all STAs to join this BSS. The STA that is creating the BSS must be able to receive and transmit at each of the data rates listed in the set.
OperationalRateSet	Set of integers	2–127 inclusive (for each integer in the set)	The set of data rates (in units of 500 kbit/s) that the STA may use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. The OperationalRateSet is a superset of the BSSBasicRateSet advertised by the BSS.

10.3.10.1.3 When generated

This primitive is generated by the SME to start either an infrastructure BSS (with the MAC entity acting as an AP), or to start an independent BSS (with the MAC entity acting as the first STA in the IBSS).

The MLME-START.request primitive must be generated after an MLME-RESET.request primitive has been used to reset the MAC entity and before an MLME-JOIN.request primitive has been used to successfully join an existing infrastructure BSS or independent BSS.

The MLME-START.request primitive must not be used after successful use of the MLME-START.request primitive or successful use of the MLME-JOIN.request without generating an intervening MLME-RESET.request primitive.

10.3.10.1.4 Effect of receipt

This primitive initiates the BSS initialization procedure once the current frame exchange sequence is complete. The MLME subsequently issues an MLME-START.confirm that reflects the results of the creation procedure.

10.3.10.2 MLME-START.confirm

10.3.10.2.1 Function

This primitive reports the results of a BSS creation procedure.

10.3.10.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-START.confirm      (
                           ResultCode
                           )
```

Name	Type	Valid range	resetDescription
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, BSS_ALREADY_STARTED_ OR_JOINED	Indicates the result of the MLME-START.request

10.3.10.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-START.request to create a new BSS.

10.3.10.2.4 Effect of receipt

The SME is notified of the results of the BSS creation procedure.

10.4 PLME SAP interface

The PHY management service interface consists of the generic PLMEGET and PLMESET primitives on PHY MIB attributes, as described previously, together with the PLME-RESET and PLME-CHARACTERISTICS primitives and the following specific primitives.

10.4.1 PLME-RESET.request

10.4.1.1 Function

This primitive shall be a request by the LME to reset the PHY. The PHY shall be always reset to the receive state to avoid accidental data transmission.

10.4.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PLME-RESET.request ()

There are no parameters associated with this primitive.

10.4.1.3 When generated

This primitive shall be generated at any time to reset the PHY.

10.4.1.4 Effect of receipt

Receipt of this primitive by the PHY sublayer shall cause the PHY entity to reset both the transmit and the receive state machines and place the PHY into the receive state.

10.4.2 PLME-CHARACTERISTICS.request

10.4.2.1 Function

This primitive is a request by the LME to provide the PHY operational characteristics.

10.4.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PLME-CHARACTERISTICS.request ()

There are no parameters associated with this primitive.

10.4.2.3 When generated

This primitive is generated by the LME, at initialization time, to request the PHY entity to provide its operational characteristics.

10.4.2.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity will be to generate a PLME-CHARACTERISTICS.confirm primitive that conveys its operational characteristics.

10.4.3 PLME-CHARACTERISTICS.confirm

10.4.3.1 Function

This primitive provides the PHY operational parameters.

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PLME-CHARACTERISTICS.confirm(  
    aSlotTime,  
    aSIFSTime,  
    aCCATime,  
    aRxTxTurnaroundTime,  
    aTxPLCPDelay,  
    aRxPLCPDelay,  
    aRxTxSwitchTime,  
    aTxRampOnTime,  
    aTxRampOffTime,  
    aTxRFDelay,  
    aRxRFDelay,  
    aAirPropagationTime,  
    aMACProcessingDelay,  
    aPreambleLength,  
    aPLCPHeaderLength,  
    aMPDUDurationFactor,  
    aMPDUMaxLength,  
    aCWmin,  
    aCWmax  
)
```

Name	Type	Description
aSlotTime	integer	The Slot Time (in μs) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in μs) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in μs) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aRxTxTurn-aroundTime	integer	The maximum time (in μs) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurn-aroundTime: $\text{aTxPLCPDelay} + \text{aRxTxSwitchTime} + \text{aTxRampOnTime} + \text{aTxRFDelay}$.
aTxPLCPDelay	integer	The nominal time (in μs) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the PMD.
aRxPLCPDelay	integer	The nominal time (in μs) that the PLCP uses to deliver a bit from the PMD receive path to the MAC.
aRxTxSwitchTime	integer	The nominal time (in μs) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in μs) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in μs) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in μs) between the issuance of a PMD-DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for IR.
aRxRFDelay	integer	The nominal time (in μs) between the end of a symbol at the air interface to the issuance of a PMD-DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	The anticipated time (in μs) it takes a transmitted signal to go from the transmitting station to the receiving station.
aMACProcessingDelay	integer	The nominal time (in μs) that the MAC uses to process a frame and prepare a response to the frame.
aPreambleLength	integer	The current PHY's Preamble Length (in μs). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value shall be rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP Header Length (in μs). If the actual value of the length of the modulated header is not an integral number of microseconds, the value shall be rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the wireless medium expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: $\text{Truncate}[(\text{PPDUbits}/\text{PSDUbits}) - 1] \times 10^9$. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer μs : $\text{aPreambleLength} + \text{aPLCPHeaderLength} + ((\text{aMPDUDurationFactor} \times 8 \times \text{PSDUoctets}) / 10^9) + (8 \times \text{PSDUoctets}) / \text{data rate}$ where data rate is in Mbit/s. The total time (in μs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: $\text{Truncate}[\text{aPreambleLength} + \text{aPLCPHeaderLength} + ((\text{aMPDUDurationFactor} \times 8 \times N) / 10^9) + (8 \times N) / \text{data rate}] + 1$, where data rate is in Mbit/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP Header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCPDU.
aCWmin	integer	The minimum size of the contention window, in units of aSlotTime.
aCWmax	integer	The maximum size of the contention window, in units of aSlotTime.

10.4.3.3 When generated

This primitive will be issued by the PHY entity in response to a PLME-CHARACTERISTICS.request.

10.4.3.4 Effect of receipt

The receipt of this primitive provides the operational characteristics of the PHY entity.

10.4.4 PLME-DSSSTESTMODE.request

10.4.4.1 Function

This primitive requests that the DSSS PHY entity enter a test mode operation. The parameters associated with this primitive are considered as recommendations and are optional in any particular implementation.

10.4.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
PLME-DSSSTESTMODE.request (
    TEST_ENABLE,
    TEST_MODE,
    SCRAMBLE_STATE,
    SPREADING_STATE,
    DATA_TYPE,
    DATA_RATE;
)
```

Name	Type	Valid range	Description
TEST_ENABLE	Boolean	True, false	If true, enables the PHY test mode according to the remaining parameters
TEST_MODE	integer	1, 2, 3	TEST_MODE selects one of three operational states: 01 = transparent receive 02 = continuous transmit 03 = 50% duty cycle
SCRAMBLE_STATE	Boolean	True, false	If true, sets the operational state of the scrambler to ON
SPREADING_STATE	Boolean	True, false	If true, selects the operational state of the chipping
DATA_TYPE	integer	1, 2, 3	Selects one of three data patterns to be used for the transmit portions of the tests
DATA_RATE	integer	2, 4	Selects between 1 and 2 Mbit/s operation 02 = 1 Mbit/s 04 = 2 Mbit/s

10.4.4.3 When generated

This primitive shall be generated at any time to enter the DSSS PHY test mode.

10.4.4.4 Effect of receipt

Receipt of this primitive by the PHY sublayer shall cause the DSSS PHY entity to enter the test mode of operation.

10.4.5 PLME-DSSSTESTOUTPUT.request

10.4.5.1 Function

This optional primitive shall be a request by the LME to enable selected test signals from the PHY. The parameters associated with this primitive are considered as recommendations and are optional in any particular implementation.

10.4.5.2 Semantics of the service primitive

The primitive parameters are as follows:

PLME-DSSSTESTOUTPUT.request (
 TEST_OUTPUT,
)

Name	Type	Valid range	Description
TEST_OUTPUT	Boolean	True, false	If true, enables the selected test signals for testing DS PHY

TEST_OUTPUT enables and disables selected signals for debugging and testing the PHY. Some signals that may be available for output are PHY-TXSTART.request, PHY-RXSTART.indicate(RXVECTOR), PHY-CCA.indicate, the chipping clock, the data clock, the symbol clock, TX data, and RX data.

10.4.5.3 When generated

This primitive shall be generated at any time to enable the test outputs when in the DSSS PHY test mode.

10.4.5.4 Effect of receipt

Receipt of this primitive by the DSSS PHY sublayer shall cause the DSSS PHY entity to enable the test outputs using the modes set by the most recent PLME-DSSSTESTMODE.request primitive.

11. MAC sublayer management entity

11.1 Synchronization

All STAs within a single BSS shall be synchronized to a common clock using the mechanisms defined herein.

11.1.1 Basic approach

A timing synchronization function (TSF) keeps the timers for all STAs in the same BSS synchronized. All STAs shall maintain a local TSF timer.

11.1.1.1 TSF for infrastructure networks

In an infrastructure network, the AP shall be the timing master and shall perform the TSF. The AP shall initialize its TSF timer independently of any simultaneously started APs in an effort to minimize the synchronization of the TSF timers of multiple APs. The AP shall periodically transmit special frames called *beacons* that contain a copy of its TSF timer to synchronize the other STAs in a BSS. A receiving STA shall always accept the timing information in beacons sent from the AP servicing its BSS. If a STA's TSF timer is different from the timestamp in the received beacon, the receiving STA shall set its local timer to the received timestamp value.

Beacons shall be generated for transmission by the AP once every BeaconPeriod time units.

11.1.1.2 TSF for an independent BSS (IBSS)

The TSF in an IBSS shall be implemented via a distributed algorithm that shall be performed by all of the members of the BSS. Each STA in the BSS shall transmit beacons according to the algorithm described in this clause. Each STA in an IBSS shall adopt the timing received from any beacon or probe response that has a TSF value later than its own TSF timer.

11.1.2 Maintaining synchronization

Each STA shall maintain a TSF timer with modulus 2^{64} counting in increments of microseconds. STAs expect to receive beacons at a nominal rate. The interval between beacons is defined by the aBeaconPeriod parameter of the STA. A STA sending a beacon shall set the value of the beacon's timestamp so that it equals the value of the STA's TSF timer at the time that the first bit of the timestamp is transmitted to the PHY plus the transmitting STA's delays through its local PHY from the MAC-PHY interface to its interface with the wireless medium (antenna, LED emission surface, etc.). The algorithms in this clause define a mechanism that maintains the synchronization of the TSF timers in a BSS to within 4 μ s plus the maximum propagation delay of the PHY for PHYs of 1 Mbit/s, or greater.

11.1.2.1 Beacon generation in infrastructure networks

The AP shall define the timing for the entire BSS by transmitting beacons according to the aBeaconPeriod attribute within the AP. This defines a series of TBTTs exactly aBeaconPeriod time units apart. Time zero is defined to be a TBTT with the beacon being a DTIM and transmitted at the beginning of a CFP. At each TBTT, the AP shall schedule a beacon as the next frame for transmission. If the medium is determined by the carrier-sense mechanism (see 9.2.1) to be unavailable, the AP shall delay the actual transmission of a beacon according to the basic medium access rules specified in Clause 9. The beacon period is included in Beacon and Probe Response frames, and STAs shall adopt that beacon period when joining the BSS.

NOTE—Though the transmission of a beacon may be delayed because of CSMA deferrals, subsequent beacons shall be scheduled at the nominal beacon interval. This is shown in Figure 64.

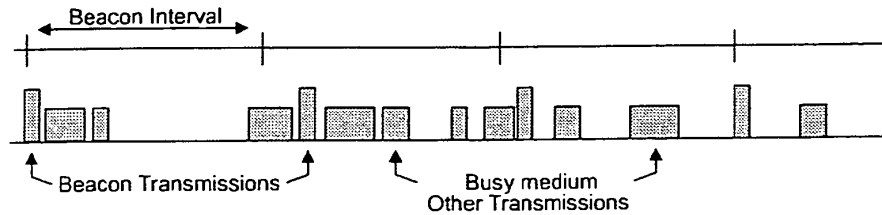


Figure 64—Beacon transmission on a busy network

11.1.2.2 Beacon generation in an IBSS

Beacon generation in an IBSS is distributed. The beacon period is included in Beacon and Probe Response frames, and STAs shall adopt that beacon period when joining the IBSS. All members of the IBSS participate in beacon generation. Each STA shall maintain its own TSF timer that is used for aBeaconPeriod timing. The beacon interval within an IBSS is established by the STA that instantiates the IBSS. This defines a series of TBTTs exactly aBeaconPeriod time units apart. Time zero is defined to be a TBTT. At each TBTT the STA shall

- Suspend the decrementing of the backoff timer for any pending non-beacon or non-ad hoc traffic indication (ATIM) transmission,
- Calculate a random delay uniformly distributed in the range between zero and twice $aCW_{min} \times aSlotTime$,
- Wait for the period of the random delay, decrementing the random delay timer using the same algorithm as for backoff,
- Cancel the remaining random delay and the pending beacon transmission, if a beacon arrives before the random delay timer has expired, and the ATIM backoff timer shall resume decrementing.
- Send a beacon if the random delay has expired and no beacon has arrived during the delay period.

(See Figure 65.)

The beacon transmission shall always occur during the Awake Period of STAs that are operating in a low-power mode. This is described in more detail in 11.2.

11.1.2.3 Beacon reception

STAs shall use information from the CF Parameter Set element of all received Beacon frames to update their NAV as specified in 9.3.2.2.

STAs in an infrastructure network shall only use other information in received Beacon frames, if the BSSID field is equal to the MAC address currently in use by the STA contained in the AP of the BSS.

STAs in an IBSS shall use other information in any received Beacon frame for which the IBSS subfield of the Capability field is set to 1 and the content of the SSID element is equal to the SSID of the IBSS. Use of this information is specified in 11.1.4.

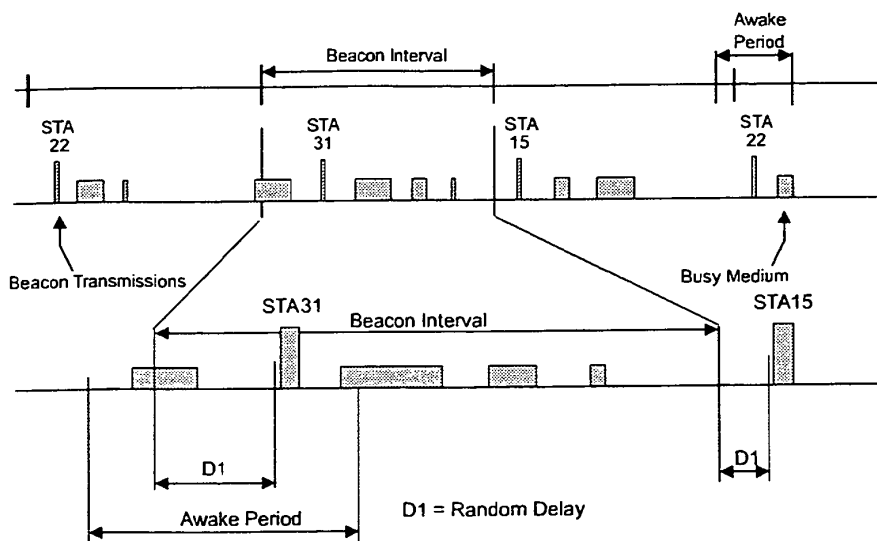


Figure 65—Beacon transmission in an IBSS

11.1.2.4 TSF timer accuracy

Upon receiving a Beacon frame with a valid FCS and BSSID or SSID, as described in 11.1.2.3, a STA shall update its TSF timer according to the following algorithm: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the timestamp was received at the MAC/PHY interface. In the case of an infrastructure BSS, the STA's TSF timer shall then be set to the adjusted value of the timestamp. In the case of an IBSS, the STA's TSF timer shall be set to the adjusted value of the received timestamp, if the adjusted value of the timestamp is later than the value of the STA's TSF timer. The accuracy of the TSF timer shall be $\pm 0.01\%$.

11.1.3 Acquiring synchronization, scanning

A STA shall operate in either a Passive Scanning mode or an Active Scanning mode depending on the current value of the ScanMode parameter of the MLME-SCAN.request primitive.

Upon receipt of the MLME-SCAN.request primitive, a STA shall perform scanning. The SSID parameter indicates the SSID for which to scan. To become a member of a particular ESS using passive scanning, a STA shall scan for Beacon frames containing that ESS's SSID, returning all Beacon frames matching the desired SSID in the BSSDescriptionSet parameter of the corresponding MLME-SCAN.confirm primitive with the appropriate bits in the Capabilities Information field indicating whether the beacon came from an Infrastructure BSS or IBSS. To actively scan, the STA shall transmit Probe frames containing the desired SSID. Upon completion of scanning, an MLME-SCAN.confirm is issued by the MLME indicating all of the BSS information received.

Upon receipt of an MLME-JOIN.request, the STA will join a BSS by adopting the BSSID, TSF timer value, PHY parameters, and the beacon period specified in the request.

Upon receipt of an MLME-SCAN.request with the broadcast SSID, the STA shall passively scan for any Beacon frames, or actively transmit Probe frames containing the broadcast SSID, as appropriate depending

upon the value of ScanMode. Upon completion of scanning, an MLME-SCAN.confirm is issued by the MLME indicating all of the BSS information received.

If a STA's scanning does not result in finding a BSS with the desired SSID and of the desired type, or does not result in finding any BSS, the STA may start an IBSS upon receipt of the MLME-START.request.

A STA may start its own BSS without first scanning for a BSS to join.

When a STA starts a BSS, that STA shall determine the BSSID of the BSS. If the BSSType indicates an infrastructure BSS, then the STA shall start an infrastructure BSS and the BSSID shall be equal to the STA's dot11StationID. The value of the BSSID shall remain unchanged, even if the value of dot11StationID is changed after the completion of the MLME-Start.request. If the BSSType indicates an IBSS, the STA shall start an IBSS, and the BSSID shall be an individual locally administered IEEE MAC address as defined in 5.2 of IEEE Std 802-1990. The remaining 46 bits of that MAC address shall be a number selected in a manner that minimizes the probability of STAs generating the same number, even when those STAs are subjected to the same initial conditions. The value SSID parameter shall be used as the SSID of the new BSS. It is important that designers recognize the need for statistical independence among the random number streams among STAs.

11.1.3.1 Passive scanning

If a ScanType is passive, the STA shall listen to each channel scanned for no longer than a maximum duration defined by the ChannelTime parameter.

11.1.3.2 Active scanning

Active scanning involves the generation of Probe frames and the subsequent processing of received Probe Response frames. The details of the active scanning procedures are as specified in the following subclauses.

11.1.3.2.1 Sending a probe response

STAs, subject to criteria below, receiving Probe Request frames shall respond with a probe response only if the SSID in the probe request is the broadcast SSID or matches the specific SSID of the STA. Probe Response frames shall be sent as directed frames to the address of the STA that generated the probe request. The probe response shall be sent using normal frame transmission rules. An AP shall respond to all probe requests meeting the above criteria. In an IBSS, the STA that generated the last beacon shall be the STA that responds to a probe request.

In each BSS there shall be at least one STA that is awake at any given time to respond to probe requests. A STA that sent a beacon shall remain in the Awake state and shall respond to probe requests until a Beacon frame with the current BSS ID is received. If the STA is an AP, it shall always remain in the Awake state and always respond to probe requests. There may be more than one STA in an IBSS that responds to any given probe request, particularly in cases where more than one STA transmitted a Beacon frame following the most recent TBTT, either due to not receiving successfully a previous beacon or due to collisions between beacon transmissions.

11.1.3.2.2 Active scanning procedure

Upon receipt of the MLME-SCAN.request with ScanType indicating an active scan, a STA shall use the following procedure:

For each channel to be scanned,

- a) Wait until the ProbeDelay time has expired or a PHYRxStart.indication has been received;
- b) Perform the Basic Access procedure as defined in 9.2.5.1;

- c) Send a probe with the broadcast destination, SSID, and broadcast BSSID;
- d) Clear and start a ProbeTimer;
- e) If PHYCCA.indication (busy) has not been detected before the ProbeTimer reaches MinChannelTime, then clear NAV and scan the next channel, else when ProbeTimer reaches MaxChannelTime, process all received probe responses;
- f) Clear NAV and scan the next channel.

See Figure 66.

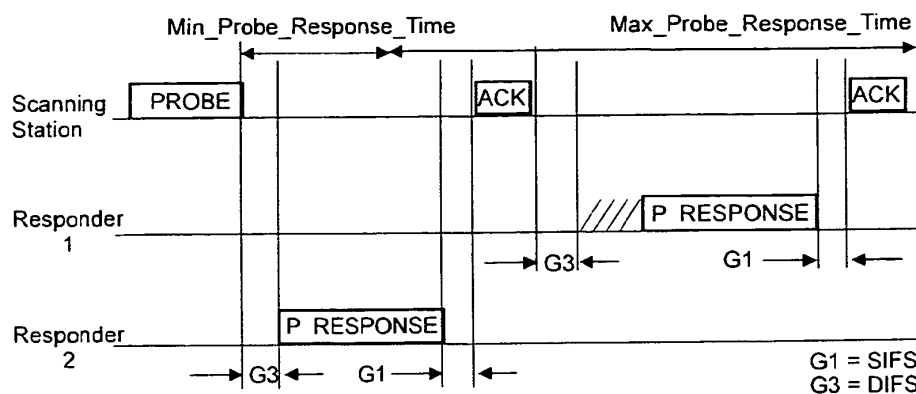


Figure 66—Probe response

When all channels in the ChannelList have been scanned, the MLME shall issue an MLME-Scan.confirm with the BSSDescriptionSet containing all of the information gathered during the scan.

11.1.3.3 Initializing a BSS

Upon receipt of an MLME-Start.request, a STA shall determine the BSS's BSSID (as described in 11.1.3), select channel synchronization information, select a beacon period, initialize and start its TSF timer, and begin transmitting beacons.

11.1.3.4 Synchronizing with a BSS

Upon receipt of an MLME-Join.request, a STA shall adopt the BSSID, channel synchronization information, and TSF timer value of the parameters in the request. Upon receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-Join.confirm indicating the operation was successful. If the JoinFailureTimeout expires prior to the receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-Join.confirm indicating the operation was unsuccessful.

11.1.4 Adjusting STA timers

In the infrastructure network, STAs shall always adopt the timer in a beacon or probe response coming from the AP in their BSS.

In an IBSS, a STA shall always adopt the information in the contents of a Beacon or Probe Response frame when that frame contains a matching SSID and the value of the time stamp is later than the STA's TSF timer. In response to an MLME-Join.request, a STA shall initialize its TSF timer to 0 and shall not transmit a

beacon or probe response until it hears a beacon or probe response from a member of the IBSS with a matching SSID.

All Beacon and Probe Response frames carry a Timestamp field. A STA receiving such a frame from another STA in an IBSS with the same SSID shall compare the Timestamp field with its own TSF time. If the Timestamp field of the received frame is later than its own TSF time, the STA shall adopt all parameters contained in the Beacon frame.

11.1.5 Timing synchronization for frequency-hopping (FH) PHYs

NOTE—This subclause pertains only to STAs using an FH PHY.

The TSF described here provides a mechanism for STAs in an FH system to synchronize their transitions from one channel to another (their “hops”). Every STA shall maintain a table of all of the hopping sequences that are used in the system. All of the STAs in a BSS shall use the same hopping sequence. Each beacon and probe response includes the channel synchronization information necessary to determine the hop pattern and timing for the BSS.

STAs shall use their TSF timer to time the `aCurrentDwellTime`. The `aCurrentDwellTime` is the length of time that STAs shall stay on each frequency in their hopping sequence. Once STAs are synchronized, they have the same TSF timer value.

STAs in the BSS shall issue an appropriate PLME service primitive for the PHY in use to tune to the next frequency in the hopping sequence whenever

TSF timer MOD `aCurrentDwellTime` = 0

11.2 Power management

11.2.1 Power management in an infrastructure network

STAs changing Power Management mode shall inform the AP of this fact using the Power Management bits within the Frame Control field of transmitted frames. The AP shall not arbitrarily transmit MSDUs to STAs operating in a power-save (PS) mode, but shall buffer MSDUs and only transmit them at designated times.

The STAs that currently have buffered MSDUs within the AP are identified in a *traffic indication map* (TIM), which shall be included as an element within all beacons generated by the AP. A STA shall determine that an MSDU is buffered for it by receiving and interpreting a TIM.

STAs operating in PS modes shall periodically listen for beacons, as determined by the STA's `ListenInterval` and `ReceiveDTIMs` parameters of the MLME-Power-Mgt.request primitive.

In a BSS operating under the DCF, or during the contention period of a BSS using the PCF, upon determining that an MSDU is currently buffered in the AP, a STA operating in the *PS mode* shall transmit a short PS-Poll frame to the AP, which shall respond with the corresponding buffered MSDU immediately, or acknowledge the PS-Poll and respond with the corresponding MSDU at a later time. If the TIM indicating the buffered MSDU is sent during a contention-free period (CFP), a CF-Pollable STA operating in the PS mode does not send a PS-Poll frame, but remains active until the buffered MSDU is received (or the CFP ends). If any STA in its BSS is in PS mode, the AP shall buffer all broadcast and multicast MSDUs and deliver them to all STAs immediately following the next Beacon frame containing a *delivery TIM* (DTIM) transmission.

A STA shall remain in its current Power Management mode until it informs the AP of a Power Management mode change via a successful frame exchange. Power Management mode shall not change during any single frame exchange sequence, as described in 9.7.

11.2.1.1 STA Power Management modes

A STA may be in one of two different power states:

- *Awake*: STA is fully powered.
- *Doze*: STA is not able to transmit or receive and consumes very low power.

The manner in which a STA transitions between these two power states shall be determined by the STA's Power Management mode. These modes are summarized in Table 23.

The Power Management mode of a STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request. Once the STA updates its Power Management mode, the MLME shall issue an MLME-POWERMGT.confirm indicating the success of the operation.

Table 23—Power Management modes

Active mode or AM	STA may receive frames at any time. In Active mode, a STA shall be in the Awake state. A STA on the polling list of a PCF shall be in Active mode for the duration of the CFP.
Power Save or PS	STA listens to selected beacons (based upon the ListenInterval parameter of the MLME-Associate.request primitive) and sends PS-Poll frames to the AP if the TIM element in the most recent beacon indicates a directed MSDU buffered for that STA. The AP shall transmit buffered directed MSDUs to a PS STA only in response to a PS-Poll from that STA, or during the CFP in the case of a CF-Pollable PS STA. In PS mode, a STA shall be in the Doze state and shall enter the Awake state to receive selected beacons, to receive broadcast and multicast transmissions following certain received beacons, to transmit, and to await responses to transmitted PS-Poll frames or (for CF-Pollable STAs) to receive contention-free transmissions of buffered MSDUs.

To change Power Management modes, a STA shall inform the AP through a successful frame exchange initiated by the STA. The Power Management bit in the Frame Control field of the frame sent by the STA in this exchange indicates the Power Management mode that the STA shall adopt upon successful completion of the entire frame exchange.

A STA that is changing from Doze to Awake in order to transmit shall perform clear channel assessment (CCA) until a frame sequence is detected by which it can correctly set its NAV, or until a period of time equal to the ProbeDelay has transpired.

11.2.1.2 AP TIM transmissions

The TIM shall identify the STAs for which traffic is pending and buffered in the AP. This information is coded in a *partial virtual bitmap*, as described in 7.3.2.6. In addition, the TIM contains an indication whether broadcast/multicast traffic is pending. Every STA is assigned an Association ID code (AID) by the AP as part of the association process. AID 0 (zero) is reserved to indicate the presence of buffered broadcast/multicast MSDUs. The AP shall identify those STAs for which it is prepared to deliver buffered MSDUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate SIDs.

11.2.1.3 TIM types

Two different TIM types are distinguished: TIM and DTIM. After a DTIM, the AP shall send out the buffered broadcast/multicast MSDUs using normal frame transmission rules, before transmitting any unicast frames.

The AP shall transmit a TIM with every beacon. Every DTIMPeriod, a TIM of type “DTIM” is transmitted within a beacon, rather than an ordinary TIM.

Figure 67 illustrates the AP and STA activity under the assumption that a DTIM is transmitted once every three TIMs. The top line in Figure 67 represents the time axis, with the beacon interval shown together with a DTIM Interval of three beacon intervals. The second line depicts AP activity. The AP schedules beacons for transmission every beacon interval, but the beacons may be delayed if there is traffic at the TBTT. This is indicated as “busy medium” on the second line. For the purposes of this figure, the important fact about beacons is that they contain TIMs, some of which may be DTIMs. Note that the second STA with ReceivedDTIMs set to false does not power up its receiver for all DTIMs.

The third and fourth lines in Figure 67 depict the activity of two STAs operating with different power management requirements. Both STAs power-on their receivers whenever they need to listen for a TIM. This is indicated as a ramp-up of the receiver power prior to the TBTT. The first STA, for example, powers up its receiver and receives a TIM in the first beacon; that TIM indicates the presence of a buffered MSDU for the receiving STA. The receiving STA then generates a PS-Poll frame, which elicits the transmission of the buffered data MSDU from the AP. Broadcast and multicast MSDUs are sent by the AP subsequent to the transmission of a beacon containing a DTIM. The DTIM is indicated by the DTIM count field of the TIM element having a value of 0.

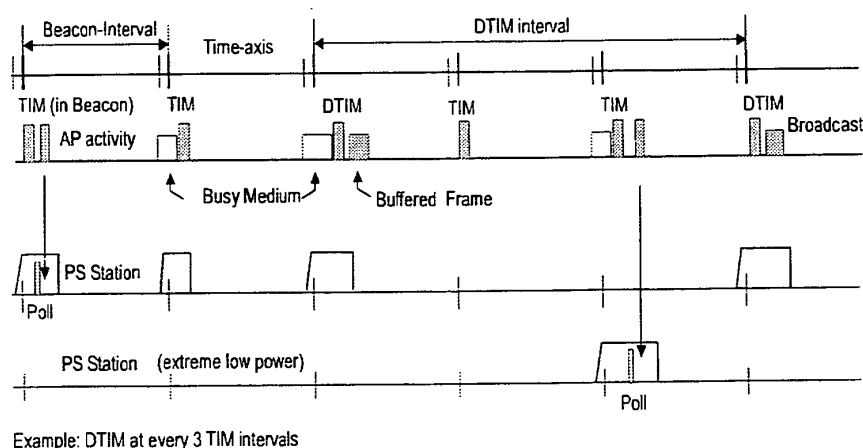


Figure 67—Infrastructure power management operation (no PCF operating)

11.2.1.4 AP operation during the contention period

APs shall maintain a Power Management status for each currently associated STA that indicates in which Power Management mode the STA is currently operating. An AP shall, depending on the Power Management mode of the STA, temporarily buffer the MSDU or management frame destined to the STA. No MSDUs or management frames received for STAs operating in the Active mode shall be buffered for power management reasons.

- a) MSDUs, or management frames destined for PS STAs, shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard.
- b) MSDUs, or management frames destined for STAs in the Active mode, shall be directly transmitted.
- c) At every beacon interval, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode, and shall send this out in the TIM field of the beacon. The bit for AID 0 (zero) shall be set whenever broadcast or multicast traffic is buffered.
- d) All broadcast/multicast MSDUs, with the Order bit in the Frame Control field clear, shall be buffered if any associated STAs are in PS mode.
- e) Immediately after every DTIM, the AP shall transmit all buffered broadcast/multicast MSDUs. The More Data field of each broadcast/multicast frame shall be set to indicate the presence of further buffered broadcast/multicast MSDUs. If the AP is unable to transmit all of the buffered broadcast/multicast MSDUs before the TBTT following the DTIM, the AP shall indicate that it will continue to deliver the broadcast/multicast MSDUs by setting the bit for AID 0 (zero) of the TIM element of every Beacon frame, until all buffered broadcast/multicast frames have been transmitted.
- f) A single buffered MSDU or management frame for a STA in the PS mode shall be forwarded to the STA after a PS-Poll has been received from that STA. The More Data field shall be set to indicate the presence of further buffered MSDUs or management frames for the polling STA. Further PS-Poll frames from the same STA shall be acknowledged and ignored until the MSDU or management frame has either been successfully delivered, or presumed failed due to maximum retries being exceeded. This prevents a retried PS-Poll from being treated as a new request to deliver a buffered frame.
- g) An AP shall have an aging function to delete pending traffic when it is buffered for an excessive time period.
- h) Whenever an AP is informed that a STA changes to the Active mode, then the AP shall send buffered MSDUs and management frames (if any exist) to that STA without waiting for a PS-Poll.

11.2.1.5 AP operation during the CFP

APs shall maintain a Power Management status for each currently associated CF-Pollable STA that indicates in which Power Management mode the STA is currently operating. An AP shall, for STAs in PS mode, temporarily buffer the MSDU destined to the STA.

- a) MSDUs destined for PS STAs shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard.
- b) MSDUs destined to STAs in the Active mode shall be transmitted as defined in Clause 9.
- c) Prior to every CFP, and at each beacon interval within the CFP, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode, set the bits in the partial virtual bitmap for STAs the point coordinator (PC) is intending to poll during this CFP, and shall send this out in the TIM field of the DTIM. The bit for AID 0 (zero) shall be set whenever broadcast or multicast traffic is buffered.
- d) All broadcast and multicast MSDUs, with the Order bit in the Frame Control field clear, shall be buffered if any associated STAs are in the PS mode, whether or not those STAs are CF-Pollable.
- e) Immediately after every DTIM (Beacon frame with DTIM Count field of the TIM element equal to zero), the AP shall transmit all buffered broadcast and multicast frames. The More Data field shall be set to indicate the presence of further buffered broadcast/multicast MSDUs. If the AP is unable to transmit all of the buffered broadcast/multicast MSDUs before the TBTT following the DTIM, the AP shall indicate that it will continue to deliver the broadcast/multicast MSDUs by setting the bit for AID 0 (zero) of the TIM element of every Beacon frame, until all buffered broadcast/multicast frames have been transmitted.
- f) Buffered MSDUs or management frames for STAs in the PS mode shall be forwarded to the CF-Pollable STAs under control of the PC. Transmission of these buffered MSDUs or management frames shall begin immediately after transmission of buffered broadcast and multicast frames (if any), and shall occur in order by increasing AID of CF-Pollable STAs. A CF-Pollable STA for which the TIM element of the most recent beacon indicated buffered MSDUs or management frames shall

be in the Awake state at least until the receipt of a directed frame from the AP in which the Frame Control field does not indicate the existence of more buffered MSDUs or management frames. After acknowledging the last of the buffered MSDUs or management frames, the CF-Pollable STA operating in the PS mode may enter the Doze state until the next DTIM is expected.

- g) An AP shall have an aging function to delete pending traffic buffered for an excessive time period. The exact specification of the aging function is beyond the scope of this standard.
- h) Whenever an AP detects that a CF-Pollable STA has changed from the PS mode to the Active mode, then the AP shall queue any buffered frames addressed to that STA for transmission to that CF-Pollable STA as directed by the AP's PC function (PCF).

11.2.1.6 Receive operation for STAs in PS mode during the contention period

STAs in PS mode shall operate as follows to receive an MSDU or management frame from the AP when no PC is operating and during the contention period when a PC is operating.

- a) STAs shall wake up early enough to be able to receive the next scheduled beacon after ListenInterval from the last TBTT.
- b) When a STA detects that the bit corresponding to its AID is set in the TIM, the STA shall issue a PS-Poll to retrieve the buffered MSDU or management frame. If more than one bit is set in the TIM, the PS-Poll shall be transmitted after a random delay uniformly distributed between zero and aCWmin.
- c) The STA shall remain in the Awake state until it receives the response to its poll, or it receives another beacon whose TIM indicates that the AP does not have any MSDUs or management frames buffered for this STA. If the bit corresponding to the STA's AID is set in the subsequent TIM, the STA shall issue another PS-Poll to retrieve the buffered MSDU or management frame(s).
- d) If the More Data field in the received MSDU or management frame indicates that more traffic for that STA is buffered, the STA, at its convenience, shall Poll until no more MSDUs or management frames are buffered for that STA.
- e) When ReceiveDTIMs is true, the STA shall wake up early enough to be able to receive every DTIM. A STA receiving broadcast/multicast MSDUs shall remain awake until the More Data field of the broadcast/multicast MSDUs indicates there are no further buffered broadcast/multicast MSDUs, or until a TIM is received indicating there are no more buffered broadcast/multicast MSDUs.

11.2.1.7 Receive operation for STAs in PS mode during the CFP

STAs in PS mode that are associated as CF-Pollable shall operate as follows in a BSS with an active PC to receive MSDUs or management frames from the AP during the CFP:

- a) STAs shall enter the Awake state so as to receive the Beacon frame (which contains a DTIM) at the start of each CFP.
- b) To receive broadcast/multicast MSDUs, the STA shall wake up early enough to be able to receive every DTIM that may be sent during the CFP. A STA receiving broadcast/multicast MSDUs shall remain awake until the More Data field of the broadcast/multicast MSDUs indicates there are no further buffered broadcast/multicast MSDUs, or until a TIM is received indicating there are no more broadcast/multicast MSDUs buffered.
- c) When a STA detects that the bit corresponding to its AID is set in the DTIM at the start of the CFP (or in a subsequent TIM during the CFP), the STA shall remain in the Awake state for at least that portion of the CFP through the time that the STA receives a directed MSDU or management frame from the AP with the More Data field in the Frame Control field indicating that no further traffic is buffered.
- d) If the More Data field in the Frame Control field of the last MSDU or management frame received from the AP indicates that more traffic for the STA is buffered, then, when the CFP ends, the STA may remain in the Awake state and transmit PS-Poll frames during the contention period to request the delivery of additional buffered MSDU or management frames, or may enter the Doze state

during the contention period (except at TBTTs for DTIMs expected during the contention period), awaiting the start of the next CFP.

11.2.1.8 STAs operating in the Active mode

A STA operating in this mode shall have its receiver activated continuously; it does not need to interpret the traffic announcement part of the beacons.

11.2.1.9 AP aging function

The AP shall have an aging function to delete buffered traffic when it has been buffered for an excessive period of time. That function shall be based on the ListenInterval parameter of the MLME-Associate.request primitive of the STA for which the traffic is buffered. The AP aging function shall not cause the buffered traffic to be discarded after any period that is shorter than the ListenInterval of the STA for which the traffic is buffered. The exact specification of the aging function is beyond the scope of this standard.

11.2.2 Power management in an IBSS

This subclause specifies the power management mechanism for use within an IBSS.

11.2.2.1 Basic approach

The basic approach is similar to the infrastructure case in that the STAs are synchronized, and multicast MSDUs and those MSDUs that are to be transmitted to a power-conserving STA are first announced during a period when all STAs are awake. The announcement is done via an ad hoc traffic indication message (ATIM). A STA in the PS mode shall listen for these announcements to determine if it needs to remain in the awake state.

When an MSDU is to be transmitted to a destination STA that is in a PS mode, the transmitting STA first transmits an ATIM frame during the ATIM Window, in which all the STAs including those operating in a PS mode are awake. The ATIM Window is defined as a specific period of time, defined by aATIMWindow, following a TBTT, during which only Beacon or ATIM frames shall be transmitted. ATIM transmission times are randomized, after a Beacon frame is either transmitted or received by the STA, using the backoff procedure with the contention window equal to aCWminx. Directed ATIMs shall be acknowledged. If a STA transmitting a directed ATIM does not receive an acknowledgment, the STA shall execute the backoff procedure for retransmission of the ATIM. Multicast ATIMs shall not be acknowledged.

If a STA receives a directed ATIM frame during the ATIM Window, it shall acknowledge the directed ATIM and stay awake for the entire beacon interval waiting for the announced MSDU(s) to be received. If a STA does not receive an ATIM, it may enter the Doze state at the end of the ATIM Window. Transmissions of MSDUs announced by ATIMs are randomized after the ATIM Window, using the backoff procedure described in Clause 9.

It is possible that an ATIM may be received from more than one STA, and that a STA that receives an ATIM may receive more than a single MSDU from the transmitting STA. ATIM frames are only addressed to the destination STA of the MSDU.

An ATIM for a broadcast or multicast MSDU shall have a destination address identical to that of the MSDU.

After the ATIM interval, only those directed MSDUs that have been successfully announced with an acknowledged ATIM, and broadcast/multicast MSDUs that have been announced with an ATIM, shall be transmitted to STAs in the PS mode. Transmission of these frames shall be done using the normal DCF access procedure.

Figure 68 illustrates the basic power-save operation.

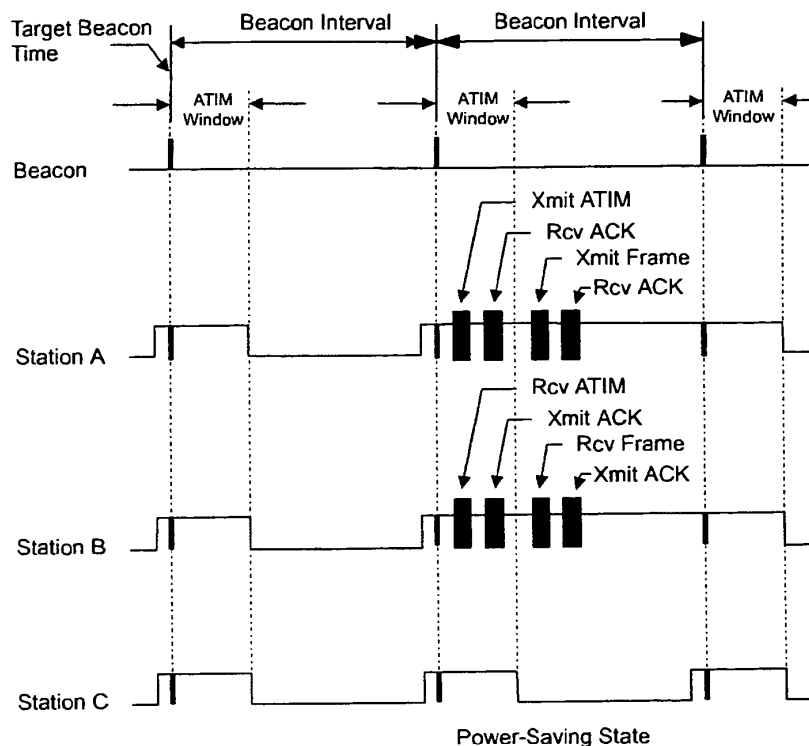


Figure 68—Power management in an IBSS—Basic operation

The estimated power-saving state of another STA may be based on the power management information transmitted by that STA and on additional information available locally, such as a history of failed transmission attempts. The use of RTS/CTS in an IBSS may reduce the number of transmissions to a STA that is in PS mode. If an RTS is sent and a CTS is not received, the transmitting STA may assume that the destination STA is in PS mode. The method of estimating the power management state of other STAs in the IBSS is outside the scope of this standard.

11.2.2.2 Initialization of power management within an IBSS

The following procedure shall be used to initialize power management within a new IBSS, or to learn about the power management being used within an existing IBSS.

- A STA joining an existing IBSS by the procedure in 11.1.3.3 shall update its ATIM Window with the value contained in the ATIM Window field of the IBSS Parameter Set element within the Beacon or Probe Response management frame received during the scan procedure.
- A STA creating a new IBSS by the procedure in 11.1.3.3 shall set the value of the ATIM Window field of the IBSS Parameter Set element within the Beacon management frames transmitted to the value of its ATIM Window.
- The start of the ATIM Window shall be the TBTT, defined in 11.1.2.2. The end of the ATIM Window shall be defined as

TSF timer MOD BeaconInterval = ATIMWindow.

- d) The ATIM Window period shall be static during the lifetime of the IBSS.
- e) An ATIM Window value of zero shall indicate that power management is not in use within the IBSS.

11.2.2.3 STA power state transitions

A STA may enter PS mode if and only if the value of the ATIM Window in use within the IBSS is greater than zero. A STA shall set the Power Management subfield in the Frame Control field of MSDUs that it transmits according to the procedure in 7.1.3.1.7.

A STA in PS mode shall transition between Awake and Doze states according to the following rules:

- a) If a STA is operating in PS mode, it shall enter the Awake state prior to each TBTT.
- b) If a STA receives a directed ATIM management frame containing its individual address, or a multicast ATIM management frame during the ATIM Window it shall remain in the Awake state until the end of the next ATIM Window.
- c) If a STA transmits a Beacon or an ATIM management frame, it shall remain in the Awake state until the end of the next ATIM Window regardless of whether an acknowledgment is received for the ATIM.
- d) If the STA has not transmitted an ATIM and does not receive either a directed ATIM management frame containing its individual address, or a multicast ATIM management frame during the ATIM Window, it may return to the Doze state following the end of the current ATIM Window.

11.2.2.4 ATIM and frame transmission

If power management is in use within an IBSS, all STAs shall buffer MSDUs for STAs that are known to be in PS mode. The algorithm used for the estimation of the power management state of STAs within the IBSS is outside the scope of this standard. MSDUs may be sent to STAs in Active mode at any valid time.

- a) Following the reception or transmission of the beacon, during the ATIM Window, the STA shall transmit a directed ATIM management frame to each STA for which it has one or more buffered unicast MSDUs. If the STA has one or more buffered multicast MSDUs, with the Strictly Ordered bit clear, it shall transmit an appropriately addressed multicast ATIM frame. A STA transmitting an ATIM management frame shall remain awake for the entire current beacon interval.
- b) All STAs shall use the backoff procedure defined in 9.2.5.2 for transmission of the first ATIM following the beacon. All remaining ATIMs shall be transmitted using the conventional DCF access procedure.
- c) ATIM management frames shall only be transmitted during the ATIM Window.
- d) A STA shall transmit no frame types other than RTS, CTS, and ACK Control frames and Beacon and ATIM management frames during the ATIM Window.
- e) Directed ATIM management frames shall be acknowledged. If no acknowledgment is received, the ATIM shall be retransmitted using the conventional DCF access procedure. Multicast ATIM management frames shall not be acknowledged.
- f) If a STA is unable to transmit an ATIM during the ATIM Window, for example due to contention with other STAs, the STA shall retain the buffered MSDU(s) and attempt to transmit the ATIM during the next ATIM Window.
- g) Immediately following the ATIM Window, a STA shall begin transmission of buffered broadcast/multicast frames for which an ATIM was previously transmitted. Following the transmission of any broadcast/multicast frames, any MSDUs and management frames addressed to STAs for which an acknowledgment for a previously transmitted ATIM frame was received shall be transmitted. All STAs shall use the backoff procedure defined in 9.2.5.2 for transmission of the first frame following the ATIM Window. All remaining frames shall be transmitted using the conventional DCF access procedure.

- h) A buffered MSDU may be transmitted using fragmentation. If an MSDU has been partially transmitted when the next beacon frame is sent, the STA shall retain the buffered MSDU and announce the remaining fragments by transmitting an ATIM during the next ATIM Window.
- i) If an STA is unable to transmit a buffered MSDU during the beacon interval in which it was announced, for example due to contention with other STAs, the STA shall retain the buffered MSDU and announce the MSDU again by transmitting an ATIM during the next ATIM Window.
- j) Following the transmission of all buffered MSDUs, a STA may transmit MSDUs without announcement to STAs that are known to be in the Awake state for the current beacon interval due to an appropriate ATIM management or Beacon frame having been transmitted or received.
- k) A STA may discard frames buffered for later transmission to power-saving STAs if the STA determines that the frame has been buffered for an excessive amount of time or if other conditions internal to the STA implementation make it desirable to discard buffered frames (for example, buffer starvation). In no case shall a frame be discarded that has been buffered for less than a BeaconPeriod. The algorithm to manage this buffering is beyond the scope of this standard.

11.3 Association and reassociation

This subclause defines how a STA associates and reassociates with an AP.

11.3.1 STA association procedures

Upon receipt of an MLME-ASSOCIATE.request, a STA shall associate with an AP via the following procedure:

- a) The STA shall transmit an association request to an AP with which that STA is authenticated.
- b) If an Association Response frame is received with a status value of "successful," the STA is now associated with the AP and the MLME shall issue an MLME-ASSOCIATE.confirm indicating the successful completion of the operation.
- c) If an Association Response frame is received with a status value other than "successful" or the AssociateFailureTimeout expires, the STA is not associated with the AP and the MLME shall issue an MLME-ASSOCIATE.confirm indicating the failure of the operation.

11.3.2 AP association procedures

An AP shall operate as follows in order to support the association of STAs.

- a) Whenever an Association Request frame is received from a STA and the STA is authenticated, the AP shall transmit an association response with a status code as defined in 7.3.1.9. If the status value is "successful," the Association ID assigned to the STA shall be included in the response. If the STA is not authenticated, the AP shall transmit a Deauthentication frame to the STA.
- b) When the association response with a status value of "successful" is acknowledged by the STA, the STA is considered to be associated with this AP.
- c) The AP shall inform the distribution system (DS) of the association and the MLME shall issue an MLME-ASSOCIATE.indication.

11.3.3 STA reassociation procedures

Upon receipt of an MLME-REASSOCIATE.request, a STA shall reassociate with an AP via the following procedure:

- a) The STA shall transmit a Reassociation Request frame to an AP.

- b) If a Reassociation Response frame is received with a status value of “successful,” the STA is now associated with the AP and the MLME shall issue an MLME-REASSOCIATE.confirm indicating the successful completion of the operation.
- c) If a Reassociation Response frame is received with a status value other than “successful” or the ReassociateFailureTimeout expires, the STA is not associated with the AP and the MLME shall issue an MLME-REASSOCIATE.confirm indicating the failure of the operation.

11.3.4 AP reassociation procedures

An AP shall operate as follows in order to support the reassociation of STAs.

- a) Whenever a Reassociation Request frame is received from a STA and the STA is authenticated, the AP shall transmit a reassociation response with a status value as defined in 7.3.1.9. If the status value is “successful,” the Association ID assigned to the STA shall be included in the response. If the STA is not authenticated, the AP shall transmit a Deauthentication frame to the STA.
- b) When the reassociation response with a status value of “successful” is acknowledged by the STA, the STA is considered to be associated with this AP.
- c) The AP shall inform the DS of the reassociation and the MLME shall issue an MLME-REASSOCIATE.indication.

11.4 Management information base (MIB) definitions

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a station. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex D.

12. Physical layer (PHY) service specification

12.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC are described in this clause. Different PHYs are defined as part of the IEEE 802.11 standard. Each PHY can consist of two protocol functions as follows:

- a) A physical layer convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 MAC sublayer protocol data units (MPDUs) into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
- b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a wireless medium (WM) between two or more STAs.

Each PMD sublayer may require the definition of a unique PLCP. If the PMD sublayer already provides the defined PHY services, the physical layer convergence function might be null.

12.2 PHY functions

The protocol reference model for the IEEE 802.11 architecture is shown in Figure 11. Most PHY definitions contain three functional entities: the PMD function, the physical layer convergence function, and the layer management function.

The PHY service is provided to the MAC entity at the STA through a service access point (SAP), called the PHY-SAP, as shown in Figure 11. A set of primitives might also be defined to describe the interface between the physical layer convergence protocol sublayer and the PMD sublayer, called the PMD-SAP.

12.3 Detailed PHY service specifications

12.3.1 Scope and field of application

The services provided by the PHY to the IEEE 802.11 MAC are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface.

12.3.2 Overview of the service

The PHY function as shown in Figure 11 is separated into two sublayers: the PLCP sublayer and the PMD sublayer. The function of the PLCP sublayer is to provide a mechanism for transferring MPDUs between two or more STAs over the PMD sublayer.

12.3.3 Overview of interactions

The primitives associated with communication between the IEEE 802.11 MAC sublayer and the IEEE 802.11 PHY fall into two basic categories:

- a) Service primitives that support MAC peer-to-peer interactions;
- b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

12.3.4 Basic service and options

All of the service primitives described here are considered mandatory unless otherwise specified.

12.3.4.1 PHY-SAP peer-to-peer service primitives

Table 24 indicates the primitives for peer-to-peer interactions.

Table 24—PHY-SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm
PHY-DATA	X	X	X

12.3.4.2 PHY-SAP sublayer-to-sublayer service primitives

Table 25 indicates the primitives for sublayer-to-sublayer interactions.

Table 25—PHY-SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm
PHY-TXSTART	X		X
PHY-TXEND	X		X
PHY-CCARESET	X		X
PHY-CCA		X	
PHY-RXSTART		X	
PHY-RXEND		X	

12.3.4.3 PHY-SAP service primitives parameters

Table 26 shows the parameters used by one or more of the PHY-SAP service primitives.

Table 26—PHY-SAP service primitive parameters

Parameter	Associated primitive	Value
DATA	PHY-DATA.request PHY-DATA.indication	Octet value X'00'–X'FF'
TXVECTOR	PHY-TXSTART.request	A set of parameters
STATUS	PHY-CCA.indication	BUSY, IDLE
RXVECTOR	PHY-RXSTART.indication	A set of parameters
RXERROR	PHY-RXEND.indication	NoError, FormatViolation, Carrier-Lost, UnsupportedRate

12.3.4.4 Vector descriptions

Several service primitives include a parameter vector. This vector is a list of parameters that may vary depending on the PHY type. Table 27 lists the parameter values required by the MAC or PHY in each of the parameter vectors. Parameters in the vectors that are management rather than MAC may be specific to the PHY and are listed in the clause covering that PHY.

Table 27—Vector descriptions

Parameter	Associate vector	Value
DATARATE	TXVECTOR, RXVECTOR	PHY dependent. The name of the field used to specify the Tx data rate and report the Rx data rate may vary for different PHYs.
LENGTH	TXVECTOR, RXVECTOR	PHY dependent

12.3.5 PHY-SAP detailed service specification

The following subclause describes the services provided by each PHY sublayer primitive.

12.3.5.1 PHY-DATA.request

12.3.5.1.1 Function

This primitive defines the transfer of an octet of data from the MAC sublayer to the local PHY entity.

12.3.5.1.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-DATA.request (DATA)

The DATA parameter is an octet of value X'00' through X'FF'.

12.3.5.1.3 When generated

This primitive is generated by the MAC sublayer to transfer an octet of data to the PHY entity. This primitive can only be issued following a transmit initialization response (PHY-TXSTART.confirm) from the PHY layer.

12.3.5.1.4 Effect of receipt

The receipt of this primitive by the PHY entity causes the PLCP transmit state machine to transmit an octet of data. When the PHY entity receives the octet, it will issue a PHY-DATA.confirm to the MAC sublayer.

12.3.5.2 PHY-DATA.indication

12.3.5.2.1 Function

This primitive indicates the transfer of data from the PHY sublayer to the local MAC entity.

12.3.5.2.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-DATA.indication (DATA)

The DATA parameter is an octet of value X'00' through X'FF'.

12.3.5.2.3 When generated

The PHY-DATA.indication is generated by a receiving PHY entity to transfer the received octet of data to the local MAC entity. The time between receipt of the last bit of the provided octet from the wireless medium and the receipt of this primitive by the MAC entity will be the sum of aRXRFDelay + aRxPLCPDelay.

12.3.5.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.3 PHY-DATA.confirm

12.3.5.3.1 Function

This primitive is issued by the PHY sublayer to the local MAC entity to confirm the transfer of data from the MAC entity to the PHY sublayer.

12.3.5.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-DATA.confirm

This primitive has no parameters.

12.3.5.3.3 When generated

This primitive will be issued by the PHY sublayer to the MAC entity whenever the PLCP has completed the transfer of data from the MAC entity to the PHY sublayer. The PHY sublayer will issue this primitive in response to every PHY-DATA.request primitive issued by the MAC sublayer.

12.3.5.3.4 Effect of receipt

The receipt of this primitive by the MAC will cause the MAC to start the next MAC entity request.

12.3.5.4 PHY-TXSTART.request

12.3.5.4.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to start the transmission of an MPDU.

12.3.5.4.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-TXSTART.request (TXVECTOR)

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit an MPDU. This vector contains both PLCP and PHY management parameters. The required PHY parameters are listed in 12.3.4.4.

12.3.5.4.3 When generated

This primitive will be issued by the MAC sublayer to the PHY entity whenever the MAC sublayer needs to begin the transmission of an MPDU.

12.3.5.4.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity will be to start the local transmit state machine.

12.3.5.5 PHY-TXSTART.confirm

12.3.5.5.1 Function

This primitive is issued by the PHY sublayer to the local MAC entity to confirm the start of a transmission. The PHY sublayer will issue this primitive in response to every PHY-TXSTART.request primitive issued by the MAC sublayer.

12.3.5.5.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXSTART.confirm

There are no parameters associated with this primitive.

12.3.5.5.3 When generated

This primitive will be issued by the PHY sublayer to the MAC entity whenever the PHY has received a PHY-TXSTART.request from the MAC entity and is ready to begin receiving data octets.

12.3.5.5.4 Effect of receipt

The receipt of this primitive by the MAC entity will cause the MAC to start the transfer of data octets.

12.3.5.6 PHY-TXEND.request

12.3.5.6.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity that the current transmission of the MPDU be completed.

12.3.5.6.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXEND.request

There are no parameters associated with this primitive.

12.3.5.6.3 When generated

This primitive will be generated whenever the MAC sublayer has received the last PHY-DATA.confirm from the local PHY entity for the MPDU currently being transferred.

12.3.5.6.4 Effect of receipt

The effect of receipt of this primitive by the local PHY entity will be to stop the transmit state machine.

12.3.5.7 PHY-TXEND.confirm

12.3.5.7.1 Function

This primitive is issued by the PHY sublayer to the local MAC entity to confirm the completion of a transmission. The PHY sublayer issues this primitive in response to every PHY-TXEND.request primitive issued by the MAC sublayer.

12.3.5.7.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXEND.confirm

There are no parameters associated with this primitive.

12.3.5.7.3 When generated

This primitive will be issued by the PHY sublayer to the MAC entity whenever the PHY has received a PHY-TXEND.request immediately after transmitting the end of the last bit of the last data octet indicating that the last data octet has been transferred.

12.3.5.7.4 Effect of receipt

The receipt of this primitive by the MAC entity provides the time reference for the contention backoff protocol.

12.3.5.8 PHY-CCARESET.request

12.3.5.8.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to reset the clear channel assessment (CCA) state machine.

12.3.5.8.2 Semantics of the service primitive

The semantics of the primitives are as follows:

PHY-CCARESET.request

There are no parameters associated with this primitive.

12.3.5.8.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity at the end of a NAV timer. This request can be used by some PHY implementations that may synchronize antenna diversity with slot timings.

12.3.5.8.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to reset the PLCP CS/CCA assessment timers to the state appropriate for the end of a received frame.

12.3.5.9 PHY-CCARESET.confirm

12.3.5.9.1 Function

This primitive is issued by the PHY sublayer to the local MAC entity to confirm that the PHY has reset the CCA state machine.

12.3.5.9.2 Semantics of the service primitive

The semantics of the primitives are as follows:

PHY-CCARESET.request

There are no parameters associated with this primitive.

12.3.5.9.3 When generated

This primitive is issued by the PHY sublayer to the MAC entity whenever the PHY has received a PHY-CCARESET.request.

12.3.5.9.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.10 PHY-CCA.indication

12.3.5.10.1 Function

This primitive is an indication by the PHY sublayer to the local MAC entity of the current state of the medium.

12.3.5.10.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-CCA.indication (STATE)

The STATE parameter can be one of two values: BUSY or IDLE. The parameter value is BUSY if the channel assessment by the PHY sublayer determines that the channel is not available. Otherwise, the value of the parameter is IDLE.

12.3.5.10.3 When generated

This primitive is generated every time the status of the channel changes from channel idle to channel busy or from channel busy to channel idle. This includes the period of time when the PHY sublayer is receiving data. The PHY sublayer maintains the channel busy indication until the period indicated by the length field in a valid PLCP Header has expired.

12.3.5.10.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.11 PHY-RXSTART.indication

12.3.5.11.1 Function

This primitive is an indication by the PHY sublayer to the local MAC entity that the PLCP has received a valid start frame delimiter (SFD) and PLCP Header.

12.3.5.11.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-RXSTART.indication (RXVECTOR)

The RXVECTOR represents a list of parameters that the PHY sublayer provides the local MAC entity upon receipt of a valid PLCP Header. This vector may contain both MAC and MAC management parameters. The required parameters are listed in 12.3.4.4.

12.3.5.11.3 When generated

This primitive is generated by the local PHY entity to the MAC sublayer whenever the PHY has successfully validated the PLCP Header error check CRC at the start of a new PLCP PDU.

12.3.5.11.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.12 PHY-RXEND.indication

12.3.5.12.1 Function

This primitive is an indication by the PHY sublayer to the local MAC entity that the MPDU currently being received is complete.

12.3.5.12.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-RXEND.indication (RXERROR)

The RXERROR parameter can convey one or more of the following values: NoError, FormatViolation, CarrierLost, or UnsupportedRate. A number of error conditions may occur after the PLCP's receive state machine has detected what appears to be a valid preamble and SFD. The following describes the parameter returned for each of those error conditions.

- *NoError*. This value is used to indicate that no error occurred during the receive process in the PLCP.
- *FormatViolation*. This value is used to indicate that the format of the received PLCP PDU was in error.
- *CarrierLost*. This value is used to indicate that during the reception of the incoming MPDU, the carrier was lost and no further processing of the MPDU can be accomplished.
- *UnsupportedRate*. This value is used to indicate that during the reception of the incoming PLCP PDU, a nonsupported data rate was detected.

12.3.5.12.3 When generated

This primitive is generated by the PHY sublayer for the local MAC entity to indicate that the receive state machine has completed a reception with or without errors.

12.3.5.12.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

13. PHY management

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a station. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex D.

14. Frequency-Hopping spread spectrum (FHSS) PHY specification for the 2.4 GHz Industrial, Scientific, and Medical (ISM) band

14.1 Overview

14.1.1 Overview of FHSS PHY

The PHY services provided to the IEEE 802.11 wireless LAN MAC for the 2.4 GHz frequency-hopping spread spectrum (FHSS) system are described in this clause. The FHSS PHY consists of the following two protocol functions:

- a) A physical layer convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 MAC sublayer protocol data units (MPDUs) into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
- b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a wireless medium (WM) between two or more STAs.

14.1.2 FHSS PHY functions

The 2.4 GHz FHSS PHY architecture is shown in Figure 11. The FHSS PHY contains three functional entities: the PMD function, the physical layer convergence function, and the physical layer management function. Each of these functions is described in detail in the following subclauses.

The FHSS PHY service is provided to the MAC entity at the STA through a PHY service access point (SAP) called the PHY-SAP, as shown in Figure 11. A set of primitives might also be defined that describe the interface between the physical layer convergence protocol sublayer and the PMD sublayer, called the PMD-SAP.

14.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PHY convergence sublayer is defined. This function simplifies provision of a PHY service interface to the IEEE 802.11 MAC services.

14.1.2.2 Physical layer management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MAC management entity.

14.1.2.3 PMD sublayer

The PMD sublayer provides a transmission interface used to send and receive data between two or more STAs.

14.1.3 Service specification method and notation

The models represented by state diagrams in the following subclauses are intended as the primary specifications of the functions provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology.

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation.

14.2 FHSS PHY-specific service parameter lists

14.2.1 Overview

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PMD requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MAC sublayer management entity (MLME). The MLME in certain PMD implementations may need to interact with the physical layer management entity (PLME) as part of the normal PHY-SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY Service Primitives as TXVECTOR and RXVECTOR. The list of these parameters and the values they may represent are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the FHSS PHY.

All of the values included in the TXVECTOR or RXVECTOR described in this subclause are considered mandatory unless otherwise specified. The 1 Mbit/s and 2 Mbit/s data rates are the only rates currently supported. Other indicated data rates are for possible future use.

14.2.2 TXVECTOR parameters

The parameters in Table 28 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service primitive.

Table 28—TXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-TXSTART.request (TXVECTOR)	1–4095
DATARATE	PHY-TXSTART.request (TXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.2.1 TXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the number of octets in the MPDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start a transmission.

14.2.2.2 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PLCP should transmit the PSDU. Its value can be any of the rates as defined in Table 28, and supported by the conformant FH PHY.

14.2.3 RXVECTOR parameters

The parameters in Table 29 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indicate service primitive.

Table 29—RXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-RXSTART.indicate (RXVECTOR)	1–4095
RSSI	PHY-RXSTART.indicate (RXVECTOR)	0–RSSI Max
DATARATE	PHY-RXSTART.request (RXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.3.1 TRXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the value contained in the LENGTH field that the PLCP has received in the PLCP Header. The MAC and PLCP will use this value to determine the number of octet transfers that will occur between the two sublayers during the transfer of the received PSDU.

14.2.3.2 RXVECTOR RSSI

The receive signal strength indicator (RSSI) is an optional parameter that has a value of 0 through RSSI Max. This parameter is a measure by the PHY sublayer of the energy observed at the antenna used to receive the current PPDU. RSSI shall be measured between the beginning of the start frame delimiter (SFD) and the end of the PLCP header error check (HEC). RSSI is intended to be used in a relative manner. Absolute accuracy of the RSSI reading is not specified.

14.3 FHSS PLCP sublayer

14.3.1 Overview

This subclause provides a convergence procedure to map MPDUs into a frame format designed for FHSS radio transceivers. The procedures for transmission, carrier sense, and reception are defined for single and multiple antenna diversity radios.

14.3.1.1 State diagram notation

The operation of the procedures can be described by state diagrams. Each diagram represents the domain and consists of a group of connected, mutually exclusive states. Only one state is active at any given time. Each state is represented by a rectangle as shown in Figure 69. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name. The lower part contains the name of any signal that is generated. Actions described by short phrases are enclosed in brackets.

Each permissible transition between the states is represented graphically by an arrow from the initial to the terminal state. A transition that is global in nature (for example, an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

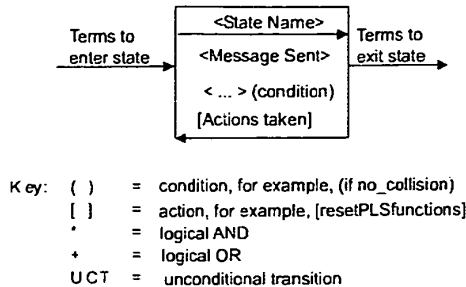


Figure 69—State diagram notation example

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard are allowed to have two or more ports. State diagrams capable of describing the operation of devices with an unspecified number of ports require qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following convention is used to describe a term-assignment statement that is associated with a transition:

- a) The character “:” (colon) is a delimiter used to denote that a term assignment statement follows.
- b) The character “<” (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

The state diagrams contain the authoritative statement of the procedures they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not, however, override any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

14.3.2 PLCP frame format

The PLCP protocol data unit (PPDU) frame format provides for the asynchronous transfer of MAC sublayer MPDUs from any transmitting STA to all receiving STAs within the wireless LAN's BSS. The PPDU illustrated in Figure 70 consists of three parts: a PLCP Preamble, a PLCP Header, and a PSDU. The PLCP Preamble provides a period of time for several receiver functions. These functions include antenna diversity, clock and data recovery, and field delineation of the PLCP Header and the PSDU. The PLCP Header is used to specify the length of the whitened PSDU field and support any PLCP management information. The PPDU contains the PLCP Preamble, the PLCP Header, and the PSDU modified by the PPDU data whitener.

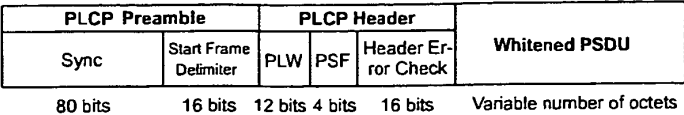


Figure 70—PLCP frame format

14.3.2.1 PLCP Preamble

The PLCP Preamble contains two separate subfields; the Preamble Synchronization (SYNC) field and the Start Frame Delimiter (SFD), to allow the PHY circuitry to reach steady-state demodulation and synchronization of bit clock and frame start.

14.3.2.1.1 Preamble SYNC field

The Preamble SYNC field is an 80-bit field containing an alternating zero-one pattern, transmitted starting with zero and ending with one, to be used by the PHY sublayer to detect a potentially receivable signal, select an antenna if diversity is utilized, and reach steady-state frequency offset correction and synchronization with the received packet timing.

14.3.2.1.2 Start Frame Delimiter (SFD)

The SFD consists of the 16-bit binary pattern 0000 1100 1011 1101 (transmitted leftmost bit first). The first bit of the SFD follows the last bit of the sync pattern. The SFD defines the frame timing.

14.3.2.2 PLCP Header field

The PLCP Header field contains three separate subfields: a 12-bit PSDU Length Word (PLW), a 4-bit PLCP Signaling field (PSF), and a 16-bit PLCP HEC field.

14.3.2.2.1 PSDU length word

The PSDU length word (PLW) is passed from the MAC as a parameter within the PHY-TXSTART.request primitive. The PLW specifies the number of octets contained in the PSDU. Its valid values are X'001'–X'FFF', representing counts of one to 4095 octets. The PLW is transmitted lsb first and msb last. The PLW is used by the receiving STA, in combination with the 32/33 coding algorithm specified in this clause, to determine the last bit in the packet.

14.3.2.2.2 PLCP Signaling field (PSF)

The 4-bit PSF is defined in Table 30. The PSF is transmitted bit 0 first and bit 3 last.

Table 30—PSF bit descriptions

Bit	Parameter name	Parameter values	Description																																				
0	Reserved	Default = 0	Reserved																																				
1:3	PLCP_BITRATE	<table> <tr> <td>b1</td><td>b2</td><td>b3</td><td>= Data Rate</td></tr> <tr> <td>0</td><td>0</td><td>0</td><td>= 1.0 Mbit/s,</td></tr> <tr> <td>0</td><td>0</td><td>1</td><td>= 1.5 Mbit/s,</td></tr> <tr> <td>0</td><td>1</td><td>0</td><td>= 2.0 Mbit/s,</td></tr> <tr> <td>0</td><td>1</td><td>1</td><td>= 2.5 Mbit/s,</td></tr> <tr> <td>1</td><td>0</td><td>0</td><td>= 3.0 Mbit/s,</td></tr> <tr> <td>1</td><td>0</td><td>1</td><td>= 3.5 Mbit/s,</td></tr> <tr> <td>1</td><td>1</td><td>0</td><td>= 4.0 Mbit/s,</td></tr> <tr> <td>1</td><td>1</td><td>1</td><td>= 4.5 Mbit/s</td></tr> </table>	b1	b2	b3	= Data Rate	0	0	0	= 1.0 Mbit/s,	0	0	1	= 1.5 Mbit/s,	0	1	0	= 2.0 Mbit/s,	0	1	1	= 2.5 Mbit/s,	1	0	0	= 3.0 Mbit/s,	1	0	1	= 3.5 Mbit/s,	1	1	0	= 4.0 Mbit/s,	1	1	1	= 4.5 Mbit/s	This field indicates the data rate of the whitened PSDU from 1 Mbit/s to 4.5 Mbit/s in 0.5 Mbit/s increments.
b1	b2	b3	= Data Rate																																				
0	0	0	= 1.0 Mbit/s,																																				
0	0	1	= 1.5 Mbit/s,																																				
0	1	0	= 2.0 Mbit/s,																																				
0	1	1	= 2.5 Mbit/s,																																				
1	0	0	= 3.0 Mbit/s,																																				
1	0	1	= 3.5 Mbit/s,																																				
1	1	0	= 4.0 Mbit/s,																																				
1	1	1	= 4.5 Mbit/s																																				

14.3.2.2.3 Header Error Check (HEC) field

The HEC field is a 16-bit CCITT CRC-16 error detection field. The HEC uses the CCITT CRC-16 generator polynomial $G(x)$ as follows:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The HEC shall be the one's complement of the sum (modulo 2) of the following:

- The remainder of $x^k \times (x^{15} + x^{14} + \dots + x^2 + x^1 + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the PSF and PLW fields of the PLCP Header;
- The remainder after multiplication by x^{16} and then division (modulo 2) by $G(x)$ of the content (treated as a polynomial) of the PSF and PLW fields.

The HEC shall be transmitted with the coefficient of the highest term first.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all ones and is then modified by division of the PSF and PLW fields by the generator polynomial, $G(x)$. The one's complement of this remainder is inserted in the HEC field with the msb transmitted first.

At the receiver, the initial remainder of the division is again preset to all ones. The division of the received PSF, PLW, and HEC fields by the generator polynomial, $G(x)$, results, in the absence of transmission errors, in a unique nonzero value, which is the following polynomial $R(x)$:

$$R(x) = x^{12} + x^{11} + x^{10} + x^8 + x^3 + x^2 + x^1 + 1$$

14.3.2.3 PLCP data whitener

The PLCP data whitener uses a length-127 frame-synchronous scrambler followed by a 32/33 bias-suppression encoding to randomize the data and to minimize the data dc bias and maximum run lengths. Data octets are placed in the transmit serial bit stream lsb first and msb last. The frame synchronous scrambler uses the generator polynomial $S(x)$ as follows:

$$S(x) = x^7 + x^4 + 1$$

and is illustrated in Figure 71. The 127-bit sequence generated repeatedly by the scrambler is (leftmost bit used first) 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 11111111. The same scrambler is used to scramble transmit data and to descramble receive data. The data whitening starts with the first bit of the PSDU, which follows the last bit of the PLCP Header. The specific bias suppression encoding and decoding method used is defined in Figure 75 and Figure 80. The format of the packet after data whitening is as shown in Figure 72.

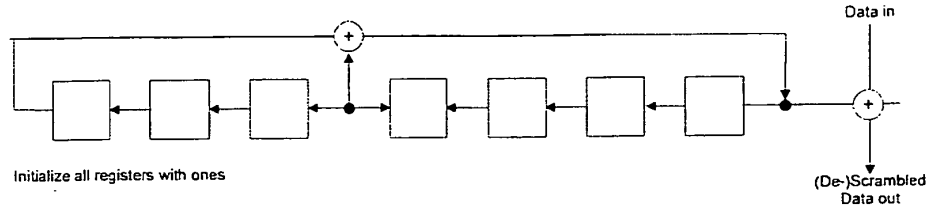


Figure 71—Frame synchronous scrambler/descrambler

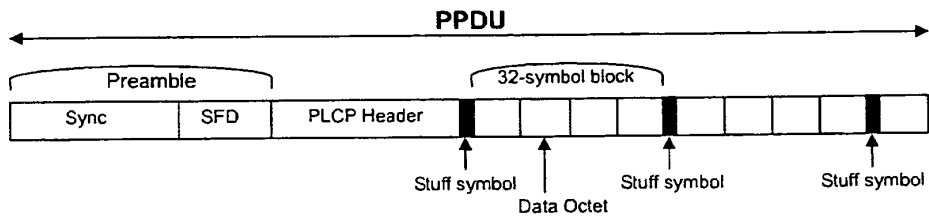


Figure 72—PLCP data whitener format

14.3.3 PLCP state machines

The PLCP consists of three state machines, as illustrated in the overview diagram of Figure 73: the transmit (TX), carrier sense/clear channel assessment (CS/CCA), and receive (RX) state machines. The three PLCP state machines are defined in the subclauses below; Figure 73 is not a state diagram itself. Execution of the PLCP state machines normally is initiated by the FH PLME state machine and begins at the CS/CCA state machine. The PLCP returns to the FH PLME state machine upon interrupt to service a PLME service request, such as PLME-SET, PLME-RESET, etc.

14.3.3.1 PLCP transmit procedure

The PLCP transmit procedure is invoked by the CS/CCA procedure immediately upon receiving a PHY-TXSTART.request(TXVECTOR) from the MAC sublayer. The CSMA/CA protocol is performed by the MAC with the PHY PLCP in the CS/CCA procedure prior to executing the transmit procedure.

14.3.3.1.1 Transmit state machine

The PLCP transmit state machine illustrated in Figure 74 includes functions that must be performed prior to, during, and after PPDU data transmission. Upon entering the transmit procedure in response to a PHY-TXSTART.request(TXVECTOR) from the MAC, the PLCP shall switch the PHY PMD circuitry from receive to transmit state; ramp on the transmit power amplifier in the manner prescribed in 14.6; and transmit the preamble sync pattern and SFD. The PLCP shall generate the PLCP Header as defined in 14.3.2.2 in

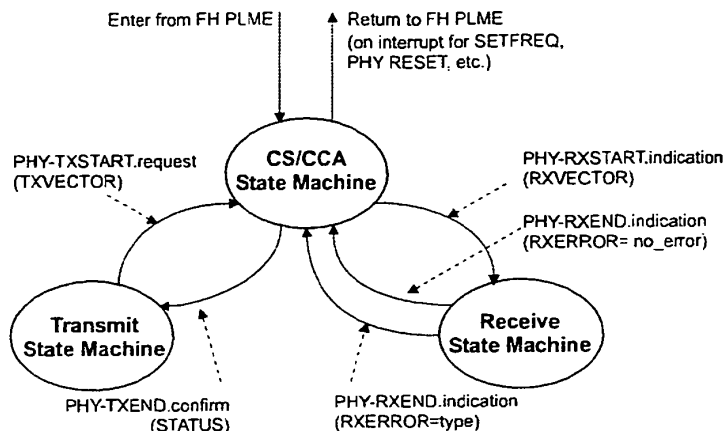


Figure 73—PLCP top-level state diagram

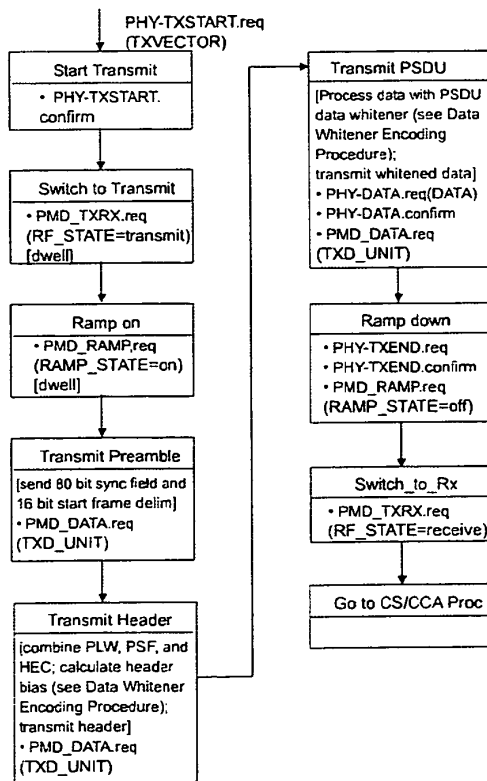


Figure 74—Transmit state machine

sufficient time to send the bits at their designated bit slot time. The PLCP shall add the PLCP Header to the start of the PSDU data.

Prior to transmitting the first PSDU data bit, the PLCP shall send a PHY-TXSTART.confirm message to the MAC indicating that the PLCP is ready to receive an MPDU data octet. The MAC will pass an MPDU data octet to the PHY with a PHY-DATA.request(DATA), which the PHY will respond to with a PHY-DATA.confirm. This sequence of PHY-DATA.request(DATA) and PHY-DATA.confirm shall be executed until the last data octet is passed to the PLCP. During transmission of the PSDU data, each bit of the PSDU shall be processed by the data whitener algorithm defined in Figure 75 and described in 14.3.2.3. Each PSDU data octet is processed and transmitted lsb first and msb last.

Data whitener encoding algorithm:

```

/*      If msb of stuff symbol = 1 then the next block is inverted; 0 = not inverted */
/*      Accumulate PLCP Header; begin stuffing on first bit of the PSDU */

/***** Calculate number of 32-symbol BSE blocks required to send PSDU;
        no padding is necessary when the number of symbols is not a multiple of 32 *****/
Input parameter: number_of_PSDU_octets, rate;          /* rate is 1 or 2 */
number_of_symbols = (number_of_PSDU_octets * 8) / rate;
number_of_blocks_in_packet = truncate((number_of_symbols + 31) / 32);

/***** Accumulate the bias in the header to use in calculating the inversion state of the first
        block of PSDU data *****/
Read in header {b(1),...,b(32)};          /* b(1) is first bit in */
header_bias = Sum{weight(b(1)),...,weight(b(32))};
/* calculate bias in header; weights are defined in Table 31 */
Transmit {b(1),...,b(32)};          /* no stuffing on header */
accum = header_bias;          /* initialize accum */
Initialize scrambler to all ones;

/***** Whiten the PSDU data with scrambler and BSE encoder *****/
For n = 1 to number_of_blocks_in_packet
{
    b(0) = 0 for 1 Mbit/s; b(0)=00 for 2 Mbit/s;          /* b(0) is the stuff symbol */
    N = min(32, number_of_symbols);          /* N = block size in symbols */
    Read in next symbol block {b(1),...,b(N)};          /* b(n) = {0,1} or {0,1,2,3};
    1 - 8 octets, use PHY-DATA.req(DATA), PHY-DATA.confirm for each octet */
    Scramble {b(1),...,b(N)};          /* see 14.3.2.3 */
    bias_next_block = Sum{weight(b(0)),...,weight(b(N))};          /* calculate bias with b(0)=0 */

    /**** if accum and bias of next block has the same sign, then invert block;
        if accum=0 or bias_next_block=0, don't invert *****/
    If {[accum * bias_next_block > 0] then
    {
        Invert {b(0),...,b(N)};          /* Invert deviation, or, negate msb of symbol */
        bias_next_block = - bias_next_block;
    }

    accum = accum + bias_next_block;
    transmit {b(0),...,b(N)};          /* b(0) is first symbol out */
    number_of_symbols = number_of_symbols - N
}

```

Figure 75—Data whitener encoding procedure

After the last MPDU octet is passed to the PLCP, the MAC will indicate the end of the frame with a *PHY-TXEND.request*. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall complete the transmit procedure by sending a *PHY-TXEND.confirm* to the MAC sublayer, ramp off the power amplifier in the manner prescribed in 14.6, and switch the PHY PMD circuitry from transmit to receive state. The execution shall then return to the CS/CCA procedure.

The weights assigned to each value of the symbols are defined in Table 31 for the 1 Mbit/s (2GFSK) and 2 Mbit/s (4GFSK) symbols.

Table 31—PLCP field bit descriptions

2GFSK	4GFSK	Weight
—	10	3
1	—	2
—	11	1
Center	Center	0
—	01	–1
0	—	–2
—	00	–3

14.3.3.1.2 Transmit state timing

The transmit timing illustrated in Figure 76 is defined from the instant that the *PHY-TXSTART.request(TXVECTOR)* is received from the MAC sublayer. The PLCP shall switch the PMD circuitry from receive to transmit, turn on and settle the transmitter, and begin transmitting the first bit of the preamble at the antenna within a maximum of 20 μ s of receiving the *PHY-TXSTART.request(TXVECTOR)*. The PLCP Preamble shall be transmitted at 1 Mbit/s and be completed in 96 μ s. The PLCP Header shall be transmitted at 1 Mbit/s and be completed in 32 μ s. The variable length PSDU shall be transmitted at the selected data rate. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall send the *PHY-TXEND.confirm* to the MAC sublayer. The PLCP shall turn off the transmitter, reducing the output energy to less than the specified off-mode transmit power within the time specified in 14.6. At the end of the power amplifier ramp down period, the PLCP shall switch the PMD circuitry from transmit to receive.

14.3.3.2 Carrier sense/clear channel assessment (CS/CCA) procedure

The PLCP CS/CCA procedure is executed while the receiver is turned on and the STA is not currently receiving or transmitting a packet. The CS/CCA procedure is used for two purposes: to detect the start of a network signal that can be received (CS) and to determine whether the channel is clear prior to transmitting a packet (CCA).

14.3.3.2.1 CS/CCA state machine

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA assessment windows is defined relative to the end of the last bit of the last packet on the air. The CS/CCA state machine is shown in Figure 77. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a MAC contention backoff slot time of 50 μ s. The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal that is received at the selected antenna up to 22 μ s after the start of the slot time with the synchronous detection performance specified in 14.6.15.3. Subclause 14.6.15.3 specifies detection performance with zero-one sync patterns and with random data patterns. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 μ s prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the asynchronous detection performance specified in 14.6.15.3.

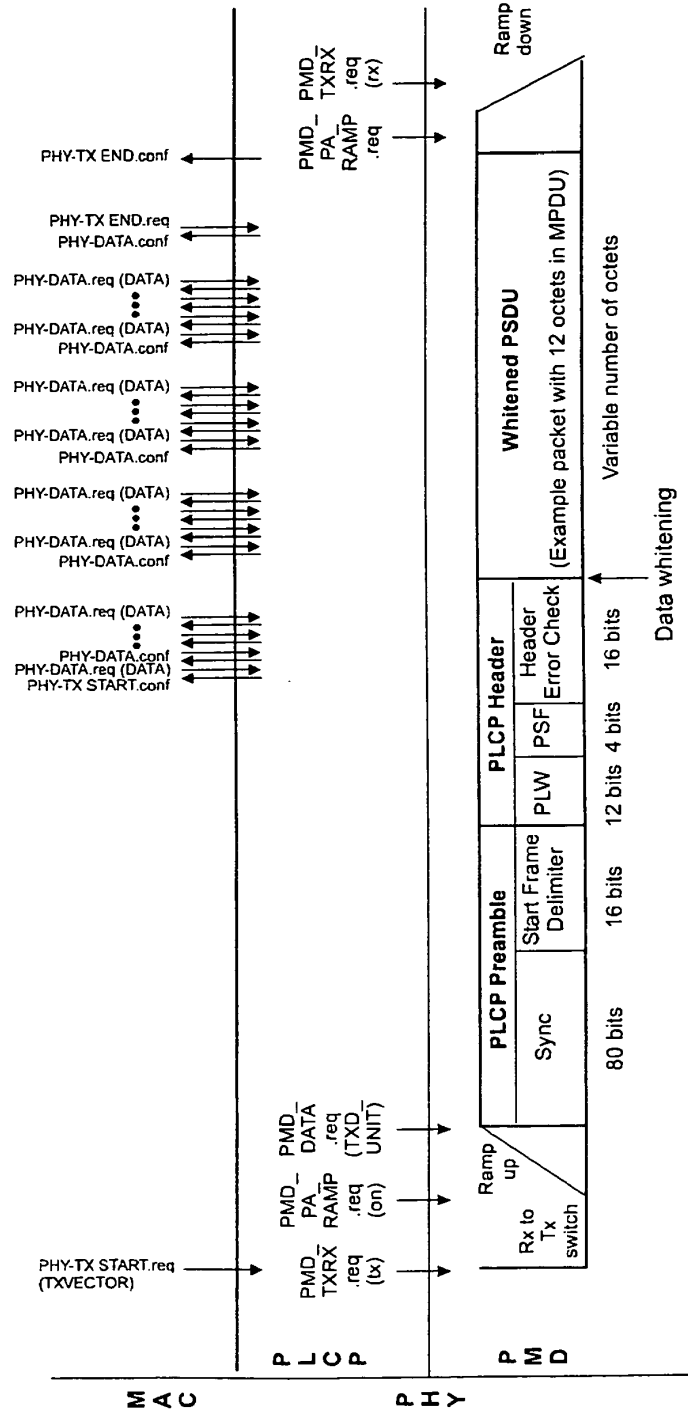


Figure 76—Transmit state timing

The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in 14.6.15.3.

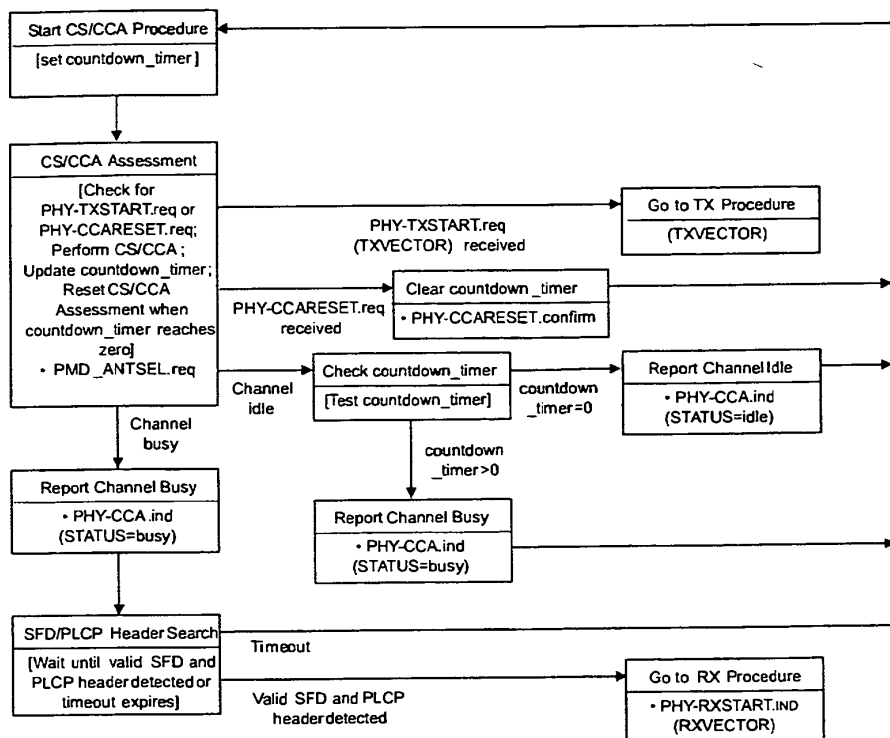


Figure 77—CS/CCA state machine

If a *PHY-TXSTART.request (TXVECTOR)* is received, the CS/CCA procedure shall exit to the transmit procedure within 1 μ s. If a *PHY-CCARESET.request* is received, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame. This service primitive is generated by the MAC at the end of a NAV period. The PHY shall indicate completion of the request by sending a *PHY-CCARESET.confirm* to the MAC.

If a CS/CCA assessment returns a channel idle result, the PHY shall send a *PHY-CCA.indicate(STATUS=idle)* to the MAC.

If a CS/CCA assessment returns a channel busy result, the PHY shall send a *PHY-CCA.indicate(STATUS=busy)* to the MAC. Upon a channel busy assessment, the PLCP shall stop any antenna switching prior to the earliest possible arrival time of the SFD and detect a valid SFD and PLCP Header if received. A valid PLCP Header is defined as containing valid PLCP Length Word and PHY Signaling field values and a valid HEC field. If a valid SFD/PLCP Header is detected, the CS/CCA procedure shall send a *PHY-RXSTART.indicate(RXVECTOR)* message to the MAC sublayer and exit to the receive procedure. The PLCP shall dwell and search for the SFD/PLCP Header for a minimum period longer than the latest possible arrival time of the SFD/PLCP Header. Indication of a busy channel does not necessarily lead to the successful reception of a frame.

The octet/bit count remaining may be a nonzero value when returning from the receive procedure if a signal in the process of being received was lost prior to the end as determined from the Length field of a valid PLCP Header. The countdown timer shall be set to the octet/bit count and used to force the CS/CCA indication to remain in the BUSY state until the predicted end of the frame regardless of actual CS/CCA indications.

However, if the CS/CCA procedure indicates the start of a new frame within the countdown timer period, it is possible to transition to the receive procedure prior to the end of the countdown timer period. If the PHY transitions to receive under these conditions, the countdown timer shall be reset to the longer of (1) the remaining time of the current frame or (2) the length of the new frame.

When a nonzero countdown timer reaches zero, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame and the CS/CCA indication shall reflect the state of the channel.

If the receive procedure encountered an unsupported rate error, the PLCP shall keep the CS/CCA state at Busy for the duration of the frame by setting the countdown timer to the value corresponding to the calculated time based on the information in the PLCP Header and the 33/32 expansion factor.

14.3.3.2.2 CS/CCA state timing

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA assessment windows is defined relative to the end of the last bit of the last packet on the air. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a slot time. The appropriate CS/CCA indication shall be available prior to the end of each 50 μ s slot time with the performance specified in 14.6. See Figure 78.

If a STA has not successfully received the previous packet, the perceived packet end time and slot boundary times will have a higher uncertainty for that STA.

14.3.3.3 PLCP receive procedure

The PLCP receive procedure is invoked by the PLCP CS/CCA procedure upon detecting a portion of the preamble sync pattern followed by a valid SFD and PLCP Header.

14.3.3.3.1 Receive state machine

The PLCP receive procedure shown in Figure 79 includes functions that must be performed while the PPDU is being received. The PLCP receive procedure begins upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall set a PPDU octet/bit counter to indicate the last bit of the packet, receive the PPDU bits, and perform the data whitening decoding procedure shown in Figure 80 on each PPDU bit. The PLCP shall pass correctly received data octets to the MAC with a series of *PHY-DATA.indicate(DATA)*. After the last PPDU bit is received and the last octet is passed to the MAC, the PLCP shall send a *PHY-RXEND.indicate(RXERROR=no_error)* to the MAC sublayer. Upon error-free completion of a packet reception, the PLCP shall exit the receive procedure and return to the PLCP CS/CCA procedure with the octet/bit count set to 0.

If the PLCP Header was decoded without a CRC error but encountered an unsupported rate, then the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR=unsupported_rate)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

If an error was detected during the reception of the PPDU, the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR=carrier_lost)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

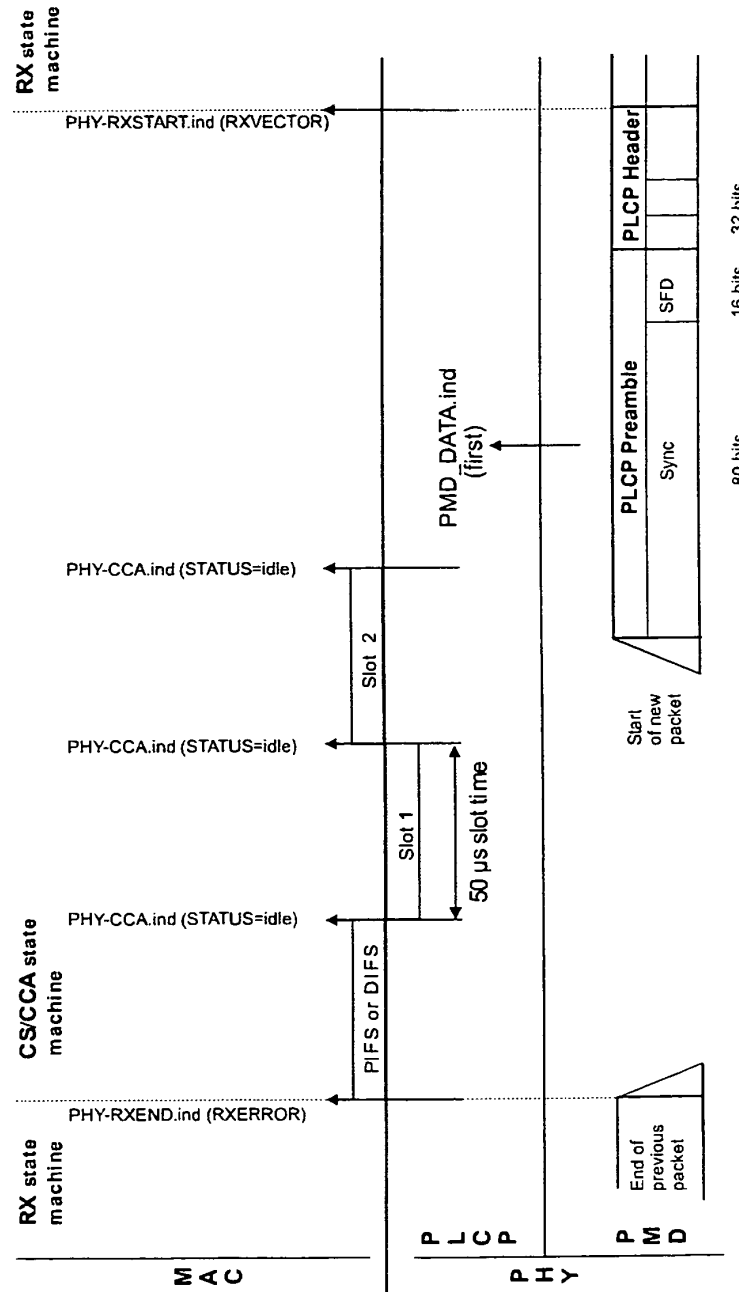


Figure 78—CS/CCA state timing

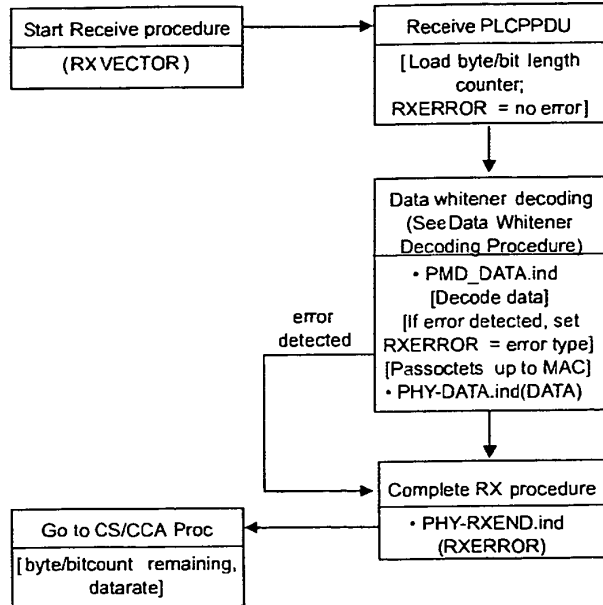


Figure 79—Receive state machine

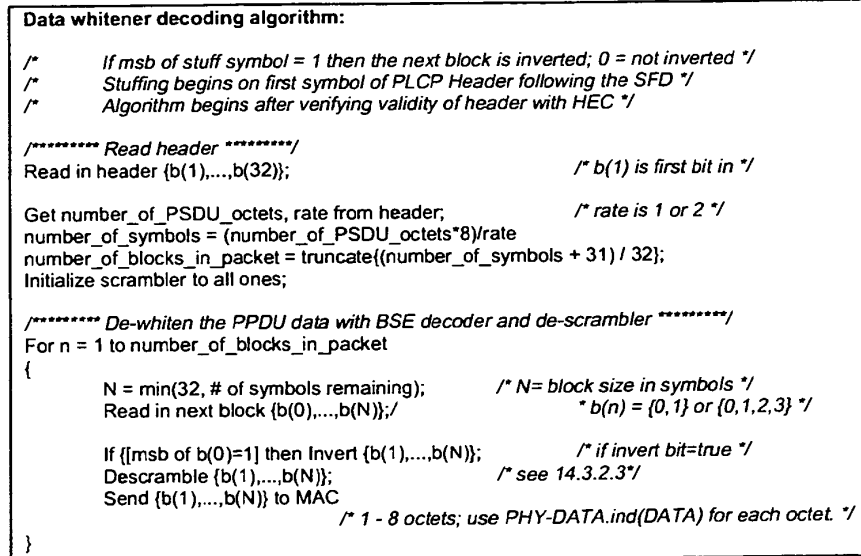


Figure 80—Data whitener decoding procedure

14.3.3.3.2 Receive state timing

The receive state timing shown in Figure 81 is defined to begin upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall begin receiving the variable length whitened PSDU immediately after the end of the last bit of the PLCP Header. The PLCP shall send a *PHY-RXEND.indicate(RXERROR)* after receiving the last PPDU data bit.

If any error was detected during the reception of the PPDU, the PLCP may send a *PHY-RXEND.indicate(RXERROR)* and terminate the receive procedure before the last bit arrives.

14.4 PLME SAP layer management

14.4.1 Overview

This subclause describes the services provided by the FHSS PLME to the upper layer management entities. The PLME/PMD services are defined in terms of service primitives. These primitives are abstract representations of the services and are not intended to restrict implementations.

14.4.2 FH PHY specific MAC sublayer management entity (MLME) procedures

14.4.2.1 Overview

The specific MAC sublayer management entity (MLME) procedures required for operating the FHSS PHY are specified in this portion of the subclause. The relationship between the MLME and FH PLME procedures is also described.

14.4.2.2 FH synchronization

The MLME of a compliant FH PHY STA shall perform the FH time synchronization procedure as defined in 11.1.5. This procedure provides for synchronized frequency hopping for all compliant FH PHY STAs within a single BSS or ad hoc network. The FH PLME accepts *PLME-SET.request* commands from the MLME to change the tune frequency at the time determined by the MLME. The tune frequency is changed by updating any combination of the Set, Pattern, and Index PHY MIB parameters.

14.4.3 FH PHY layer management entity state machines

14.4.3.1 Overview

This portion of this subclause describes the FH PHY layer management state machines to turn the PMD on/off, reset the PLCP state machine, and change the frequency hop channel.

14.4.3.2 PLME state machine

The PLME state machine in Figure 82 begins with a *PLME-SET.request (dot11CurrentPowerState= ON)*, which turns on the PHY circuitry, resets the PLME and PLCP state machines, and sends a *PLME-SET.confirm*. The MAC then sends a series of three *PLME-SET.request* primitives to update the *dot11CurrentSet*, *dot11CurrentPattern*, and *dot11CurrentIndex* PHY MIB parameters, which together tune the PMD to the selected channel. The PLME then transfers execution to the PLCP state machine as defined in 14.3.3.

Upon receiving a PLME request from a higher-level LME, the PLCP shall return execution to the PLME state machine and process the request. A *PLME-RESET.request* shall cause a reset to the PLME and PLCP state machines. A *PLME-SET.request* updating the *dot11CurrentIndex* or a combination of the *dot11CurrentSet*, *dot11CurrentPattern*, and *dot11CurrentIndex* shall cause the PLCP to terminate a receive

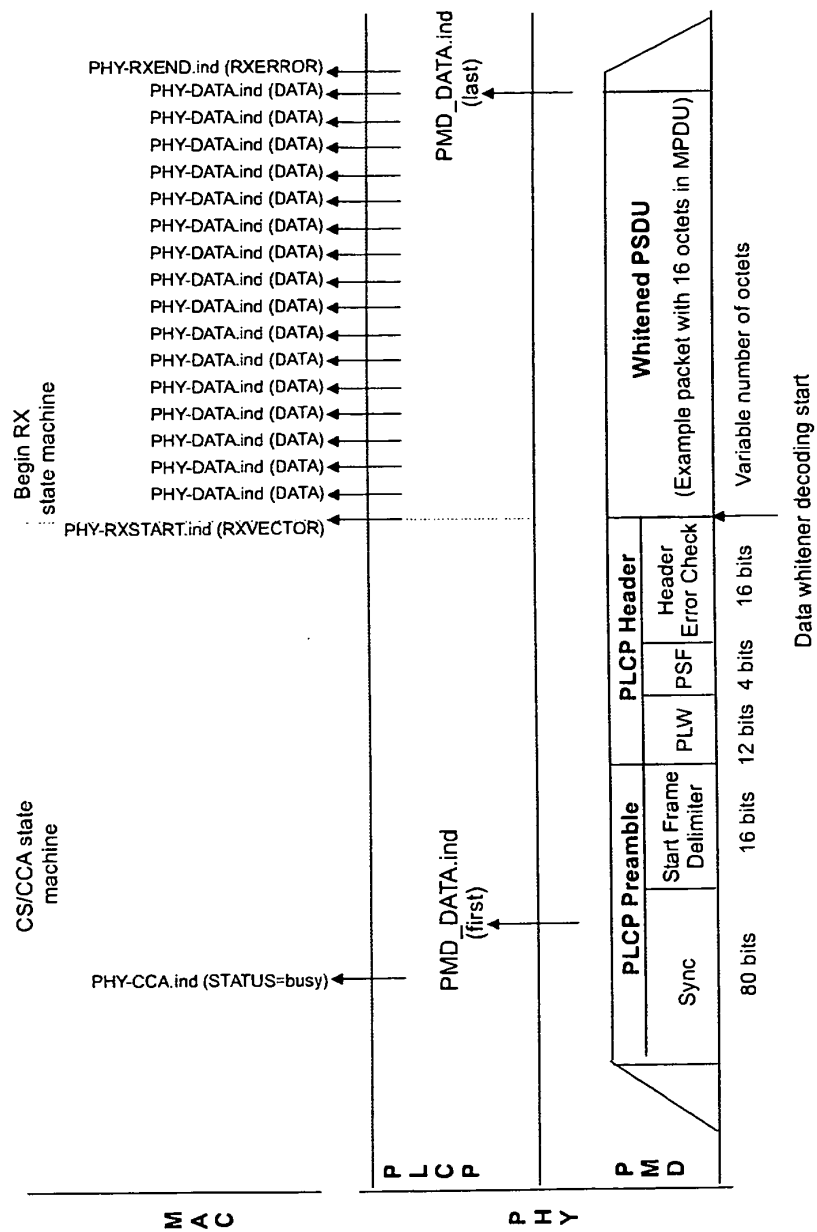


Figure 81—Receive timing

or CS/CCA process and change frequency before returning to the PLCP state machine. A *PLME-SET.request(dot11CurrentPowerState=OFF)* shall cause the PLCP to terminate a receive or CS/CCA process, power down the PMD circuitry, and return the PLME state machine to the idle state. *PLME-SET.requests* to any parameter other than the ones identified within this paragraph shall be executed and control shall be returned to the PLCP state machine. The MAC should not send a PLME request while the PLCP is in the transmit state.

All *PLME-GET.requests* shall be processed in parallel and with no interruption to the execution of any state machine in process.

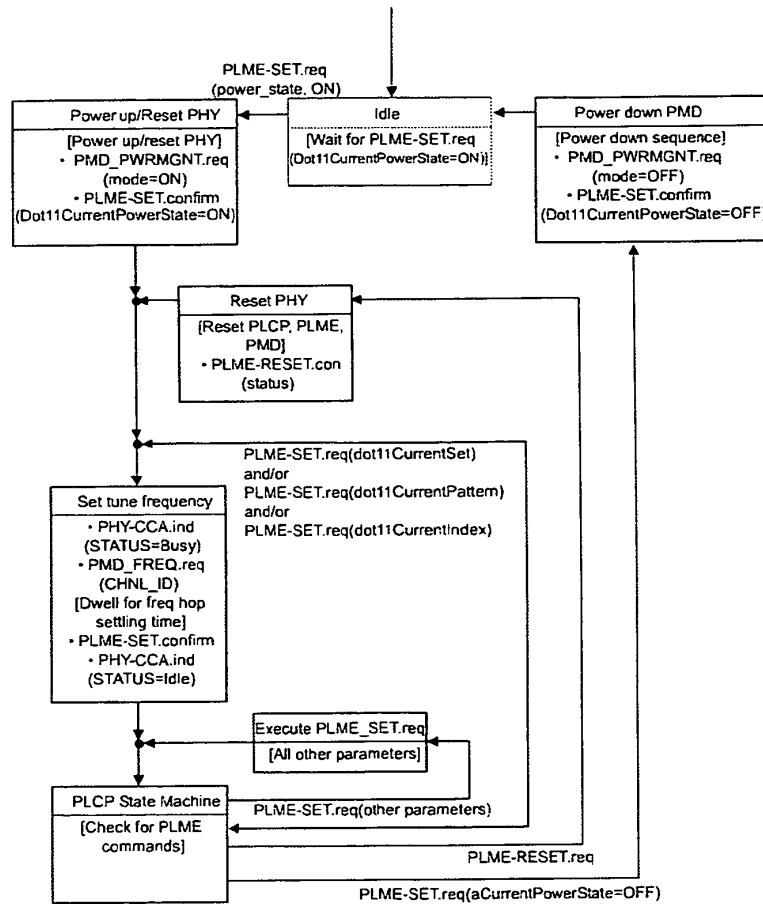


Figure 82—PLME state machine

14.4.3.3 PLME management primitives

The FH PLME uses the generic management primitives defined in 10.2 to manage all FH PHY parameters.

14.5 FHSS PMD sublayer services

14.5.1 Scope and field of application

The PMD services provided to the PLCP for the FHSS PHY are described in this subclause. Also defined in this subclause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire FHSS PHY is shown in Figure 83.

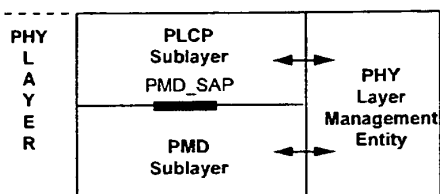


Figure 83—PMD layer reference model

14.5.2 Overview of services

In general, the FHSS PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which the signals required by these primitives are imposed onto the medium. In the FHSS PMD sublayer at the receiver the process is reversed. The combined function of the transmitting and receiving FHSS PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving PLCP sublayer.

14.5.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the FHSS PMD sublayer fall into the following two basic categories:

- Service primitives that support PLCP peer-to-peer interactions;
- Service primitives that have local significance and support sublayer-to-sublayer interactions.

14.5.4 Basic service and options

All of the service primitives described in this subclause are considered mandatory unless otherwise specified.

14.5.4.1 PMD_SAP peer-to-peer service primitives

Table 32 indicates the primitives for peer-to-peer interactions.

Table 32—PMD-SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_DATA	X	X	—	—

14.5.4.2 PMD_SAP sublayer-to-sublayer service primitives

Table 33 indicates the primitives for sublayer-to-sublayer interactions.

Table 33—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXRX	X	—	—	—
PMD_PA_RAMP	X	—	—	—
PMD_ANTSEL	X	—	—	—
PMD_TXPWRLVL	X	—	—	—
PMD_FREQ	X	—	—	—
PMD_RSSI	—	X	—	—
PMD_PWRMGMT	X	—	—	—

14.5.4.3 PMD_SAP service primitives parameters

Table 34 shows the parameters used by one or more of the PMD_SAP service primitives.

Table 34—List of parameters for PMD primitives

Parameter	Associate primitive	Value
TXD_UNIT	PMD_DATA.request	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RXD_UNIT	PMD_DATA.indicate	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RF_STATE	PMD_TXRX.request	TRANSMIT, RECEIVE
RAMP_STATE	PMD_PA_RAMP.request	ON, OFF
ANTENNA_STATE	PMD_ANTSEL.request	1 to 255
TXPWR_LEVEL	PMD_TXPWRLVL.request	LEVEL1, LEVEL2, LEVEL3, LEVEL4
CHNL_ID	PMD_FREQ.request	2–80 inclusive
STRENGTH	PMD_RSSI.indicate	0 to RSSI Max
MODE	PMD_PWRMGMT.request	ON, OFF

14.5.5 PMD_SAP detailed service specification

This subclause describes the services provided by each PMD primitive.

14.5.5.1 PMD_DATA.request

14.5.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

14.5.5.1.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.request (TXD_UNIT)

The TXD_UNIT parameter can take on one of two values: one or zero. This parameter represents a single data bit. The effect of this parameter is that the PMD will properly modulate the medium to represent ones or zeros as defined in the FHSS PMD modulation specifications for a given data rate.

14.5.5.1.3 When generated

This primitive is generated by the PLCP sublayer to request the transmission of a single data bit on the PMD sublayer. The bit clock is assumed to be resident or part of the PLCP and this primitive is issued at every clock edge once the PLCP has begun transmitting data.

14.5.5.1.4 Effect of receipt

The receipt of this primitive will cause the PMD entity to encode and transmit a single data bit.

14.5.5.2 PMD_DATA.indicate

14.5.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

14.5.5.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.indicate (RXD_UNIT)

The RXD_UNIT parameter can take on one of two values: one or zero. This parameter represents the current state of the medium as determined by the FHSS PMD modulation specifications for a given data rate.

14.5.5.2.3 When generated

The PMD_DATA.indicate is generated to all receiving PLCP entities in the network after a PMD_DATA.request is issued.

14.5.5.2.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.3 PMD_TXRX.request

14.5.5.3.1 Function

This primitive is used to place the PMD entity into the transmit or receive function.

14.5.5.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXRX.request (RF_STATE)

The RF_STATE parameter can take on one of two values: TRANSMIT or RECEIVE. When the value of the primitive is TRANSMIT, the RF state of the radio is transmit. If the value of the primitive is RECEIVE, the RF state of the radio is receive.

14.5.5.3.3 When generated

This primitive is generated whenever the mode of the radio needs to be set or when changing from transmit to receive or receive to transmit.

14.5.5.3.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the mode of the radio to be in either transmit or receive.

14.5.5.4 PMD_PA_RAMP.request

14.5.5.4.1 Function

This primitive defines the start of the ramp up or ramp down of the radio transmitter's power amplifier.

14.5.5.4.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PA_RAMP.request (RAMP_STATE)

The RAMP_STATE parameter can take on one of two values: ON or OFF. When the value of the primitive is ON, the state of the transmit power amplifier is "on." If the value of the primitive is OFF, the state of the transmit power amplifier is "off."

14.5.5.4.3 When generated

This primitive is issued only during transmit and to establish the initial state. It is generated by the PLCP at the start of the transmit function to turn the transmitter's power amplifier "on." A power amplifier ramp-up period follows the change of state from "off" to "on." After the PLCP has transferred all required data to the PMD entity, this primitive again will be issued by the PLCP to place the transmit power amplifier back into the "off" state. A power amplifier ramp-down period follows the change of state from "on" to "off."

14.5.5.4.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power amplifier to turn on or off.

14.5.5.5 PMD_ANTSEL.request

14.5.5.5.1 Function

This primitive is used to select which antenna the PMD entity will use to transmit or receive data.

14.5.5.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.request (ANTENNA_STATE)

The ANTENNA_STATE parameter can take on values from one to N (where N is the number of antennas supported). When the value of the primitive is a ONE, the PMD will switch to antenna 1 for receive or transmit; if the value of the primitive is TWO, the PMD entity will switch to antenna 2 for receive or transmit, etc.

14.5.5.5.3 When generated

This primitive is generated at various times by the PLCP entity to select an antenna. During receive, this primitive can be used to manage antenna diversity. During transmit, this primitive can be used to select a transmit antenna. This primitive will also be used during CCA.

14.5.5.5.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to select the antenna specified.

14.5.5.6 PMD_TXPWRLVL.request

14.5.5.6.1 Function

This primitive defines the power level the PMD entity will use to transmit data.

14.5.5.6.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXPWRLVL.request (TXPOWER_LEVEL)

The TXPOWER_LEVEL parameter can be one of the values listed in Table 35.

Table 35—Transmit power levels

TXPWR_LEVEL	Level description
LEVEL1	Defined as TxPowerLevel1 in MIB
LEVEL2	Defined as TxPowerLevel2 in MIB
LEVEL3	Defined as TxPowerLevel3 in MIB
LEVEL4	Defined as TxPowerLevel4 in MIB
LEVEL5	Defined as TxPowerLevel5 in MIB
LEVEL6	Defined as TxPowerLevel6 in MIB
LEVEL7	Defined as TxPowerLevel7 in MIB
LEVEL8	Defined as TxPowerLevel8 in MIB

14.5.5.6.3 When generated

This primitive is generated as part of the transmit sequence.

14.5.5.6.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power level to be modify.

14.5.5.7 PMD_FREQ.request

14.5.5.7.1 Function

This primitive defines the frequency the PMD entity will use to receive or transmit data. Since changing the radio frequency is not an immediate function, this primitive serves also as an indication of the start of this process. The completion of this process is dictated by other PMD specifications.

14.5.5.7.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_FREQ.request (CHANNEL_ID)

The CHANNEL_ID parameter can be one of the values listed in Table 38, Table 39, Table 40, or Table 41.

14.5.5.7.3 When generated

This primitive is generated by the PLCP whenever a change to a new frequency is required.

14.5.5.7.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to change to a new frequency defined by the value of the CHNL_ID.

14.5.5.8 PMD_RSSI.indicate

14.5.5.8.1 Function

This primitive transfers a receiver signal strength indication of the physical medium from the PMD sublayer to the PLCP sublayer. This value will be used by the PLCP to perform any diversity or clear channel assessment functions required by the PLCP or other sublayers.

14.5.5.8.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RSSI.indicate (STRENGTH)

The STRENGTH parameter can be a value from 0 to 15. This parameter is an indication by the PMD sublayer of the magnitude of the energy observed at the selected antenna. This reported value is used to generate the RSSI term in the PHY-RXSTART.ind(RXVECTOR) primitive and might also be used by any diversity function. Since RSSI is only used in a relative manner by the MAC sublayer, this parameter is defined to have no more than 16 values, ranging from 0 through RSSI_Max. The value zero is the weakest signal strength, while RSSI_Max is the strongest signal strength.

14.5.5.8.3 When generated

This primitive is generated continually by the PMD entity to transfer a receive signal strength indication to the PLCP.

14.5.5.8.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.9 PMD_PWRMGMT.request

14.5.5.9.1 Function

This primitive is used by the higher-layer entities to manage or control the power consumption of the PMD when not in use. This allows higher-layer entities to put the radio into a sleep or standby mode when receipt or sending of any data is not expected.

14.5.5.9.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PWRMGMT.request (MODE)

The MODE parameter can have one of two values: ON or OFF. When the value of the parameter is ON, the PMD entity will enter into a fully functional mode that allows it to send or receive data. When the value of the parameter is OFF, the PMD entity will place itself in a standby or power-saving mode. In the low-power mode, the PMD entity is not expected to be able to perform any request by the PLCP, nor is it expected to indicate any change in PMD state or status.

14.5.5.9.3 When generated

This primitive is delivered by the PLCP but actually is generated by a higher-layer management entity.

14.5.5.9.4 Effect of receipt

Upon receipt of this primitive, the PMD entity will enter a fully functional or low power consumption state depending on the value of the primitive's parameter.

14.6 FHSS PMD sublayer, 1.0 Mbit/s

14.6.1 1 Mbit/s PMD operating specifications, general

In general, the PMD accepts convergence layer service primitives and provides the actual means by which the signals required by these primitives are imposed on the medium. In the PMD sublayer at the receiver, the process is reversed. The combined function of the transmitting and receiving PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving convergence sublayer.

14.6.2 Regulatory requirements

Wireless LANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PMD specification establishes minimum technical requirements for interoperability, based upon established regulations for Europe, Japan, and North America at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PMD specification. Regulatory requirements that do not affect interoperability are not addressed within this standard. Implementors are referred to the following regulatory sources for further information.

Operation in countries within Europe, or other regions outside Japan or North America, may be subject to additional or alternative national regulations.

The documents listed below specify the current regulatory requirements for various geographic areas at the time this standard was developed. They are provided for information only, and are subject to change or revision at any time.

Geographic area	Approval standards	Documents	Approval authority
Europe	European Telecommunications Standards Institute (ETSI)	ETS 300-328, ETS 300-339	National type approval authorities
France	Règle technique applicable aux équipements radioélectriques de transmission de données à large bande fonctionnant dans la bande de fréquences à 2,4 GHz et utilisant la technique de l'étalement de spectre (Édition février 1995)	SP/DGPT/ATIAS/23, ETS 300-328, ETS 300-339	Direction Générale des Postes et Télécommunications (DGPT)
Japan	Association of Radio Industries and Businesses (ARIB)	RCR STD-33A	Ministry of Telecommunications (MKN)
North America Canada USA	Industry Canada (IC) Federal Communications Commission (FCC)	GL36 CFR47, Part 15, Sections 15.205, 15.209, 15.247	IC FCC
Spain	Suplemento Del Numero 164 Del Boletín Oficial Del Estado (Published 10 July 1991, Revised 25 June 1993)	ETS 300-328, ETS 300-339	Cuadro Nacional De Atribución De Frecuencias

14.6.3 Operating frequency range

A conformant PMD implementation shall be able to select the carrier frequency (F_c) from the full geographic-specific set of available carrier frequencies. Table 36 summarizes these frequencies for a number of geographic locations.

Table 36—Operating frequency range

Lower Limit	Upper limit	Regulatory range	Geography
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	North America
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	Europe ^a
2.473 GHz	2.495 GHz	2.471–2.497 GHz	Japan
2.447 GHz	2.473 GHz	2.445–2.475 GHz	Spain
2.448 GHz	2.482 GHz	2.4465–2.4835 GHz	France
NOTE—The frequency ranges in this table are subject to the geographic-specific regulatory authorities.			

^aExcluding Spain and France.

14.6.4 Number of operating channels

The number of transmit and receive frequency channels used for operating the PMD entity is 79 for the USA and Europe, and 23 for Japan. Table 37 summarizes these frequencies for a number of geographic locations. This is more fully defined in Table 38 through Table 41.

Table 37—Number of operating channels

Minimum	Hopping set	Geography
75	79	North America
20	79	Europe ^a
Not applicable	23	Japan
20	27	Spain
20	35	France
NOTE—The number of required hopping channels is subject to the geographic-specific regulatory authorities.		

^aExcluding Spain and France.

14.6.5 Operating channel center frequency

The channel center frequency is defined in sequential 1.0 MHz steps beginning with the first channel, channel 2.402 GHz for the USA and Europe excluding Spain and France, as listed in Table 38. The channel centers for Japan, starting at 2.473 GHz with 1 MHz increments, are listed in Table 39. The channel centers for Spain and France are listed in Table 40 and Table 41, respectively.

**Table 38—Requirements in North America and Europe
(excluding Spain and France; values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
2	2.402	28	2.428	54	2.454
3	2.403	29	2.429	55	2.455
4	2.404	30	2.430	56	2.456
5	2.405	31	2.431	57	2.457
6	2.406	32	2.432	58	2.458
7	2.407	33	2.433	59	2.459
8	2.408	34	2.434	60	2.460
9	2.409	35	2.435	61	2.461
10	2.410	36	2.436	62	2.462
11	2.411	37	2.437	63	2.463
12	2.412	38	2.438	64	2.464

**Table 38—Requirements in North America and Europe
(excluding Spain and France; values specified in GHz) (continued)**

Channel #	Value	Channel #	Value	Channel #	Value
13	2.413	39	2.439	65	2.465
14	2.414	40	2.440	66	2.466
15	2.415	41	2.441	67	2.467
16	2.416	42	2.442	68	2.468
17	2.417	43	2.443	69	2.469
18	2.418	44	2.444	70	2.470
19	2.419	45	2.445	71	2.471
20	2.420	46	2.446	72	2.472
21	2.421	47	2.447	73	2.473
22	2.422	48	2.448	74	2.474
23	2.423	49	2.449	75	2.475
24	2.424	50	2.450	76	2.476
25	2.425	51	2.451	77	2.477
26	2.426	52	2.452	78	2.478
27	2.427	53	2.453	79	2.479
—	—	—	—	80	2.480

**Table 39—Requirements in Japan
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
73	2.473	81	2.481	89	2.489
74	2.474	82	2.482	90	2.490
75	2.475	83	2.483	91	2.491
76	2.476	84	2.484	92	2.492
77	2.477	85	2.485	93	2.493
78	2.478	86	2.486	94	2.494
79	2.479	87	2.487	95	2.495
80	2.480	88	2.488	—	—

**Table 40—Requirements in Spain
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
47	2.447	56	2.456	65	2.465
48	2.448	57	2.457	66	2.466
49	2.449	58	2.458	67	2.467
50	2.450	59	2.459	68	2.468
51	2.451	60	2.460	69	2.469
52	2.452	61	2.461	70	2.470
53	2.453	62	2.462	71	2.471
54	2.454	63	2.463	72	2.472
55	2.455	64	2.464	73	2.473

**Table 41—Requirements in France
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
48	2.448	60	2.460	72	2.472
49	2.449	61	2.461	73	2.473
50	2.450	62	2.462	74	2.474
51	2.451	63	2.463	75	2.475
52	2.452	64	2.464	76	2.476
53	2.453	65	2.465	77	2.477
54	2.454	66	2.466	78	2.478
55	2.455	67	2.467	79	2.479
56	2.456	68	2.468	80	2.480
57	2.457	69	2.469	81	2.481
58	2.458	70	2.470	82	2.482
59	2.459	71	2.471	—	—

14.6.6 Occupied channel bandwidth

Occupied channel bandwidth shall meet all applicable local geographic regulations for 1 MHz channel spacing. The rate at which the PMD entity will hop is governed by the MAC. The hop rate is an attribute with a maximum dwell time subject to local geographic regulations.

14.6.7 Minimum hop rate

The minimum hop rate shall be governed by the regulatory authorities.

14.6.8 Hop sequences

The hopping sequence of an individual PMD entity is used to create a pseudorandom hopping pattern utilizing uniformly the designated frequency band. Sets of hopping sequences are used to co-locate multiple PMD entities in similar networks in the same geographic area and to enhance the overall efficiency and throughput capacity of each individual network.

An FH pattern, F_x , consists of a permutation of all frequency channels defined in Table 38 and Table 39. For a given pattern number, x , the hopping sequence can be written as follows:

$$F_x = \{f_x(1), f_x(2), \dots, f_x(p)\} \quad (1)$$

where

$f_x(i)$ is the channel number (as defined in 14.6.4) for i^{th} frequency in x^{th} hopping pattern;
 p is the number of frequency channels in hopping pattern (79 for North America and most of Europe, 23 for Japan, 35 for France, 27 for Spain).

Given the hopping pattern number, x , and the index for the next frequency, i (in the range 1 to p), the channel number shall be defined to be as follows:

$$\begin{aligned} f_x(i) &= [b(i) + x] \bmod (79) + 2 && \text{in North America and most of Europe, with } b(i) \text{ defined in Table 42.} \\ &= [(i - 1) \times x] \bmod (23) + 73 && \text{in Japan.} \\ &= [b(i) + x] \bmod (27) + 47 && \text{in Spain with } b(i) \text{ defined in Table 43.} \\ &= [b(i) + x] \bmod (35) + 48 && \text{in France with } b(i) \text{ defined in Table 44.} \end{aligned}$$

Table 42—Base-Hopping sequence $b(i)$ for North America and most of Europe

i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$
1	0	11	76	21	18	31	34	41	14	51	20	61	48	71	55
2	23	12	29	22	11	32	66	42	57	52	73	62	15	72	35
3	62	13	59	23	36	33	7	43	41	53	64	63	5	73	53
4	8	14	22	24	71	34	68	44	74	54	39	64	17	74	24
5	43	15	52	25	54	35	75	45	32	55	13	65	6	75	44
6	16	16	63	26	69	36	4	46	70	56	33	66	67	76	51
7	71	17	26	27	21	37	60	47	9	57	65	67	49	77	38
8	47	18	77	28	3	38	27	48	58	58	50	68	40	78	30
9	19	19	31	29	37	39	12	49	78	59	56	69	1	79	46
10	61	20	2	30	10	40	25	50	45	60	42	70	28	—	—

Table 43—Base-Hopping sequence $b(i)$ for Spain

i	$b(i)$	i	$b(i)$	i	$b(i)$
1	13	10	19	19	14
2	4	11	8	20	1
3	24	12	23	21	20
4	18	13	15	22	7
5	5	14	22	23	16
6	12	15	9	24	2
7	3	16	21	25	11
8	10	17	0	26	17
9	25	18	6	27	26

Table 44—Base-Hopping sequence $b(i)$ for France

i	$b(i)$	i	$b(i)$	i	$b(i)$
1	17	13	31	25	15
2	5	14	20	26	3
3	18	15	29	27	11
4	32	16	22	28	30
5	23	17	12	29	24
6	7	18	6	30	9
7	16	19	28	31	27
8	4	20	14	32	19
9	13	21	25	33	2
10	33	22	0	34	21
11	26	23	8	35	34
12	10	24	1	—	—

The sequences are designed to ensure some minimum distance in frequency between contiguous hops. The minimum hop size is 6 MHz for North America and Europe, including Spain and France, and 5 MHz for Japan.

The hopping pattern numbers x are divided into three sets. The sets are designed to avoid prolonged collision periods between different hopping sequences in a set. Hopping sequence sets contain 26 sequences for North America and Europe, and 4 sequences per set for Japan:

For North America and most of Europe:

$x = \{0,3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,51,54,57,60,63,66,69,72,75\}$	Set 1
$x = \{1,4,7,10,13,16,19,22,25,28,31,34,37,40,43,46,49,52,55,58,61,64,67,70,73,76\}$	Set 2
$x = \{2,5,8,11,14,17,20,23,26,29,32,35,38,41,44,47,50,53,56,59,62,65,68,71,74,77\}$	Set 3

For Japan:

$x = \{6, 9, 12, 15\}$ Set 1
 $x = \{7, 10, 13, 16\}$ Set 2
 $x = \{8, 11, 14, 17\}$ Set 3

For Spain:

$x = \{0, 3, 6, 9, 12, 15, 18, 21, 24\}$ Set 1
 $x = \{1, 4, 7, 10, 13, 16, 19, 22, 25\}$ Set 2
 $x = \{2, 5, 8, 11, 14, 17, 20, 23, 26\}$ Set 3

For France:

$x = \{0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30\}$ Set 1
 $x = \{1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31\}$ Set 2
 $x = \{2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32\}$ Set 3

The three sets of hopping sequences for North America and most of Europe, of 26 patterns each, are listed in Tables B.1, B.2, and B.3 in Annex B. Similarly, there are three sets for Japan of four patterns each. The three sets for Spain have nine patterns each. The three sets for France have 11 patterns each. The channel numbers listed under each pattern refer to the actual frequency values listed in Table 38 and Table 39.

14.6.9 Unwanted emissions

Conformant PMD implementations shall limit the emissions that fall outside of the operating frequency range, defined in Table 36, to the geographically applicable limits.

14.6.10 Modulation

The minimum set of requirements for a PMD to be compliant with the IEEE 802.11 FHSS PHY shall be as follows.

The PMD shall be capable of operating using two-level Gaussian frequency shift key (GFSK) modulation with a nominal bandwidth bit-period (BT)=0.5. The PMD shall accept symbols from the set $\{\{1\}, \{0\}\}$ from the PLCP. The symbol $\{1\}$ shall be encoded with a peak deviation of $(+f_d)$, giving a peak transmit frequency of $(F_c + f_d)$, which is greater than the carrier center frequency (F_c). The symbol $\{0\}$ shall be encoded with a peak frequency deviation of $(-f_d)$, giving a peak transmit frequency of $(F_c - f_d)$.

An incoming bit stream at 1 Mbit/s will be converted to symbols at $F_{clk} = 1$ Msymbols/s, as shown in Table 45.

Table 45—Symbol encoding into carrier deviation (1 Mbit/s, 2-GFSK)

Symbol	Carrier deviation
1	$1/2 \times h2 \times F_{clk}$
0	$-1/2 \times h2 \times F_{clk}$
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

The deviation factor h_2 for 2GFSK (measured as difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32.

The minimum frequency deviation, as shown in Figure 84, shall be greater than 110 kHz relative to the nominal center frequency F_c . F_d is the average center frequency of the last 8 bits of the Preamble Sync field, measured as the deviation at the midsymbol. Midsymbol is defined as the point that is midway between the zero crossings derived from a best fit to the last 8 bits of the Sync field. Maximum deviation is not specified, but modulation is subject to the occupied bandwidth limits of 14.6.5.

The zero crossing error shall be less than $\pm 1/8$ of a symbol period. The zero crossing error is the time difference between the ideal symbol periods and measured crossings of F_c . This is illustrated in Figure 84.

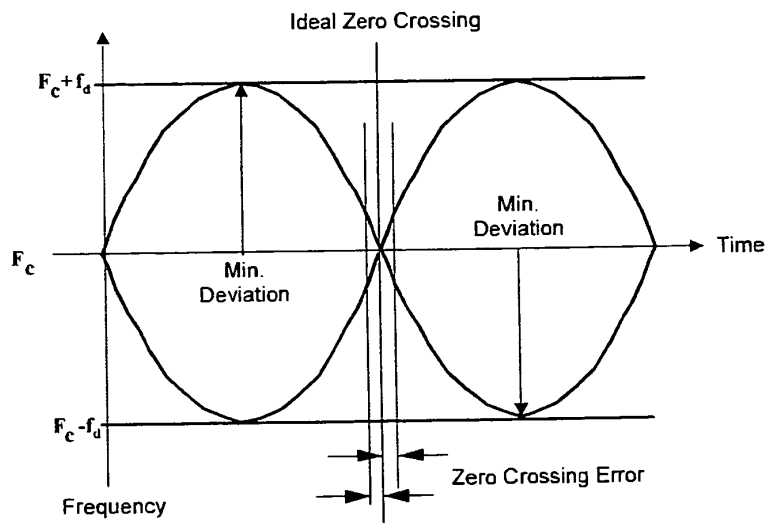


Figure 84—Transmit modulation mask

14.6.11 Channel data rate

A compliant IEEE 802.11 FHSS PMD shall be capable of transmitting and receiving at a nominal data rate of 1.0 Mbit/s $\pm$ 50 parts per million (ppm).

14.6.12 Channel switching/settling time

The time to change from one operating channel frequency, as specified in 14.6.3, is defined as 224 μ s. A conformant PMD meets this switching time specification when the operating channel center frequency has settled to within ± 60 kHz of the nominal channel center frequency as outlined in 14.6.3.

14.6.13 Receive to transmit switch time

The maximum time for a conformant PMD to switch the radio from the receive state to the transmit state and place the start of the first bit on the air shall be 19 μ s. At the end of this 19 μ s, the RF carrier shall be within the nominal transmit power level range, and within the described modulation specifications.

14.6.14 PMD transmit specifications

The following portion of this subclause describes the transmit functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP, and the transmit PMD entity provides the actual means by which the signals required by the PLCP primitives are imposed onto the medium.

14.6.14.1 Nominal transmit power

The nominal transmit power of a frame is defined as the power averaged between the start of the first symbol in the PLCP Header to the end of the last symbol in the PLCP Header. When in the transmit state, the transmit power shall be within 2 dB of the nominal transmit power from the start of the Preamble SYNC field to the last symbol at the end of the frame.

14.6.14.2 Transmit power levels

Unless governed by more stringent local geographic regulations, the radiated emissions from compliant devices shall meet IEEE Std C95.1-1991 limits for controlled or uncontrolled environments, in accordance with their intended usage. In addition, all conformant PMD implementations shall support at least one power level with a minimum equivalent isotropically radiated power (EIRP) of 10 mW.

14.6.14.3 Transmit power level control

If a conformant PMD implementation has the ability to transmit in a manner that results in the EIRP of the transmit signal exceeding the level of 100 mW, at least one level of transmit power control shall be implemented. This transmit power control shall be such that the level of the emission is reduced to a level at or below 100 mW under the influence of said power control.

14.6.14.4 Transmit spectrum shape

Within the operational frequency band the transmitter shall pass a spectrum mask test. The duty cycle between Tx and Rx is nominally 50% and the transmit frame length is nominally 400 μ s. The adjacent channel power is defined as the sum of the power measured in a 1 MHz band. For a pseudorandom data pattern, the adjacent channel power shall be a function of the offset between channel number N and the assigned transmitter channel M , where M is the actual transmitted center frequency and N is a channel separated from it by an integer number of megahertz.

Channel offset:

$|N-M|=2$ -20 dBm or -40 dBc, whichever is the lower power.

$|N-M|\geq 3$ -40 dBm or -60 dBc, whichever is the lower power.

The levels given in dBc are measured relative to the transmitter power measured in a 1 MHz channel centered on the transmitter center frequency. The adjacent channel power and the transmitter power for this subclause of the specification shall be measured with a resolution bandwidth of 100 kHz, a video bandwidth of 300 kHz, and a peak detector, and with the measurement device set to maximum hold.

For any transmit center frequency M , two exceptions to the spectrum mask requirements are permitted within the operational frequency band, provided the exceptions are less than -50 dBc, where each offset channel exceeded counts as a separate exception. An exception occurs when the total energy within a given 1 MHz channel as defined in 14.6.5 exceeds the levels specified above.

14.6.14.5 Transmit center frequency tolerance

The PMD transmit center frequency shall be within ± 60 kHz of the nominal center frequency as specified in 14.6.5.

14.6.14.6 Transmitter ramp periods

The transmitter shall go from off to within 2 dB of the nominal transmit power in 8 μ s or less. The transmitter shall go from within 2 dB of the nominal transmit power to off (less than -50 dBm) in 8 μ s or less.

14.6.15 PMD receiver specifications

The following portion of this subclause describes the receive functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP. The Receive PMD entity provides the actual means by which the signals required by the PLCP primitives are recovered from the medium. The PMD sublayer monitors signals on the medium and will return symbols from the set $\{\{1\}, \{0\}\}$ to the PLCP sublayer.

14.6.15.1 Input signal range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with a frame error ratio (FER) $\leq 3\%$ for PSDUs of 400 octets generated with pseudorandom data, for receiver input signal levels in the range from -20 dBm to the receiver sensitivity (as specified in 14.6.15.4), across the frequency band of operation.

14.6.15.2 Receive center frequency acceptance range

An IEEE 802.11 FHSS compliant PMD shall meet all specifications with an input signal having a center frequency range of ± 60 kHz from nominal.

14.6.15.3 CCA power threshold

In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -85 dBm that starts synchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 90% probability of detection, during the preamble within the CCA assessment window. In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -85 dBm that starts asynchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 70% probability of detection, during the preamble within the CCA window. In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -65 dBm, the PHY shall signal busy, with a 70% probability of detection, during random data within the CCA window. This specification applies to a PMD operating with a nominal EIRP of < 100 mW. A compliant PMD operating at a nominal output power greater than 100 mW shall use the following equation to define the CCA threshold, where P_t represents transmit power.

$$\text{CCA threshold (preamble)} = -85 \text{ dBm} - \left[5 \times \log_{10} \left(\frac{P_t}{100 \text{ mW}} \right) \right] \text{ dBm}$$

$$\text{CCA threshold (random data)} = \text{CCA threshold (preamble)} + 20 \text{ dB}$$

14.6.15.4 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudorandom data. The sensitivity shall be less than or equal to -80 dBm. The reference sensitivity is defined as -80 dBm for the 1 Mbit/s FH PHY specifications.

14.6.15.5 Intermodulation

Intermodulation protection (IMp) is defined as the ratio of the minimum amplitude of one of two equal interfering signals to the desired signal amplitude, where the interfering signals are spaced 4 MHz and 8 MHz removed from the center frequency of the desired signal, both on the same side of center frequency. The IMp protection ratio is established at the interfering signal level that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -77 dBm. Each interfering signal is modulated with the FH PMD modulation uncorrelated in time to each other or the desired signal. The PMD shall have the IMp for the interfering signal at 4 MHz and 8 MHz be ≥ 30 dB.

14.6.15.6 Desensitization

Desensitization (Dp) is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER at the output of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -77 dBm. The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 46. The spectral purity of the interferer shall be sufficient to ensure that the measurement is limited by the receiver performance.

Table 46—1 Mbit/s Dp

Interferer frequency ^a	Dp minimum
$M = N \pm 2$	30 dB
$M = N \pm 3$ or more	40 dB

^aWhere M is the interferer frequency and N is the desired channel frequency.

14.6.15.7 Receiver radiation

The signal leakage when receiving shall not exceed -50 dBm EIRP in the operating frequency range. The FHSS PHY shall conform with out-of-band spurious emissions by regulatory bodies.

14.6.16 Operating temperature range

Two temperature ranges for full operation compliance to the FH PHY are specified. Type 1 is defined as 0 °C to 40 °C and is designated for office environments. Type 2 is defined as -30 °C to +70 °C and is designated for industrial environments.

14.7 FHSS PMD sublayer, 2.0 Mbit/s

14.7.1 Overview

This subclause details the RF specification differences of the optional 2 Mbit/s operation from the baseline 1 Mbit/s PMD as contained in 14.6. Unless otherwise specified in this subclause, the compliant PMD shall also meet all requirements of 14.6 when transmitting at 2 Mbit/s. When implementing the 2 Mbit/s option, the preamble and PHY Header shall be transmitted at 1 Mbit/s. STAs implementing the 2 Mbit/s option shall also be capable of transmitting and receiving PPDU's at 1 Mbit/s.

14.7.2 Four-Level GFSK modulation

For an FHSS 2 Mbit/s PMD, the modulation scheme shall be four-level Gaussian frequency shift keying (4GFSK), with a nominal symbol-period bandwidth product (BT) of 0.5. The four-level deviation factor, defined as the frequency separation of adjacent symbols divided by symbol rate, h_4 , shall be related to the deviation factor of the 2GFSK modulation, h_2 , by the following equation:

$$h_4/h_2 = 0.45 \pm 0.01$$

An incoming bit stream at 2 Mbit/s will be converted to 2-bit words or symbols, with a rate of $F_{clk} = 1$ Msymbol/s. The first received bit will be encoded as the LMB of the symbol in Table 47. The bits will be encoded into symbols as shown in Table 47.

Table 47—Symbol encoding into carrier deviation

1 Mbit/s, 2GFSK	
Symbol	Carrier deviation
1	$1/2 \times h_2 \times F_{clk}$
0	$-1/2 \times h_2 \times F_{clk}$
2 Mbit/s, 4GFSK	
Symbol	Carrier deviation
10	$3/2 \times h_4 \times F_{clk}$
11	$1/2 \times h_4 \times F_{clk}$
01	$-1/2 \times h_4 \times F_{clk}$
00	$-3/2 \times h_4 \times F_{clk}$
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

The deviation factor h_2 for 2GFSK (measured as the difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32. The deviation factor h_2 will be no less than 0.30 (with maximum dictated by regulatory bandwidth requirement). Accordingly, h_4 (measured as a difference between the outermost frequencies, divided by 3, divided by 1 MHz) is nominally $0.45 \times 0.32 = 0.144$, and it will be no less than $0.45 \times 0.3 = 0.135$.

The modulation error shall be less than ± 15 kHz at the midsymbol time for 4GFSK, from the frequency deviations specified above, for a symbol surrounded by identical symbols, and less than ± 25 kHz for any symbol. The deviation is relative to the actual center frequency of the RF carrier. For definition purposes, the actual center frequency is the midfrequency between symbols 11 and 01. The actual center frequency shall be within ± 60 kHz of the nominal channel center frequency defined in 14.6.5 and shall not vary by more than ± 10 kHz/ms, from the start to end of the PPDU. The peak-to-peak variation of the actual center frequency over the PPDU shall not exceed 15 kHz. Symbols and terms used within this subclause are illustrated in Figure 85.

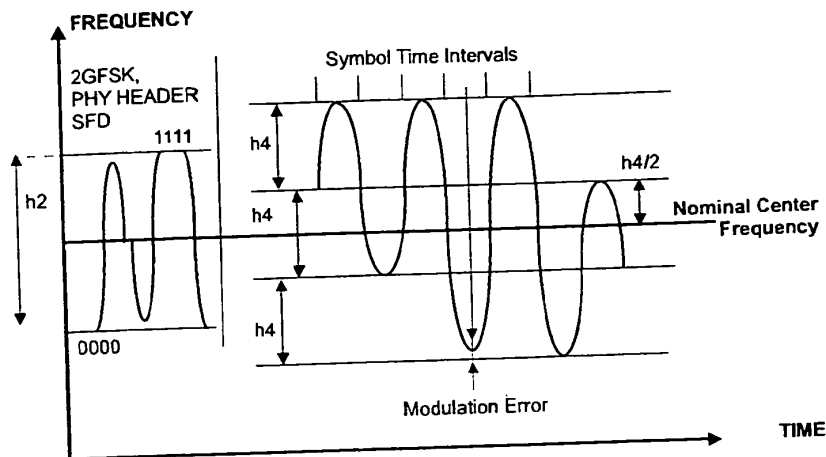


Figure 85—Four-Level GFSK transmit modulation

14.7.2.1 Frame structure for HS FHSS PHY

The high rate FHSS PPDU consists of PLCP Preamble, PLCP Header, and whitened PSDU. The PLCP Preamble and PLCP Header format are identical to the 1 Mbit/s PHY, as described in 14.3.2. The whitened PSDU is transmitted in 2GFSK, 4GFSK, or potentially a higher-rate format, according to the rate chosen. The rate is indicated in a 3-bit field in a PLCP Header, having a value of 1 or 2 bits/symbol (or Mbit/second).

The PPDU is transmitted as four-level symbols, with the amount determined by $\text{number\_of\_symbols} = (\text{number\_of\_PSDU\_octets} \times 8) / \text{rate}$.

The input bits are scrambled according to the method in 14.3.2.3.

The scrambled bit stream is divided into groups of rate (1 or 2) consecutive bits. The bits are mapped into symbols according to Table 47.

A bias suppression algorithm is applied to the resulting symbol stream. The bias suppression algorithm is defined in 14.3.2.3, Figure 72, and Figure 75. A polarity control symbol is inserted prior to each block of 32 symbols (or less for the last block). The polarity control signals are 4GFSK symbols 10 or 00. The algorithm is equivalent to the case of 2GFSK, with the polarity symbol 2GFSK "1" replaced with 4GFSK symbol "10," and the 2GFSK polarity symbol "0" replaced with a 4GFSK symbol "00."

14.7.3 Channel data rate

The data rate for the whitened PSDU at the optional rate shall be 2.0 Mbit/s $\pm$ 50 ppm.

14.7.3.1 Input dynamic range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with an FER $\leq$ 3% for PSDUs of 400 octets generated with pseudorandom data, for receiver input signal levels in the range from -20 dBm to the receiver sensitivity (as specified in 14.7.3.2), across the frequency band of operation.

14.7.3.2 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudorandom data. The sensitivity shall be less than or equal to -75 dBm. The reference sensitivity is defined as -75 dBm for the 2 Mbit/s FH PHY specifications.

14.7.3.3 IMp

IMp is defined as the ratio to -77 dBm of the minimum amplitude of one of the two equal-level interfering signals at 4 MHz and 8 MHz removed from center frequency, both on the same side of center frequency, that cause the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -72 dBm (3 dB above the specified sensitivity specified in 14.7.3.2). Each interfering signal is modulated with the FH 1 Mbit/s PMD modulation uncorrelated in time to each other or the desired signal. The FHSS optional 2 Mbit/s rate IMp shall be ≥ 25 dB.

14.7.3.4 Dp

Dp is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -72 dB (3 dB above sensitivity specified in 14.7.3.2). The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 48.

Table 48—2 Mbit/s Dp

Interferer frequency ^a	DP minimum
$M = N \pm 2$	20 dB
$M = N \pm 3$ or more	30 dB

^aWhere M is the interferer frequency and N is the desired channel frequency.

14.8 FHSS PHY management information base (MIB)

14.8.1 Overview

The following is the MIB for the FHSS PHY.

14.8.2 FH PHY attributes

This subclause defines the attributes for the FHSS MIB. Table 49 lists these attributes and the default values. Following the table is a description of each attribute.

Table 49—FHSS PHY attributes

Attribute	Default value	Operational semantics	Operational behavior
dot11PHYType	FHSS = X'01'	Static	Identical for all FH PHYs
dot11RegDomainsSupported	FCC = X'10' IC = X'20' ETSI = X'30' Spain = X'31' France = X'32' MKK = X'40'	Static	Implementation dependent
dot11CurrentRegDomain	X'00'	Dynamic LME	Implementation dependent
dot11TempType	Type 1 = X'01' Type 2 = X'02' Type 3 = X'03'	Static	Implementation dependent
dot11SupportedDataRatesTX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedDataRatesRX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedTxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11CurrentTxAntenna	Ant 1 = default	Dynamic LME	Implementation dependent
dot11SupportedRxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11DiversitySupport	Available = X'01' Not avail. = X'02' Control avail. = X'03'	Static	Implementation dependent
dot11DiversitySelectionRx	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant 4 = X'04' Ant 5 = X'05' Ant 6 = X'06' Ant 7 = X'07' Ant 8 = X'08'	Dynamic LME	Implementation dependent
dot11NumberSupportedPowerLevels	Lvl1 = X'01' Lvl2 = X'02' Lvl3 = X'03' Lvl4 = X'04' Lvl5 = X'05' Lvl6 = X'06' Lvl7 = X'07' Lvl8 = X'08'	Static	Implementation dependent
dot11TxPowerLevel1	Factory default	Static	Implementation dependent
dot11TxPowerLevel2	Factory default	Static	Implementation dependent
dot11TxPowerLevel3	Factory default	Static	Implementation dependent

Table 49—FHSS PHY attributes (continued)

Attribute	Default value	Operational semantics	Operational behavior
dot11TxPowerLevel4	Factory def.	Static	Implementation dependent
dot11TxPowerLevel5	Factory def.	Static	Implementation dependent
dot11TxPowerLevel6	Factory def.	Static	Implementation dependent
dot11TxPowerLevel7	Factory def.	Static	Implementation dependent
dot11TxPowerLevel8	Factory def.	Static	Implementation dependent
dot11CurrentTxPowerLevel	TxPowerLevel1	Dynamic LME	Implementation dependent
dot11HopTime	224 μ s	Static	Identical for all FH PHYs
dot11CurrentChannelNumber	X'00'	Dynamic PLME	
dot11MaxDwellTime	390 TU	Static	Regulatory domain dependent
dot11CurrentSet	X'00'	Dynamic PLME	
dot11CurrentPattern	X'00'	Dynamic PLME	
dot11CurrentIndex	X'00'	Dynamic PLME	
dot11CurrentPowerState	X'01' off X'02' on	Dynamic LME	

NOTE—The column titled “Operational semantics” contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entity. Whenever an attribute is defined as dynamic, the column also shows which entity has control over the attribute. LME refers to the MAC sublayer management entity (MLME), while PHY refers to the physical layer management entity (PLME).

14.8.2.1 FH PHY attribute definitions

14.8.2.1.1 dot11PHYType

The dot11PHYType is FHSS. The LME uses this attribute to determine what PLCP and PMD are providing services to the MAC. It also is used by the MAC to determine what MAC sublayer management state machines must be invoked to support the PHY. The value of this attribute is defined as the integer 01 to indicate the FHSS PHY.

14.8.2.1.2 dot11RegDomainsSupported

Operational requirements for FHSS PHY are defined by agencies representing certain geographical regulatory domains. These regulatory agencies may define limits on various parameters that differ from region to region. This parameters may include dot11TxPowerLevels, and dot11MaxDwellTime, as well as the total number of frequencies in the hopping pattern. The values shown in Table 50 indicate regulatory agencies supported by this document.

Since a PLCP and PMD might be designed to support operation in more than one regulatory domain, this attribute can actually represent a list of agencies. This list can be one or more of the above agencies and must be terminated using the null terminator. Upon activation of the PLCP and PMD, the information in this list must be used to set the value of the dot11CurrentRegDomain attribute.

14.8.2.1.3 dot11CurrentRegDomain

The dot11CurrentRegDomain attribute for the FHSS PHY is defined as the regulatory domain under which the PMD is currently operating. This value must be one of the values listed in the dot11RegDomainsSupported list. This MIB attribute is managed by the LME.

Table 50—Regulatory domain codes

Code point	Regulatory agency	Region
X'10'	FCC	United States
X'20'	IC	Canada
X'30'	ETSI	Most of Europe
X'31'	Spain	Spain
X'32'	France	France
X'40'	MKK	Japan

14.8.2.1.4 dot11TempType

The parameter dot11TempType defines the temperature range supported by the PHY. Type 1 equipment (X'01') supports a temperature range of 0 °C to 40 °C. Type 2 equipment (X'02') supports a temperature range of -20 °C to +55 °C. Type 3 equipment (X'03') supports a temperature range of -30 °C to +70 °C.

14.8.2.1.5 dot11CurrentPowerState

The dot11CurrentPowerState attribute for the FHSS PHY allows the MAC sublayer management entity to control the power state of the PHY. This attribute can be updated using the PLMESET.request. The permissible values are ON and OFF.

14.8.2.1.6 dot11SupportedDataRatesTX

The dot11SupportedDataRatesTX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the transmit mode for this implementation. Table 51 shows the possible values appearing in the list.

Table 51—Supported data rate codes (dot11SupportedDataRatesTX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

14.8.2.1.7 dot11SupportedDataRatesRX

The dot11SupportedDataRatesRX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the receive mode for this implementation. Table 52 shows the possible values appearing in the list.

14.8.2.1.8 aMPDUMaxLength

The aMPDUMaximumLength attribute for the FHSS PHY is defined as the maximum PSDU, in octets, that the PHY shall ever be capable of accepting. This value for the FHSS PHY is set at 4095 octets. The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve

Table 52—Supported data rate codes (dot11SupportedDataRatesRX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

high performance in a variety of RF channel conditions, particularly with respect to indoor multipath, channel stability for moving STAs, and interference in the 2.4 GHz band.

14.8.2.1.9 dot11SupportedTxAntennas

The dot11SupportedTxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to transmit data. Table 53 shows the possible values appearing in the list, where $N \leq 255$.

Table 53—Number of transmit antennas

Code point	Antenna number
X'01'	Tx Antenna 1
X'02'	Tx Antenna 2
X'03'	Tx Antenna 3
...	...
N	Tx Antenna N
X'00'	Null terminator

14.8.2.1.10 dot11CurrentTxAntenna

The dot11CurrentTxAntenna attribute for the FHSS PHY is used to describe the current antenna the implementation is using for transmission. This value should represent one of the antennas appearing in the dot11SupportedTxAntennas list.

14.8.2.1.11 dot11SupportedRxAntenna

The dot11SupportedRxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to receive data. In the FHSS PHY primitives, one of these values is passed as part of the PHY-RXSTART.indicate to the MAC sublayer for every received packet. Table 54 shows the possible values appearing in the list, where $N \leq 255$.

Table 54—Number of receive antennas

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
...	...
<i>N</i>	Rx Antenna <i>N</i>
X'00'	Null terminator

14.8.2.1.12 dot11DiversitySupport

The dot11DiversitySupport attribute for the FHSS PHY is used to describe the implementation's diversity support. Table 55 shows the possible values appearing in the list.

Table 55—Diversity support codes

Code point	Diversity support
X'01'	Diversity available
X'02'	No diversity
X'03'	Control available

The value X'01' indicates that this implementation uses two or more antennas for diversity. The value X'02' indicates that the implementation has no diversity support. The value X'03' indicates that the choice of antennas used during diversity is programmable. (See 14.8.2.1.13.)

14.8.2.1.13 dot11DiversitySelectionRx

The dot11DiversitySelectionRx attribute for the FHSS PHY is a null terminated list describing the receive antenna or antennas currently in use during diversity and packet reception. Table 56 shows the possible values appearing in the list, where $N \leq 255$.

Table 56—Diversity select antenna codes

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
...	...
<i>N</i>	Rx Antenna <i>N</i>
X'00'	Null terminator

The null terminated list can consist of one or more of the receive antennas listed in the dot11SupportedRxAntennas attribute. This attribute can be changed dynamically by the LME.

14.8.2.1.14 dot11NumberSupportedPowerLevels

The dot11NumberSupportedPowerLevels attribute for the FHSS PHY describes the number of power levels this implementation supports. This attribute can be an integer of value 1 through 8, inclusive.

14.8.2.1.15 dot11TxPowerLevel1-8

Some implementations may provide up to eight different transmit power levels. The dot11TxPowerLevels attribute for the FHSS PHY is a list of up to eight power levels supported. Table 57 describes the list.

Table 57—Transmit power levels

Attribute	Power level
TxPowerLevel1	Default setting
TxPowerLevel2	Level 2
TxPowerLevel3	Level 3
TxPowerLevel4	Level 4
TxPowerLevel5	Level 5
TxPowerLevel6	Level 6
TxPowerLevel7	Level 7
TxPowerLevel8	Level 8

14.8.2.1.16 dot11CurrentTxPowerLevel

The dot11CurrentTxPowerLevel attribute for the FHSS PHY is defined as the current transmit output power level. This level shall be one of the levels implemented in the list of attributes called dot11TxPowerLevel N (where N is 1–8). This MIB attribute is also used to define the sensitivity of the CCA mechanism when the output power exceeds 100 mW. This MIB attribute is managed by the LME.

14.8.2.1.17 dot11HopTime

The dot11HopTime attribute for the FHSS PHY describes the time allocated for the PHY to change to a new frequency. For the FHSS PHY, this time period is 224 μ s.

14.8.2.1.18 dot11CurrentChannelNumber

The dot11CurrentChannelNumber attribute for the FHSS PHY is defined as the current operating channel number of the PMD. The values of this attribute correspond to the values shown in Table 38. This MIB attribute is managed by the PLME and is updated as the result of a PLMESET.request to dot11CurrentSet, dot11CurrentPattern, or dot11CurrentIndex.

14.8.2.1.19 dot11MaxDwellTime

The dot11MaxDwellTime attribute for the FHSS PHY is defined as the maximum time the PMD can dwell on a channel and meet the requirements of the current regulatory domain. For the FCC regulatory domain, this number is 390 TU (FCC = 400 ms). The recommended dwell time for the FHSS PHY is 19 TU.

14.8.2.1.20 dot11CurrentSet

The FHSS PHY contains three sets of hopping patterns. The dot11CurrentSet attribute for the FHSS PHY defines what set the STA is using to determine the hopping pattern. Its value can be 1, 2, or 3. This attribute is managed by the PLME.

14.8.2.1.21 dot11CurrentPattern

There are up to 78 patterns in each hopping set used by the FHSS PHY. The dot11CurrentPattern attribute for the FHSS PHY defines the x value used in Equation (1) in 14.6.8 to calculate the current channel number. Its value has various ranges, always within the overall range of 0 to 77, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.1.22 dot11CurrentIndex

The FHSS PHY addresses each channel in the selected hopping pattern through an index. The dot11CurrentIndex attribute for the FHSS PHY defines the i value used in the equation for $f_x(i)$ in 14.6.8 to calculate the current channel number. Its value has various ranges, always within the overall range of 1 to 79, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.1.23 dot11CurrentPowerState

The parameter dot11CurrentPowerState defines the operational state of the FHSS PHY. When this attribute has a value of X'01', the PHY is "OFF." When this attribute has a value of X'02', the PHY is "ON." This attribute is managed by the PLME.

14.9 FH PHY characteristics

Following are the static FH PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive. The definitions of these characteristics are in 10.4.3.

Table 57a—FH PHY characteristics

Characteristic	Value	Notes
aSlotTime	50 μ s	—
aSIFSTime	28 μ s	In order to account for variations between implementations, this value has a tolerance as specified in 9.2.3.1.
aCCATime	27 μ s	This period includes the aRxRFDelay and the aRxPLCPDelay.
aRxTxTurnaroundTime	20 μ s	—
aTxPLCPDelay	1 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	2 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxTxSwitchTime	10 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOnTime	8 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOffTime	8 μ s	—
aTxRFDelay	1 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	4 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μ s	Variations in the actual propagation time are accounted for in the allowable range of aSIFSTime.
aMACProcessingDelay	2 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime are met.
aPreambleLength	96 μ s	—
aPLCPHeaderLength	32 μ s	—
aMPDUDurationFactor	31250000	This factor is calculated as $[(33/32) - 1] \times 10^9$ to account for the expansion due to the data whitener encoding algorithm.
aMPDUMaxLength	4095	The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve high performance in a variety of RF channel conditions, particularly with respect to indoor multipath, channel stability for moving STAs, and interference in the 2.4 GHz band.
aCWmin	15	—
aCWmax	1023	—

15. Direct sequence spread spectrum (DSSS) PHY specification for the 2.4 GHz band designated for ISM applications

15.1 Overview

The PHY for the direct sequence spread spectrum (DSSS) system is described in this clause. The RF LAN system is initially aimed for the 2.4 GHz band designated for ISM applications as provided in the USA according to FCC 15.247, in Europe by ETS 300-328, and in other countries according to 15.4.6.2.

The DSSS system provides a wireless LAN with both a 1 Mbit/s and a 2 Mbit/s data payload communication capability. According to the FCC regulations, the DSSS system shall provide a processing gain of at least 10 dB. This shall be accomplished by chipping the baseband signal at 11 MHz with an 11-chip PN code. The DSSS system uses baseband modulations of differential binary phase shift keying (DBPSK) and differential quadrature phase shift keying (DQPSK) to provide the 1 Mbit/s and 2 Mbit/s data rates, respectively.

15.1.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC by the 2.4 GHz DSSS system are described in this clause. The DSSS PHY layer consists of two protocol functions:

- a) A physical layer convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function shall be supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 MAC sublayer protocol data units (MPDU) into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
- b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a wireless medium (WM) between two or more STAs each using the DSSS system.

15.1.2 DSSS PHY functions

The 2.4 GHz DSSS PHY architecture is depicted in the reference model shown in Figure 11. The DSSS PHY contains three functional entities: the PMD function, the physical layer convergence function, and the layer management function. Each of these functions is described in detail in the following subclauses.

The DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 12.

15.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a physical layer convergence sublayer is defined. This function simplifies the PHY service interface to the IEEE 802.11 MAC services.

15.1.2.2 PMD sublayer

The PMD sublayer provides a means to send and receive data between two or more STAs. This clause is concerned with the 2.4 GHz ISM bands using direct sequence modulation.

15.1.2.3 Physical layer management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MAC management entity.

15.1.3 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the IEEE 802.11 DSSS PHY compliant developer.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

15.2 DSSS PLCP sublayer

15.2.1 Overview

This clause provides a convergence procedure in which MPDUs are converted to and from PPDU. During transmission, the MPDU shall be prepended with a PLCP Preamble and Header to create the PPDU. At the receiver, the PLCP Preamble and header are processed to aid in demodulation and delivery of the MPDU.

15.2.2 PLCP frame format

Figure 86 shows the format for the PPDU including the DSSS PLCP Preamble, the DSSS PLCP Header, and the MPDU. The PLCP Preamble contains the following fields: Synchronization (Sync) and Start Frame Delimiter (SFD). The PLCP Header contains the following fields: IEEE 802.11 Signaling (Signal), IEEE 802.11 Service (Service), LENGTH (Length), and CCITT CRC-16. Each of these fields is described in detail in 15.2.3.

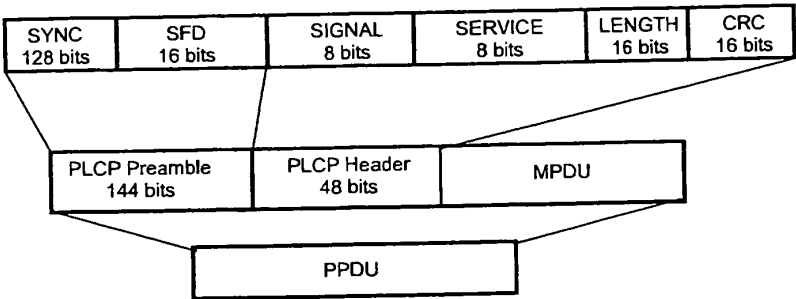


Figure 86—PLCP frame format

15.2.3 PLCP field definitions

The entire PLCP Preamble and Header shall be transmitted using the 1 Mbit/s DBPSK modulation described in 15.4.7. All transmitted bits shall be scrambled using the feedthrough scrambler described in 15.2.4.

15.2.3.1 PLCP Synchronization (SYNC) field

The SYNC field shall consist of 128 bits of scrambled ones. This field shall be provided so that the receiver can perform the necessary operations for synchronization.

15.2.3.2 PLCP Start Frame Delimiter (SFD)

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PLCP Preamble. The SFD shall be a 16-bit field, X'F3A0' (msb to lsb). The lsb shall be transmitted first in time.

15.2.3.3 PLCP IEEE 802.11 Signal (SIGNAL) field

The 8-bit IEEE 802.11 signal field indicates to the PHY the modulation that shall be used for transmission (and reception) of the MPDU. The data rate shall be equal to the signal field value multiplied by 100 kbit/s. The DSSS PHY currently supports two mandatory modulation services given by the following 8-bit words, where the lsb shall be transmitted first in time:

- a) X'0A' (msb to lsb) for 1 Mbit/s DBPSK
- b) X'14' (msb to lsb) for 2 Mbit/s DQPSK

The DSSS PHY rate change capability is described in 15.2.5. This field shall be protected by the CCITT CRC-16 frame check sequence described in 15.2.3.6.

15.2.3.4 PLCP IEEE 802.11 Service (SERVICE) field

The 8-bit IEEE 802.11 service field shall be reserved for future use. The value of X'00' signifies IEEE 802.11 device compliance. The lsb shall be transmitted first in time. This field shall be protected by the CCITT CRC-16 frame check sequence described in 15.2.3.6.

15.2.3.5 PLCP Length (LENGTH) field

The PLCP Length field shall be an unsigned 16-bit integer that indicates the number of microseconds (16 to $2^{16}-1$ as defined by `aMPDUMaxLength`) required to transmit the MPDU. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 12.3.5.4. The length field provided in the TXVECTOR is in bytes and is converted to microseconds for inclusion in the PLCP LENGTH field. The lsb shall be transmitted first in time. This field shall be protected by the CCITT CRC-16 frame check sequence described in 15.2.3.6.

15.2.3.6 PLCP CRC (CCITT CRC-16) field

The IEEE 802.11 SIGNAL, IEEE 802.11 SERVICE, and LENGTH fields shall be protected with a CCITT CRC-16 frame check sequence (FCS). The CCITT CRC-16 FCS shall be the one's complement of the remainder generated by the modulo 2 division of the protected PLCP fields by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling.

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with a packet length of 192 μ s (24 bytes) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 (leftmost bit transmitted first in time)

The one's complement FCS for these protected PLCP Preamble bits would be the following:

0101 1011 0101 0111 (leftmost bit transmitted first in time)

Figure 87 depicts this example.

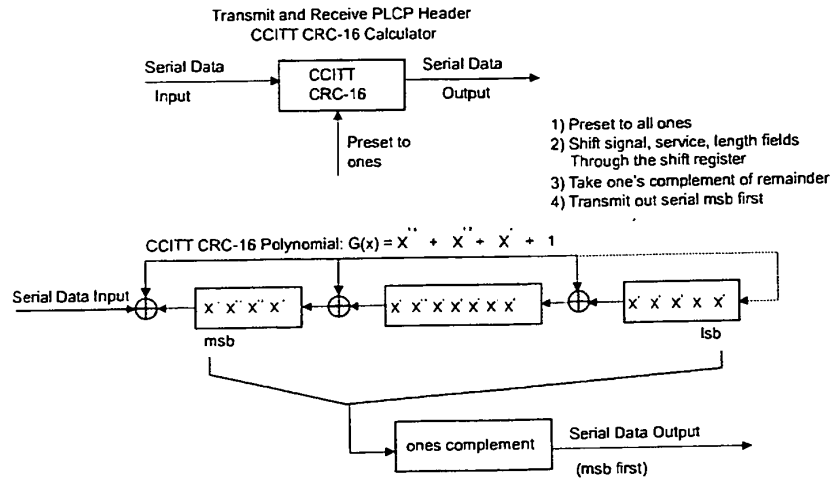


Figure 87—CCITT CRC-16 implementation

An illustrative example of the CCITT CRC-16 FCS using the information from Figure 87 follows in Figure 88.

Data	CRC registers msb	lsb
	1111111111111111	; initialize preset to 1's
0	1110111111011111	
1	1101111111011110	
0	1010111101011101	
1	0101111010111010	
0	1011110101110100	
0	0110101011001001	
0	1101010110010010	
0	1011101100000101	
0	0110011000101011	
0	1100110001010110	
0	1000100010001101	
0	000000100111011	
0	0000001001110110	
0	0000010011101100	
0	0000100111011000	
0	0001001110110000	
0	0010011101100000	
0	0100111011000000	
0	1001110110000000	
0	0010101100100001	
0	0101011001000010	
0	1010110010000100	
1	0101100100001000	
1	1010001000110001	
0	0101010001000011	
0	1010100010000110	
0	010000100101101	
0	1000001001011010	
0	0001010010010101	
0	0010100100101010	
0	0101001001010100	
0	1010010010101000	
	010110101010111	; one's complement, result = CRC FCS parity

Figure 88—Example CRC calculation

15.2.4 PLCP/DSSS PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted by the DSSS PHY. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 89 and Figure 90 show typical implementations of the data scrambler and descrambler, but other implementations are possible.

The scrambler should be initialized to any state except all ones when transmitting.

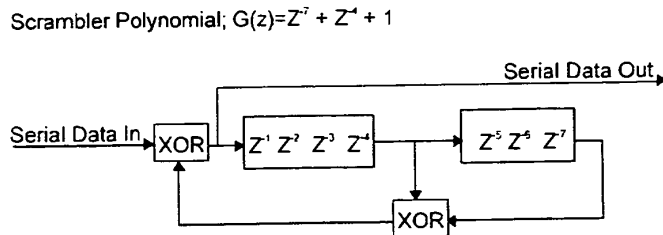


Figure 89—Data scrambler

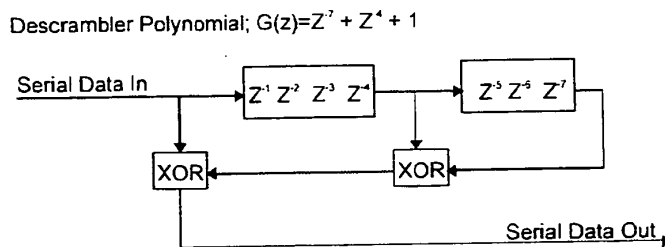


Figure 90—Data descrambler

15.2.5 PLCP data modulation and modulation rate change

The PLCP Preamble shall be transmitted using the 1 Mbit/s DBPSK modulation. The IEEE 802.11 SIGNAL field shall indicate the modulation that shall be used to transmit the MPDU. The transmitter and receiver shall initiate the modulation indicated by the IEEE 802.11 SIGNAL field starting with the first symbol (1 bit for DBPSK or 2 bits for DQPSK) of the MPDU. The MPDU transmission rate shall be set by the DATA-RATE parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 15.4.4.1.

15.2.6 PLCP transmit procedure

The PLCP transmit procedure is shown in Figure 91.

In order to transmit data, PHY-TXSTART.request shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate channel through station management via the PLME. Other transmit parameters such as DATARATE, TX antenna, and TX power are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR) as described in 15.4.4.2.

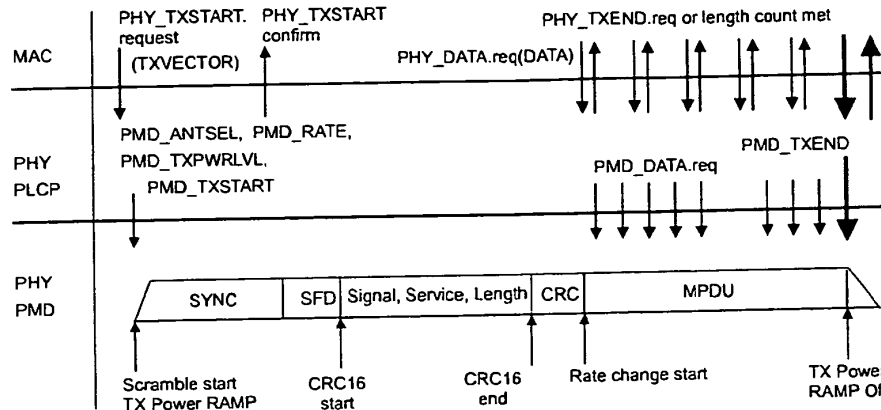


Figure 91—PLCP transmit procedure

Based on the status of clear channel assessment (CCA) indicated by PHY-CCA.indicate, the MAC will assess that the channel is clear. A clear channel shall be indicated by PHY-CCA.indicate(IDLE). If the channel is clear, transmission of the PPDU shall be initiated by issuing the PHY-TXSTART.request (TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request are the PLCP Header parameters SIGNAL (DATARATE), SERVICE, and LENGTH, and the PMD parameters of TX_ANTENNA and TX_PWR_LEVEL. The PLCP Header parameter LENGTH is calculated from the TXVECTOR element by multiplying by 8 for 1 Mbit/s and by 4 for 2 Mbit/s.

The PLCP shall issue PMD_ANTSEL, PMD_RATE, and PMD_TXPWRLVL primitives to configure the PHY. The PLCP shall then issue a PMD_TXSTART.request and the PHY entity shall immediately initiate data scrambling and transmission of the PLCP Preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for TX power-up ramp described in 15.4.7.7 shall be included in the PLCP synchronization field. Once the PLCP Preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated with the first data symbol of the MPDU as described in 15.2.5. The PHY proceeds with MPDU transmission through a series of data octet transfers from the MAC. At the PMD layer, the data octets are sent in lsb to msb order and presented to the PHY layer through PMD_DATA.request primitives. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by the issuance of the PHY-TXEND.request. Normal termination occurs after the transmission of the final bit of the last MPDU octet according to the number supplied in the DSSS PHY preamble LENGTH field. The packet transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled). It is recommended that chipping continue during power-down. Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical state machine implementation of the PLCP transmit procedure is provided in Figure 92.

15.2.7 PLCP receive procedure

The PLCP receive procedure is shown in Figure 93.

In order to receive data, PHY-TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through station management via the PLME, the PHY is set to the appropriate channel and the CCA method is chosen. Other receive parameters such as receive signal strength indication (RSSI), signal quality (SQ), and indicated DATARATE may be accessed via the PHY-SAP.

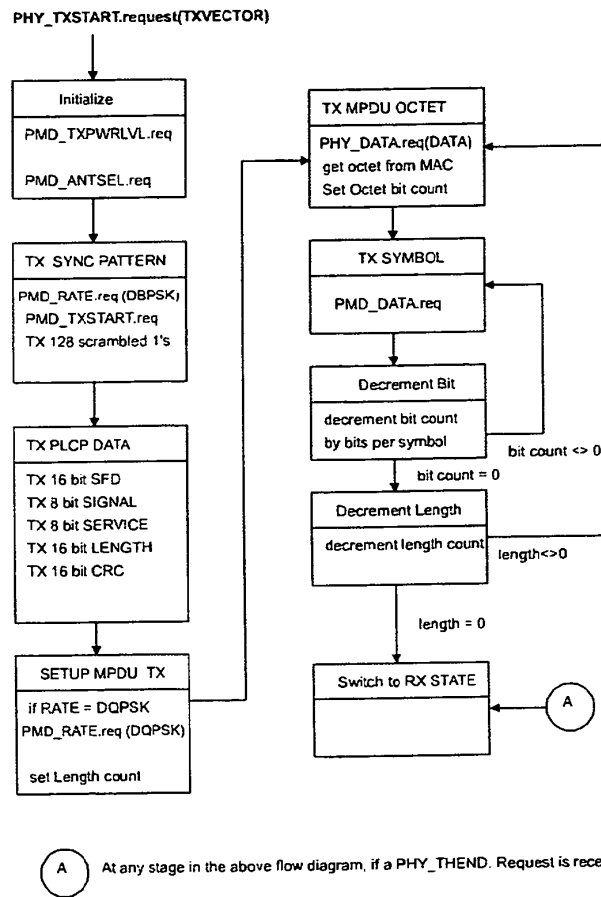


Figure 92—PLCP transmit state machine

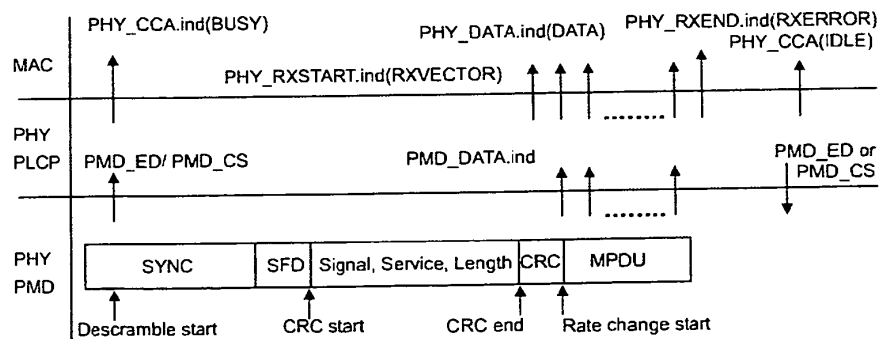


Figure 93—PLCP receive procedure

Upon receiving the transmitted energy, according to the selected CCA mode, the PMD_ED shall be enabled (according to 15.4.8.4) as the RSSI strength reaches the ED_THRESHOLD and/or PMD_CS shall be enabled after code lock is established. These conditions are used to indicate activity to the MAC via PHY-CCA.indicate according to 15.4.8.4. PHY-CCA.indicate(BUSY) shall be issued for energy detection and/or code lock prior to correct reception of the PLCP frame. The PMD primitives PMD_SQ and PMD_RSSI are issued to update the RSSI and SQ parameters reported to the MAC.

After PHY-CCA.indicate is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CCITT CRC-16 processing shall be initiated and the PLCP IEEE 802.11 SIGNAL, IEEE 802.11 SERVICE and LENGTH fields are received. The CCITT CRC-16 FCS shall be processed. If the CCITT CRC-16 FCS check fails, the PHY receiver shall return to the RX Idle state as depicted in Figure 94. Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX Idle state.

If the PLCP Header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the MPDU length in bytes (calculated from the LENGTH field in microseconds), the antenna used for receive (RX_ANTENNA), RSSI, and SQ.

The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indicate(DATA) primitive exchanges. The rate change indicated in the IEEE 802.11 SIGNAL field shall be initiated with the first symbol of the MPDU as described in 15.2.5. The PHY proceeds with MPDU reception. After the reception of the final bit of the last MPDU octet indicated by the PLCP Preamble LENGTH field, the receiver shall be returned to the RX Idle state as shown in Figure 94. A PHY-RXEND.indicate(NoError) primitive shall be issued. A PHY-CCA.indicate(IDLE) primitive shall be issued following a change in PHYCS (PHY carrier sense) and/or PHYED (PHY energy detection) according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the MPDU as indicated by the PLCP LENGTH field, the error condition PHY-RXEND.indicate(CarrierLost) shall be reported to the MAC. The DSSS PHY will ensure that the CCA will indicate a busy medium for the intended duration of the transmitted packet.

If the PLCP Header is successful, but the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(UnsupportedRate). If the PLCP Header is successful, but the SERVICE field is out of IEEE 802.11 DSSS specification, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(FormatViolation). Also, in both cases, the DSSS PHY will ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted frame as indicated by the Length field. The intended duration is indicated by the Length field ($\text{length} \times 1 \mu\text{s}$).

A typical state machine implementation of the PLCP receive procedure is provided in Figure 94.

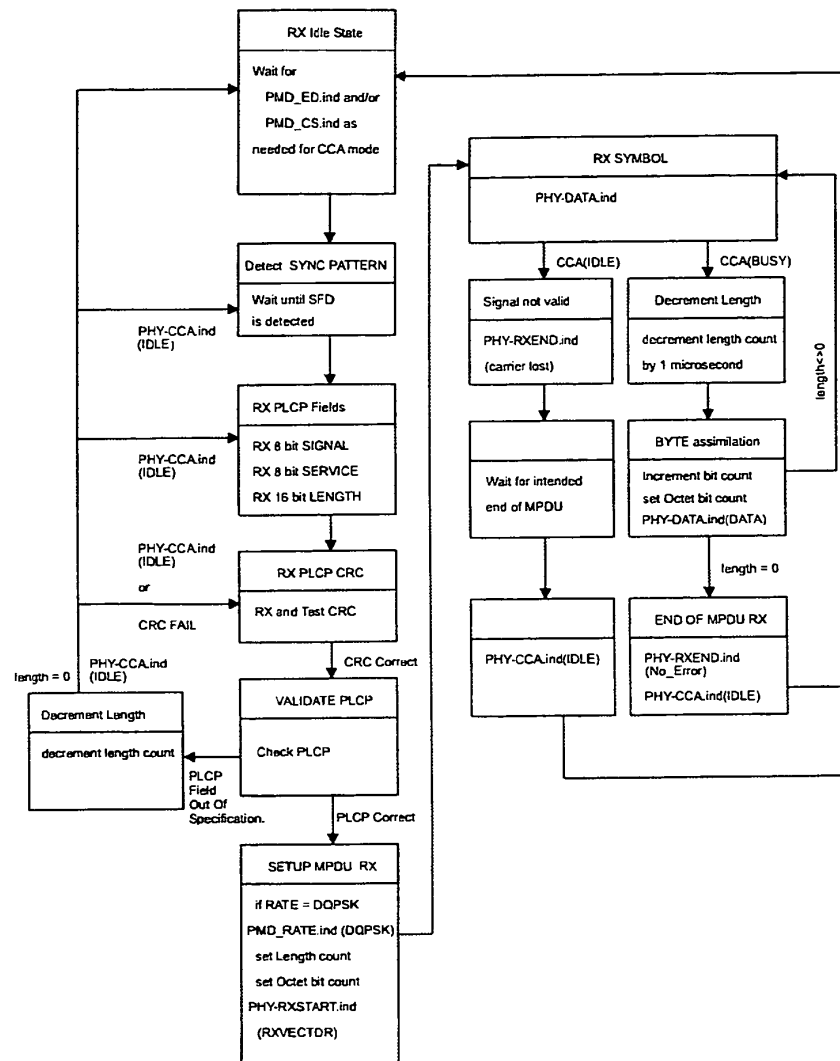


Figure 94—PLCP receive state machine

15.3 DSSS physical layer management entity (PLME)

15.3.1 PLME_SAP sublayer management primitives

Table 58 lists the MIB attributes that may be accessed by the PHY sublayer entities and intralayer of higher-layer management entities (LMEs). These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 10.

15.3.2 DSSS PHY MIB

All DSSS PHY MIB attributes are defined in Clause 12, with specific values defined in Table 58.

Table 58—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11PhyOperationComplianceGroup		
dot11PHYdot11TempType	DSSS-2.4 (02)	Static
dot11TempType	Implementation dependent	Static
dot11RegDomainsSupported	Implementation dependent	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11PhyRateGroup		
dot11SupportedDataRatesTx	X'02', X'04'	Static
dot11SupportedDataRatesRx	X'02', X'04'	Static
dot11PhyAntennaComplianceGroup		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupport	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11PhyTxPowerComplianceGroup		
dot11NumberSupportedPowerLevels	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSComplianceGroup		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11CCAModeSupported	Implementation dependent	Static
dot11CurrentCCAMode	Implementation dependent	Dynamic
dot11EDThreshold	Implementation dependent	Dynamic
dot11AntennasListGroup		
dot11SupportedTxAntenna	Implementation dependent	Static
dot11SupportedRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRx	Implementation dependent	Dynamic
NOTE—The column titled “Operational semantics” contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entities.		

15.3.3 DS PHY characteristics

The static DS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 59. The definitions of these characteristics are in 10.4.3.

Table 59—DS PHY characteristics

Characteristic	Value
aSlotTime	20 μ s
aSIFSTime	10 μ s
aCCATime	$\leq 15 \mu$ s
aRxDxTurnaroundTime	$\leq 5 \mu$ s
aTxPLCPDelay	Implementors may choose any value for this delay as long as the requirements of aRxDxTurnaroundTime are met.
aRxDxPLCPDelay	Implementors may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxDxSwitchTime	$\leq 5 \mu$ s
aTxRampOnTime	Implementors may choose any value for this delay as long as the requirements of aRxDxTurnaroundTime are met.
aTxRampOffTime	Implementors may choose any value for this delay as long as the requirements of aSIFSTime are met.
aTxRFDelay	Implementors may choose any value for this delay as long as the requirements of aRxDxTurnaroundTime are met.
aRxDxRFDelay	Implementors may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μ s
aMACProcessingDelay	0 (not applicable)
aPreambleLength	144 μ s
aPLCPHeaderLength	48 μ s
aMPDUDurationFactor	0
aMPDUMaxLength	$4 \leq x \leq (2^{13} - 1)$
aCWmin	31
aCWmax	1023

15.4 DSSS PMD sublayer

15.4.1 Scope and field of application

This subclause describes the PMD services provided to the PLCP for the DSSS PHY. Also defined in this subclause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this standard. The relationship of this standard to the entire DSSS physical layer is shown in Figure 95.

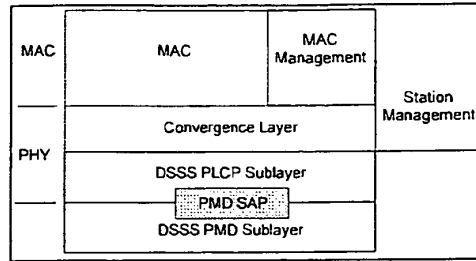


Figure 95—PMD layer reference model

15.4.2 Overview of service

The DSSS PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which data shall be transmitted or received from the medium. The combined function of DSSS PMD sublayer primitives and parameters for the receive function results in a data stream, timing information, and associated received signal parameters being delivered to the PLCP sublayer. A similar functionality shall be provided for data transmission.

15.4.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the DSSS PMD fall into two basic categories:

- Service primitives that support PLCP peer-to-peer interactions, and
- Service primitives that have local significance and that support sublayer-to-sublayer interactions.

15.4.4 Basic service and options

All of the service primitives described in this clause are considered mandatory unless otherwise specified.

15.4.4.1 PMD_SAP peer-to-peer service primitives

Table 60 indicates the primitives for peer-to-peer interactions.

Table 60—PMD_SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PHY-RXSTART		X		—
PHY-RXEND		X		—
PHY-CCA		X		—
PHY-TXSTART	X		X	—
PHY-TXEND	X		X	—
PHY-DATA	X	X	X	—

15.4.4.2 PMD_SAP peer-to-peer service primitive parameters

Several service primitives include a parameter vector. This vector shall be a list of parameters that may vary depending on PHY type. Table 61 indicates the parameters required by the MAC or DSSS PHY in each of the parameter vectors used for peer-to-peer interactions.

Table 61—DSSS PMD_SAP peer-to-peer service primitives

Parameter	Associated primitive	Value
LENGTH	RXVECTOR, TXVECTOR	0 to $2^{13} - 1$
DATARATE	RXVECTOR, TXVECTOR	1, 2 Mbit/s
SERVICE	RXVECTOR, TXVECTOR	1, 2 Mbit/s
TXPWR_LEVEL	TXVECTOR	1, 2 Mbit/s
TX_ANTENNA	TXVECTOR	1, 2 Mbit/s
RSSI	RXVECTOR	1, 2 Mbit/s
SQ	RXVECTOR	1, 2 Mbit/s
RX_ANTENNA	RXVECTOR	1, 2 Mbit/s

15.4.4.3 PMD_SAP sublayer-to-sublayer service primitives

Table 62 indicates the primitives for sublayer-to-sublayer interactions.

Table 62—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXSTART	X		—	—
PMD_TXEND	X		—	—
PMD_ANTSEL	X	X	—	—
PMD_TXPWRVLV	X		—	—
PMD_RATE	X	X	—	—
PMD_RSSI		X	—	—
PMD_SQ		X	—	—
PMD_CS		X	—	—
PMD_ED	X	X	—	—

15.4.4.4 PMD_SAP service primitive parameters

Table 63 indicates the parameters for the PMD primitives.

Table 63—List of parameters for the PMD primitives

Parameter	Associate primitive	Value
DATA	PHY-DATA.request PHY-DATA.indicate	Octet value: X'00'–X'FF'
TXVECTOR	PHY-DATA.request	A set of parameters
RXVECTOR	PHY-DATA.indicate	A set of parameters
TXD_UNIT	PMD_DATA.request	One(1), Zero(0): DBPSK dibit combinations 00,01,11,10: DQPSK
RXD_UNIT	PMD_DATA.indicate	One(1), Zero(0): DBPSK dibit combinations 00,01,11,10: DQPSK
RF_STATE	PMD_TXE.request	Receive, Transmit
ANT_STATE	PMD_ANTSEL.indicate PMD_ANTSEL.request	1 to 256
TXPWR_LEVEL	PHY-TXSTART	0, 1, 2, 3 (max of 4 levels)
RATE	PMD_RATE.indicate PMD_RATE.request	X'0A' for 1 Mbit/s DBPSK X'14' for 2 Mbit/s DQPSK
RSSI	PMD_RSSI.indicate	0–8 bits of RSSI
SQ	PMD_SQ.indicate	0–8 bits of SQ

15.4.5 PMD_SAP detailed service specification

The following subclauses describe the services provided by each PMD primitive.

15.4.5.1 PMD_DATA.request

15.4.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

15.4.5.1.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.request(TXD_UNIT)

The TXD_UNIT parameter takes on the value of either one(1) or zero(0) for DBPSK modulation or the dibit combination 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single block of data, which, in turn, shall be used by the PHY to be differentially encoded into a DBPSK or DQPSK transmitted symbol. The symbol itself shall be spread by the PN code prior to transmission.

15.4.5.1.3 When generated

This primitive shall be generated by the PLCP sublayer to request transmission of a symbol. The data clock for this primitive shall be supplied by the PMD layer based on the PN code repetition.

15.4.5.1.4 Effect of receipt

The PMD performs the differential encoding, PN code modulation, and transmission of the data.

15.4.5.2 PMD_DATA.indicate

15.4.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

15.4.5.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.indicate(RXD_UNIT)

The RXD_UNIT parameter takes on the value of one (1) or zero (0) for DBPSK modulation or as the dibit 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single symbol that has been demodulated by the PMD entity.

15.4.5.2.3 When generated

This primitive, which is generated by the PMD entity, forwards received data to the PLCP sublayer. The data clock for this primitive shall be supplied by the PMD layer based on the PN code repetition.

15.4.5.2.4 Effect of receipt

The PLCP sublayer either interprets the bit or bits that are recovered as part of the PLCP convergence procedure or passes the data to the MAC sublayer as part of the MPDU.

15.4.5.3 PMD_TXSTART.request

15.4.5.3.1 Function

This primitive, which is generated by the PHY PLCP sublayer, initiates PPDU transmission by the PMD layer.

15.4.5.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXSTART.request

15.4.5.3.3 When generated

This primitive shall be generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY-DATA.request primitive shall be provided to the PLCP sublayer prior to issuing the PMD_TXSTART command.

15.4.5.3.4 Effect of receipt

PMD_TXSTART initiates transmission of a PPDU by the PMD sublayer.

15.4.5.4 PMD_TXEND.request

15.4.5.4.1 Function

This primitive, which is generated by the PHY PLCP sublayer, ends PPDU transmission by the PMD layer.

15.4.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PMD_TXEND.rcquest

15.4.5.4.3 When generated

This primitive shall be generated by the PLCP sublayer to terminate the PMD layer transmission of the PPDU.

15.4.5.4.4 Effect of receipt

PMD_TXEND terminates transmission of a PPDU by the PMD sublayer.

15.4.5.5 PMD_ANTSEL.request

15.4.5.5.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the antenna used by the PHY for transmission or reception (when diversity is disabled).

15.4.5.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.request(ANT_STATE)

ANT_STATE selects which of the available antennas should be used for transmit. The number of available antennas shall be determined from the MIB table parameters aSuprtRxAntennas and aSuprtTxAntennas.

15.4.5.5.3 When generated

This primitive shall be generated by the PLCP sublayer to select a specific antenna for transmission or reception (when diversity is disabled).

15.4.5.5.4 Effect of receipt

PMD_ANTSEL immediately selects the antenna specified by ANT_STATE.

15.4.5.6 PMD_ANTSEL.indicate

15.4.5.6.1 Function

This primitive, which is generated by the PHY PLCP sublayer, reports the antenna used by the PHY for reception of the most recent packet.

15.4.5.6.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.indicate(ANT_STATE)

ANT_STATE reports which of the available antennas was used for reception of the most recent packet.

15.4.5.6.3 When generated

This primitive shall be generated by the PLCP sublayer to report the antenna used for the most recent packet reception.

15.4.5.6.4 Effect of receipt

PMD_ANTSEL immediately reports the antenna specified by ANT_STATE.

15.4.5.7 PMD_TXPWRLVL.request

15.4.5.7.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the power level used by the PHY for transmission.

15.4.5.7.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXPWRLVL.request(TXPWR_LEVEL)

TXPWR_LEVEL selects which of the optional transmit power levels should be used for the current packet transmission. The number of available power levels shall be determined by the MIB parameter dot11NumberSupportedPowerLevels. Subclause 15.4.7.3 provides further information on the optional DSSS PHY power-level-control capabilities.

15.4.5.7.3 When generated

This primitive shall be generated by the PLCP sublayer to select a specific transmit power. This primitive shall be applied prior to setting PMD_TXSTART to the transmit state.

15.4.5.7.4 Effect of receipt

PMD_TXPWRLVL immediately sets the transmit power level given by TXPWR_LEVEL.

15.4.5.8 PMD_RATE.request

15.4.5.8.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the modulation rate that shall be used by the DSSS PHY for transmission.

15.4.5.8.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RATE.request(RATE)

The RATE parameter selects which of the DSSS PHY data rates shall be used for MPDU transmission. Subclause 15.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in 15.2.

15.4.5.8.3 When generated

This primitive shall be generated by the PLCP sublayer to change or set the current DSSS PHY modulation rate used for the MPDU portion of a PPDU.

15.4.5.8.4 Effect of receipt

The receipt of PMD_RATE selects the rate that shall be used for all subsequent MPDU transmissions. This rate shall be used for transmission only. The DSSS PHY shall still be capable of receiving all the required DSSS PHY modulation rates.

15.4.5.9 PMD_RATE.indicate

15.4.5.9.1 Function

This primitive, which is generated by the PMD sublayer, indicates which modulation rate was used to receive the MPDU portion of the PPDU. The modulation shall be indicated in the PLCP Preamble IEEE 802.11 SIGNALING field.

15.4.5.9.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RATE.indicate(RATE)

In receive mode, the RATE parameter informs the PLCP layer which of the DSSS PHY data rates was used to process the MPDU portion of the PPDU. Subclause 15.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in 15.2.

15.4.5.9.3 When generated

This primitive shall be generated by the PMD sublayer when the PLCP Preamble IEEE 802.11 SIGNALING field has been properly detected.

15.4.5.9.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only.

15.4.5.10 PMD_RSSI.indicate**15.4.5.10.1 Function**

This optional primitive, which is generated by the PMD sublayer, provides to the PLCP and MAC entity the received signal strength.

15.4.5.10.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RSSI.indicate(RSSI)

The RSSI shall be a measure of the RF energy received by the DSSS PHY. RSSI indications of up to 8 bits (256 levels) are supported.

15.4.5.10.3 When generated

This primitive shall be generated by the PMD when the DSSS PHY is in the receive state. It shall be continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

15.4.5.10.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only. The RSSI may be used in conjunction with signal quality (SQ) as part of a CCA scheme.

15.4.5.11 PMD_SQ.indicate**15.4.5.11.1 Function**

This optional primitive, which is generated by the PMD sublayer, provides to the PLCP and MAC entity the SQ of the DSSS PHY PN code correlation. The SQ shall be sampled when the DSSS PHY achieves code lock and shall be held until the next code lock acquisition.

15.4.5.11.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_SQ.indicate(SQ)

The SQ shall be a measure of the PN code correlation quality received by the DSSS PHY. SQ indications of up to 8 bits (256 levels) are supported.

15.4.5.11.3 When generated

This primitive shall be generated by the PMD when the DSSS PHY is in the receive state and code lock is achieved. It shall be continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

15.4.5.11.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only. The SQ may be used in conjunction with RSSI as part of a CCA scheme.

15.4.5.12 PMD_CS.indicate

15.4.5.12.1 Function

This primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has acquired (locked) the PN code and data is being demodulated.

15.4.5.12.2 Semantics of the service primitive

The PMD_CS (carrier sense) primitive in conjunction with PMD_ED provides CCA status through the PLCP layer PHYCCA primitive. PMD_CS indicates a binary status of ENABLED or DISABLED. PMD_CS shall be ENABLED when the correlator SQ indicated in PMD_SQ is greater than the CS_THRESHOLD parameter. PMD_CS shall be DISABLED when the PMD_SQ falls below the correlation threshold.

15.4.5.12.3 When generated

This primitive shall be generated by the PHY sublayer when the DSSS PHY is receiving a PPDU and the PN code has been acquired.

15.4.5.12.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PHYCCA indicator. This parameter shall indicate that the RF medium is busy and occupied by a DSSS PHY signal. The DSSS PHY should not be placed into the transmit state when PMD_CS is ENABLED.

15.4.5.13 PMD_ED.indicate

15.4.5.13.1 Function

This optional primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has detected RF energy indicated by the PMD_RSSI primitive that is above a predefined threshold.

15.4.5.13.2 Semantics of the service primitive

The PMD_ED (energy detect) primitive, along with the PMD_SQ, provides CCA status at the PLCP layer through the PHYCCA primitive. PMD_ED indicates a binary status of ENABLED or DISABLED. PMD_ED shall be ENABLED when the RSSI indicated in PMD_RSSI is greater than the ED_THRESHOLD parameter. PMD_ED shall be DISABLED when the PMD_RSSI falls below the energy detect threshold.

15.4.5.13.3 When generated

This primitive shall be generated by the PHY sublayer when the PHY is receiving RF energy from any source that exceeds the ED_THRESHOLD parameter.

15.4.5.13.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PMD_ED indicator. This parameter shall indicate that the RF medium may be busy with an RF energy source that is not DSSS PHY compliant. If a DSSS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

15.4.5.14 PMD_ED.request

15.4.5.14.1 Function

This optional primitive, which is generated by the PHY PLCP, sets the energy detect ED_THRESHOLD value.

15.4.5.14.2 Semantics of the service primitive

The primitive shall provide the following parameters:

PMD_ED.request(ED_THRESHOLD)

ED_THRESHOLD is the value that the RSSI indicated shall exceed for PMD_ED to be enabled.

15.4.5.14.3 When generated

This primitive shall be generated by the PLCP sublayer to change or set the current DSSS PHY energy detect threshold.

15.4.5.14.4 Effect of receipt

The receipt of PMD_ED immediately changes the energy detection threshold as set by the ED_THRESHOLD parameter.

15.4.5.15 PHY-CCA.indicate

15.4.5.15.1 Function

This primitive, which is generated by the PMD, indicates to the PLCP layer that the receiver has detected RF energy that adheres to the CCA algorithm.

15.4.5.15.2 Semantics of the service primitive

The PHY-CCA primitive provides CCA status at the PLCP layer to the MAC.

15.4.5.15.3 When generated

This primitive shall be generated by the PHY sublayer when the PHY is receiving RF energy from any source that exceeds the ED_THRESHOLD parameter (PMD_ED is active), and optionally is a valid correlated DSSS PHY signal whereby PMD_CS would also be active.

15.4.5.15.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PHY-CCA indicator. This parameter indicates that the RF medium may be busy with an RF energy source that may or may not be DSSS PHY compliant. If a DSSS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

15.4.6 PMD operating specifications, general

The following subclauses provide general specifications for the DSSS PMD sublayer. These specifications apply to both the Receive and the Transmit functions and general operation of a DSSS PHY.

15.4.6.1 Operating frequency range

The DSSS PHY shall operate in the frequency range of 2.4 GHz to 2.4835 GHz as allocated by regulatory bodies in the USA and Europe or in the 2.471 GHz to 2.497 GHz frequency band as allocated by regulatory authority in Japan.

15.4.6.2 Number of operating channels

The channel center frequencies and CHNL_ID numbers shall be as shown in Table 64. The FCC (US), IC (Canada), and ETSI (Europe) specify operation from 2.4 GHz to 2.4835 GHz. For MKK (Japan), operation is specified as 2.471 GHz to 2.497 GHz. France allows operation from 2.4465 GHz to 2.4835 GHz, and Spain allows operation from 2.445 GHz to 2.475 GHz. For each supported regulatory domain, all channels in Table 64 marked with "X" shall be supported.

Table 64—DSSS PHY frequency channel plan

CHNL_ID	Frequency	Regulatory domains					
		X'10' FCC	X'20' IC	X'30' ETSI	X'31' Spain	X'32' France	X'40' MKK
1	2412 MHz	X	X	X	—	—	—
2	2417 MHz	X	X	X	—	—	—
3	2422 MHz	X	X	X	—	—	—
4	2427 MHz	X	X	X	—	—	—
5	2432 MHz	X	X	X	—	—	—
6	2437 MHz	X	X	X	—	—	—
7	2442 MHz	X	X	X	—	—	—
8	2447 MHz	X	X	X	—	—	—
9	2452 MHz	X	X	X	—	—	—
10	2457 MHz	X	X	X	X	X	—
11	2462 MHz	X	X	X	X	X	—
12	2467 MHz	—	—	X	—	X	—
13	2472 MHz	—	—	X	—	X	—
14	2484 MHz	—	—	—	—	—	X

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 30 MHz. Channel 14 shall be designated specifically for operation in Japan.

15.4.6.3 Spreading sequence

The following 11-chip Barker sequence shall be used as the PN code sequence:

+1, -1, +1, +1, -1, +1, +1, +1, -1, -1, -1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

15.4.6.4 Modulation and channel data rates

Two modulation formats and data rates are specified for the DSSS PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate shall be based on 1 Mbit/s DBPSK modulation. The DBPSK encoder is specified in Table 65. The enhanced access rate shall be based on 2 Mbit/s DQPSK. The DQPSK encoder is specified in Table 66. (In the tables, $+j\omega$ shall be defined as counterclockwise rotation.)

Table 65—1 Mbit/s DBPSK encoding table

Bit input	Phase change ($+j\omega$)
0	0
1	π

Table 66—2 Mbit/s DQPSK encoding table

Dibit pattern (d0,d1) d0 is first in time	Phase change ($+j\omega$)
00	0
01	$\pi/2$
11	π
10	$3\pi/2$ ($-\pi/2$)

15.4.6.5 Transmit and receive in-band and out-of-band spurious emissions

The DSSS PHY shall conform with in-band and out-of-band spurious emissions as set by regulatory bodies. For the USA, refer to FCC 15.247, 15.205, and 15.209. For Europe, refer to ETS 300-328.

15.4.6.6 Transmit-to-receive turnaround time

The TX-to-RX turnaround time shall be less than 10 μ s, including the power-down ramp specified in 15.4.7.7.

The TX-to-RX turnaround time shall be measured at the air interface from the trailing edge of the last transmitted symbol to valid CCA detection of the incoming signal. The CCA should occur within 25 μ s (10 μ s for turnaround time plus 15 μ s for energy detect) or by the next slot boundary occurring after 25 μ s has elapsed (refer to 15.4.8.4). A receiver input signal 3 dB above the ED threshold described in 15.4.8.4 shall be present at the receiver.

15.4.6.7 Receive-to-transmit turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface, using PHYTXSTART.request and shall be ≤ 5 μ s. This includes the transmit power-up ramp described in 15.4.7.7.

15.4.6.8 Slot time

The slot time for the DSSS PHY shall be the sum of the RX-to-TX turnaround time (5 μ s) and the energy detect time (15 μ s specified in 15.4.8.4). The propagation delay shall be regarded as being included in the energy detect time.

15.4.6.9 Transmit and receive antenna port impedance

The impedance of the transmit and receive antenna port(s) shall be 50 Ω if the port is exposed.

15.4.6.10 Transmit and receive operating temperature range

Three temperature ranges for full operation compliance to the DSSS PHY are specified in Clause 13. Type 1 shall be defined as 0 °C to 40 °C, and is designated for office environments. Type 2 shall be defined as –20 °C to +50 °C, and Type 3 shall be defined as –30 °C to +70 °C. Types 2 and 3 are designated for industrial environments.

15.4.7 PMD transmit specifications

The following subclauses describe the transmit functions and parameters associated with the PMD sublayer.

15.4.7.1 Transmit power levels

The maximum allowable output power as measured in accordance with practices specified by the regulatory bodies is shown in Table 67. In the USA, the radiated emissions should also conform with the IEEE uncontrolled radiation emission standard (IEEE Std C95.1-1991).

Table 67—Transmit power levels

Maximum output power	Geographic location	Compliance document
1000 mW	USA	FCC 15.247
100 mW (EIRP)	Europe	ETS 300-328
10 mW/MHz	Japan	MPT ordinance for Regulating Radio Equipment, Article 49-20

15.4.7.2 Minimum transmitted power level

The minimum transmitted power shall be no less than 1 mW.

15.4.7.3 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. At a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

15.4.7.4 Transmit spectrum mask

The transmitted spectral products shall be less than –30 dB (dB relative to the SfN_x/x peak) for $f_c - 22$ MHz $< f < f_c - 11$ MHz, $f_c + 11$ MHz $< f < f_c + 22$ MHz, –50 dB for $f < f_c - 22$ MHz, and $f > f_c + 22$ MHz, where f_c

is the channel center frequency. The transmit spectral mask is shown in Figure 96. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

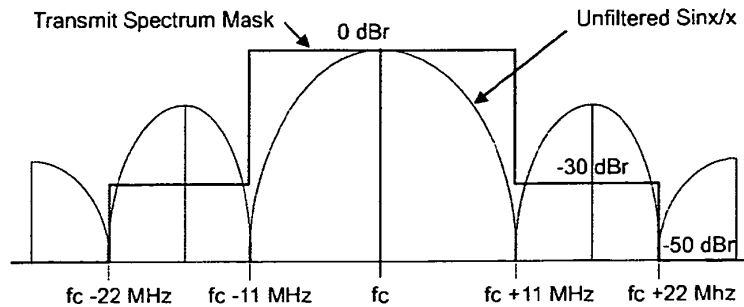


Figure 96—Transmit spectrum mask

15.4.7.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ± 25 ppm maximum.

15.4.7.6 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be better than ± 25 ppm maximum.

15.4.7.7 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 μ s. The transmit power-on ramp is shown in Figure 97.

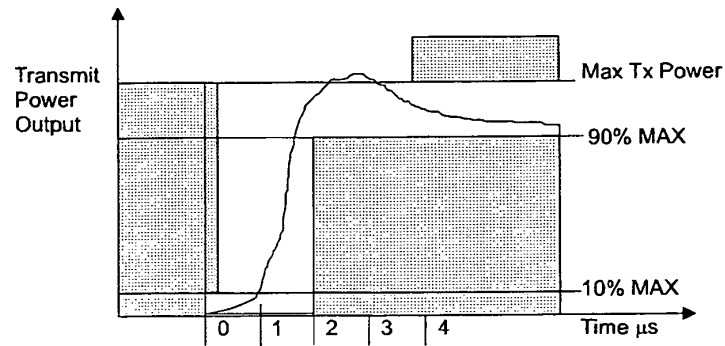


Figure 97—Transmit power-on ramp

The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 μ s. The transmit power down ramp is shown in Figure 98.

The transmit power ramps shall be constructed such that the DSSS PHY emissions conform with the spurious frequency product specification defined in 15.4.6.5.

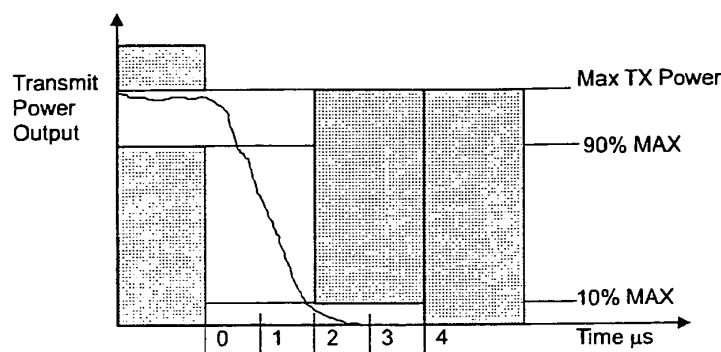


Figure 98—Transmit power-down ramp

15.4.7.8 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak $\text{SIN}(x)/x$ power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

15.4.7.9 Transmit modulation accuracy

The transmit modulation accuracy requirement for the DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude measured during each chip period. Worst-case vector error magnitude shall not exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation (0.707, 0.707), (0.707, -0.707), (-0.707, 0.707), (-0.707, -0.707) shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 99 illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE 802.11 vendor compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all 1s.

The eye pattern of the I channel shall be used to determine the I and Q sampling point. The chip clock provided by the vendor radio shall be time delayed such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 100). This is the ideal center of the eye and may not be the point of maximum eye opening.

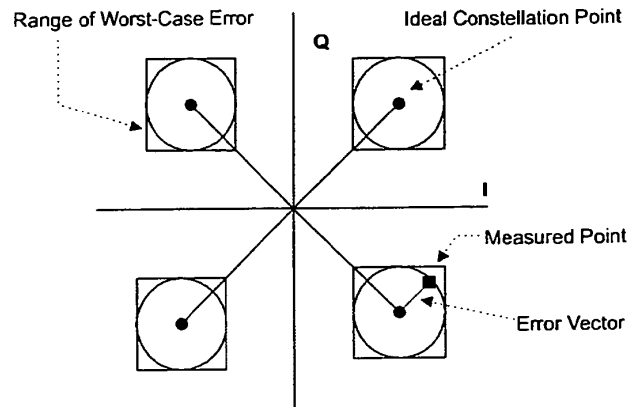


Figure 99—Modulation accuracy measurement example

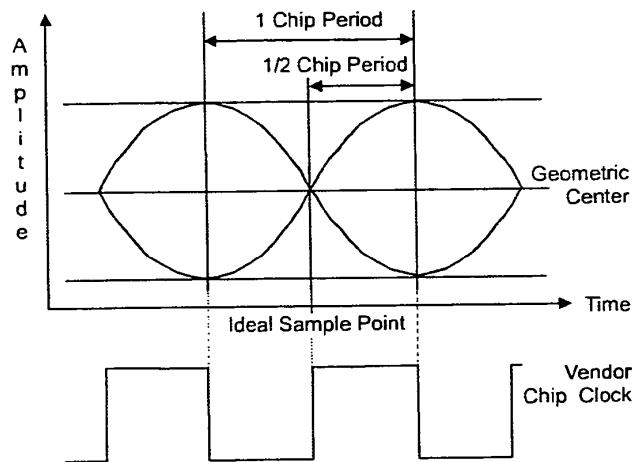


Figure 100—Chip clock alignment with baseband eye pattern

Using the aligned chip clock, 1000 samples of the I and Q baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for I and Q samples.

$$I_{\text{mean}} = \sum_{n=1}^{1000} |I(n)| / 1000$$

$$Q_{\text{mean}} = \sum_{n=1}^{1000} |Q(n)| / 1000$$

Calculate the dc corrected I and Q samples for all $n=1000$ sample pairs.

$$I_{dc}(n) = I(n) - I_{mean}$$

$$Q_{dc}(n) = Q(n) - Q_{mean}$$

Calculate the average magnitude of I and Q samples.

$$I_{mag} = \sum_{n=1}^{1000} |I_{dc}(n)| / 1000$$

$$Q_{mag} = \sum_{n=1}^{1000} |Q_{dc}(n)| / 1000$$

Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs.

$$V_{err}(n) = \left[\frac{1}{2} \times (\{|I_{dc}(n)|/I_{mag}\}^2 + \{|Q_{dc}(n)|/Q_{mag}\}^2) \right]^{\frac{1}{2}} - V_{correction}$$

with $V_{correction}$ = error induced by the reference receiver system.

A vendor DSSS PHY implementation shall be compliant if for all $n=1000$ samples the following condition is met:

$$V_{err}(n) < 0.35$$

15.4.8 PMD receiver specifications

The following subclauses describe the receive functions and parameters associated with the PMD sublayer.

15.4.8.1 Receiver minimum input level sensitivity

The frame error ratio (FER) shall be less than 8×10^{-2} at an MPDU length of 1024 bytes for an input level of -80 dBm measured at the antenna connector. This FER shall be specified for 2 Mbit/s DQPSK modulation. The test for the minimum input level sensitivity shall be conducted with the energy detection threshold set ≤ -80 dBm.

15.4.8.2 Receiver maximum input level

The receiver shall provide a maximum FER of 8×10^{-2} at an MPDU length of 1024 bytes for a maximum input level of -4 dBm measured at the antenna. This FER shall be specified for 2 Mbit/s DQPSK modulation.

15.4.8.3 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 30 MHz separation in each channel group defined in 15.4.6.2.

The adjacent channel rejection shall be ≥ 35 dB with an FER of 8×10^{-2} using 2 Mbit/s DQPSK modulation described in 15.4.6.4 and an MPDU length of 1024 bytes.

The adjacent channel rejection shall be measured using the following method:

Input a 2 Mbit/s DQPSK modulated signal at a level 6 dB greater than specified in 15.4.8.1. In an adjacent channel (≥ 30 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion that adheres to the transmit mask specified in 15.4.7.4 to a level 41 dB above the level specified in 15.4.8.1. The adjacent channel signal shall be derived from a separate signal source. It cannot be a frequency shifted version of the reference channel. Under these conditions, the FER shall be no worse than 8×10^{-2} .

15.4.8.4 CCA

The DSSS PHY shall provide the capability to perform CCA according to at least one of the following three methods:

- *CCA Mode 1:* Energy above threshold. CCA shall report a busy medium upon detection of any energy above the ED threshold.
- *CCA Mode 2:* Carrier sense only. CCA shall report a busy medium only upon detection of a DSSS signal. This signal may be above or below the ED threshold.
- *CCA Mode 3:* Carrier sense with energy above threshold. CCA shall report a busy medium upon detection of a DSSS signal with energy above the ED threshold.

The energy detection status shall be given by the PMD primitive, PMD_ED. The carrier sense status shall be given by PMD_CS. The status of PMD_ED and PMD_CS is used in the PLCP convergence procedure to indicate activity to the MAC through the PHY interface primitive PHY-CCA.indicate.

A busy channel shall be indicated by PHY-CCA.indicate of class BUSY.

A clear channel shall be indicated by PHY-CCA.indicate of class IDLE.

The PHY MIB attribute dot11CCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured through the PHY MIB attribute dot11CurrentCCAMode.

The CCA shall be TRUE if there is no energy detect or carrier sense. The CCA parameters are subject to the following criteria:

- a) The energy detection threshold shall be ≤ -80 dBm for TX power > 100 mW, -76 dBm for 50 mW $<$ TX power ≤ 100 mW, and -70 dBm for TX power ≤ 50 mW.
- b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within $5 \mu\text{s}$ of the start of a MAC slot boundary, the CCA indicator shall report channel busy before the end of the slot time. This implies that the CCA signal is available as an exposed test point. Refer to Figure 47 for a definition of slot time boundary.
- c) In the event that a correct PLCP Header is received, the DSSS PHY shall hold the CCA signal inactive (channel busy) for the full duration as indicated by the PLCP LENGTH field. Should a loss of carrier sense occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted packet.

Conformance to DSSS PHY CCA shall be demonstrated by applying a DSSS compliant signal, above the appropriate ED threshold a), such that all conditions described in b) and c) above are demonstrated.

16. Infrared (IR) PHY specification

16.1 Overview

The physical layer for the infrared system is specified in this clause. The IR PHY uses near-visible light in the 850 nm to 950 nm range for signaling. This is similar to the spectral usage of both common consumer devices such as infrared remote controls, as well as other data communications equipment, such as Infrared Data Association (IrDA) devices.

Unlike many other infrared devices, however, the IR PHY is not directed. That is, the receiver and transmitter do not have to be aimed at each other and do not need a clear line-of-sight. This permits the construction of a true LAN system, whereas with an aimed system, it would be difficult or impossible to install a LAN because of physical constraints.

A pair of conformant infrared devices would be able to communicate in a typical environment at a range up to about 10 m. This standard allows conformant devices to have more sensitive receivers, and this may increase range up to about 20 m.

The IR PHY relies on both reflected infrared energy as well as line-of-sight infrared energy for communications. Most designs anticipate that *all* of the energy at the receiver is reflected energy. This reliance on reflected infrared energy is called *diffuse infrared* transmission.

This standard specifies the transmitter and receiver in such a way that a conformant design will operate well in most environments where there is no line-of-sight path from the transmitter to the receiver. However, in an environment that has few or no reflecting surfaces, and where there is no line-of-sight, an IR PHY system may suffer reduced range.

The IR PHY will operate only in indoor environments. Infrared radiation does not pass through walls, and is significantly attenuated passing through most exterior windows. This characteristic can be used to “contain” an IR PHY in a single physical room, like a classroom or conference room. Different LANs using the IR PHY can operate in adjacent rooms separated only by a wall without interference, and without the possibility of eavesdropping.

At the time of this standard's preparation, the only known regulatory standards that apply to the use of infrared radiation are safety regulations, such as IEC 60825-1: 1998 [B2] and ANSI Z136.1-1993 [B1]. While a conformant IR PHY device can be designed to also comply with these safety standards, conformance with this standard does not ensure conformance with other standards.

Worldwide, there are currently no frequency allocation or bandwidth allocation regulatory restrictions on infrared emissions.

Emitter (typically LED) and detector (typically PIN diode) devices for infrared communications are relatively inexpensive at the infrared wavelengths specified in the IR PHY, and at the electrical operating frequencies required by this PHY.

While many other devices in common use also use infrared emissions in the same optical band, these devices usually transmit infrared intermittently and do not interfere with the proper operation of a compliant IR PHY. If such a device does interfere, by transmitting continuously and with a very strong signal, it can be physically isolated (placing it in a different room) from the IEEE 802.11 LAN.

16.1.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC by the IR system are described in this clause. The IR PHY layer consists of two protocol functions as follows:

- a) A physical layer convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 MAC sublayer protocol data units (MPDU) into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
- b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, the wireless medium (WM) between two or more STAs.

16.1.2 IR PHY functions

The IR PHY contains three functional entities: the PMD function, the physical layer convergence function, and the layer management function. Each of these functions is described in detail below.

The IR PHY service is provided to the MAC entity at the STA through a service access point (SAP) as described in Clause 12. For a visual guide to the relationship of the IR PHY to the remainder of the system, refer to Figure 11.

16.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a physical layer convergence sublayer is defined. This function simplifies the PHY service interface to the IEEE 802.11 MAC services. The PHY-specific preamble is normally associated with this convergence layer.

16.1.2.2 PMD sublayer

The PMD sublayer provides a clear channel assessment (CCA) mechanism, transmission mechanism, and reception mechanism that are used by the MAC via the PLCP to send or receive data between two or more STAs.

16.1.2.3 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MAC management entity. Subclause 16.4 lists the MIB variables that may be accessed by the PHY sublayer entities and intra-layer of higher-layer management entities (LMEs). These variables are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 10.

16.1.3 Service specification method and notation

The models represented by figures and state diagrams are intended as illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the IEEE 802.11 IR PHY compliant developer. Conformance to this standard is not dependent on following the model, and an implementation that follows the model closely may not be conformant.

Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation. In particular, the PHY-SAP operations are defined and described as instantaneous; however, this may be difficult to achieve in an implementation.

16.2 IR PLCP sublayer

While the PLCP sublayer and the PMD sublayer are described separately, the separation and distinction between these sublayers is artificial, and is not meant to imply that the implementation must separate these functions. This distinction is made primarily to provide a point of reference from which to describe certain functional components and aspects of the PMD. The functions of the PLCP can be subsumed by a PMD sublayer; in this case, the PMD will incorporate the PHY-SAP as its interface, and will not offer a PMD-SAP.

16.2.1 Overview

A convergence procedure is provided by which MPDUs are converted to and from PLCPDUs. During transmission, the MPDU (PLCSDU) is prepended with a PLCP Preamble and PLCP Header to create the PLCPDU. At the receiver, the PLCP Preamble is processed and the internal data fields are processed to aid in demodulation and delivery of the MPDU (PSDU).

16.2.2 PLCP frame format

Figure 101 shows the format for the PLCPDU including the PLCP Preamble, the PLCP Header, and the PSDU. The PLCP Preamble contains the following fields: Synchronization (SYNC) and Start Frame Delimiter (SFD). The PLCP Header contains the following fields: Data Rate (DR), DC Level Adjustment (DCLA), Length (LENGTH), and Cyclic Redundancy Check (CRC). Each of these fields is described in detail in 16.2.4.

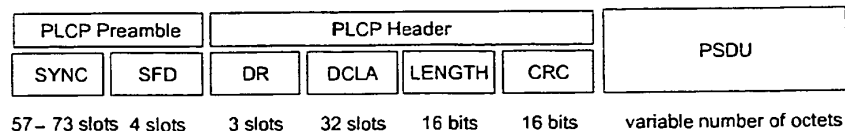


Figure 101—PLCPDU frame format

16.2.3 PLCP modulation and rate change

The PLCP Preamble shall be transmitted using the basic pulse defined in 16.3.3.2. The PLCSDU, LENGTH, and CRC fields shall be transmitted using pulse position modulation (PPM). PPM maps bits in the octet into symbols: 16-PPM maps four bits into a 16-position symbol, and 4-PPM maps two bits into a 4-position symbol. The basic L-PPM time unit is the slot. A slot corresponds to one of the L positions of a symbol and has a 250 ns duration. The PLCSDU, LENGTH, and CRC fields are transmitted at one of two bit rates: 1 Mbit/s or 2 Mbit/s. The Data Rate field indicates the data rate that will be used to transmit the PLCSDU, LENGTH, and CRC fields. The 1 Mbit/s data rate uses 16-PPM (basic access rate), and the 2 Mbit/s data rate uses 4-PPM (enhanced access rate). The transmitter and receiver will initiate the modulation or demodulation indicated by the DR field starting with the first 4 bits (in 16-PPM) or 2 bits (in 4-PPM) of the LENGTH field. The PSDU transmission rate is set by the DATARATE parameter in the PHY-TXSTART.request primitive. Any conformant IR PHY shall be capable of receiving at 1 Mbit/s and 2 Mbit/s. Transmission at 2 Mbit/s is optional.

A PHY-TXSTART.request that specifies a data rate that is not supported by a PHY instance will cause the PHY to indicate an error to its MAC instance. A PHY is not permitted under any circumstance to transmit at a different rate than the requested rate.

16.2.4 PLCP field definitions

16.2.4.1 PLCP Synchronization (SYNC) field

The SYNC field consists of a sequence of alternated presence and absence of a pulse in consecutive slots. The SYNC field has a minimum length of 57 L-PPM slots and a maximum length of 73 L-PPM slots and shall terminate with the absence of a pulse in the last slot. This field is provided so that the receiver can perform clock recovery (slot synchronization), automatic gain control (optional), signal-to-noise ratio estimation (optional), and diversity selection (optional).

The SYNC field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol. See 16.3.2.1 for legal symbols.

16.2.4.2 PLCP Start Frame Delimiter (SFD) field

The SFD field length is four L-PPM slots and consists of the binary sequence 1001, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot. The leftmost bit shall be transmitted first. The SFD field is provided to indicate the start of the PLCP Preamble and to perform bit and symbol synchronization.

The SFD field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

16.2.4.3 PLCP Data Rate (DR) field

The DR field indicates to the PHY the data rate that shall be used for the transmission or reception of the PLCS DU, LENGTH, and CRC fields. The transmitted value shall be provided by the PHY-TXSTART.request primitive as described in Clause 12. The DR field has a length of three L-PPM slots. The leftmost bit, as shown below, shall be transmitted first. The IR PHY currently supports two data rates defined by the slot pattern shown for the three L-PPM slots following the SFD, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot:

1 Mbit/s: 000

2 Mbit/s: 001

The DR field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

16.2.4.4 PLCP DC Level Adjustment (DCLA) field

The DCLA field is required to allow the receiver to stabilize the dc level after the SYNC, SFD, and DR fields. The leftmost bit, as shown below, shall be transmitted first. The length of the DCLA field is 32 L-PPM slots and consists of the contents shown, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot:

1 Mbit/s: 00000000100000000000000000000000

2 Mbit/s: 00100010001000100010001000100010

The DCLA field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

16.2.4.5 PLCP LENGTH field

The LENGTH field is an unsigned 16-bit integer that indicates the number of octets to be transmitted in the PSDU. The transmitted value shall be provided by the PHYTXSTART.request primitive as described in Clause 12. The lsb shall be transmitted first. This field is modulated and sent in L-PPM format. This field is protected by the CRC described in 16.2.4.6.

16.2.4.6 PLCP CRC field

The LENGTH field shall be protected by a 16-bit CRC-CCITT. The CRC-CCITT is the one's complement of the remainder generated by the modulo 2 division of the LENGTH field by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits will be processed in transmit order. The msb of the 16-bit CRC-CCITT shall be transmitted first. This field shall be modulated and sent in L-PPM format. All CRC-CCITT calculations shall be made prior to L-PPM encoding on transmission and after L-PPM decoding on reception.

16.2.4.7 PSDU field

This field is composed of a variable number of octets. The minimum is 0 (zero) and the maximum is 2500. The lsb of each octet shall be transmitted first. All the octets of this field shall be modulated and sent in L-PPM format.

16.2.5 PLCP procedures

16.2.5.1 PLCP transmit procedure

All commands issued by the MAC require that a confirmation primitive be issued by the PHY. The confirmation primitives provide flow control between the MAC and the PHY.

The transmit procedure is as follows:

- a) Based on the status of CCA, the MAC shall determine whether the channel is clear.
- b) If the channel is clear, transmission of the PSDU shall be initiated by a PHY-TXSTART.request with parameters LENGTH and DATARATE.
- c) The PHY entity shall immediately initiate transmission of the PLCP Preamble and PLCP Header based on the LENGTH and DATARATE parameters passed in the PHY-TXSTART.request. Once the PLCP Preamble and PLCP Header transmission is completed, the PHY entity shall issue a PHY-TXSTART.confirm.
- d) Each octet of the PSDU is passed from the MAC to the PHY by a single PHY-DATA.request primitive. Each PHY-DATA.request shall be confirmed by the PHY with a PHY-DATA.confirm before the next request can be made.
- e) At the PHY layer each PSDU octet shall be divided into symbols of 2 bits or 4 bits each. The symbols shall be modulated using L-PPM and transmitted into the medium.
- f) Transmission is terminated by the MAC through the primitive PHY-TXEND.request. The PHY shall confirm the resulting end of transmission with a PHY-TXEND.confirm.

16.2.5.2 PLCP receive procedure

The receive procedure is as follows:

- a) CCA is provided to the MAC via the PHY-CCA.indicate primitive. When the PHY senses activity on the medium, it shall indicate that the medium is busy with a PHY-CCA.indicate with a value of BUSY. This will normally occur during the SYNC field of the PLCP Preamble.
- b) The PHY entity shall begin searching for the SFD field. Once the SFD field is detected, the PHY entity shall attempt to receive the PLCP Header. After receiving the DR and DCLA fields, the PHY shall initiate processing of the received CRC and LENGTH fields. The data rate indicated in the DR field applies to all symbols in the latter part of the received PHYSDU, commencing with the first symbol of the LENGTH field. The CRC-CCITT shall be checked for correctness immediately after its reception.
- c) If the CRC-CCITT check fails, or the value received in the DR field is not one supported by the PHY, then a PHY-RXSTART.indicate shall not be issued to the MAC. When the medium is again free, the PHY shall issue a PHY-CCA.indicate with a value of IDLE.
- d) If the PLCP Preamble and PLCP Header reception is successful, the PHY shall send a PHY-RXSTART.indicate to the MAC; this includes the parameters DATARATE and LENGTH.
In the absence of errors, the receiving PHY shall report the same length to its local MAC, in the RXVECTOR parameter of the PHY-RXSTART.indicate primitive, that the peer MAC presented to its local PHY entity in the TXVECTOR parameter of its respective PHY-TXSTART.request.
- e) The received PLCSDU L-PPM symbols shall be assembled into octets and presented to the MAC using a series of PHY-DATA.indicate primitives, one per octet.
- f) Reception shall be terminated after the reception of the final symbol of the last PLCSDU octet indicated by the PLCP Header's LENGTH field. After the PHY-DATA.indicate for that octet is issued, the PHY shall issue a PHY-RXEND.indicate primitive to its MAC.
- g) After issuing the PHY-RXEND.indicate primitive, and when the medium is no longer busy, the PHY shall issue a PHY-CCA.indicate primitive with a value of IDLE.

16.2.5.3 CCA procedure

CCA is provided to the MAC via the PHY-CCA.indicate primitive.

The CCA procedure is as follows:

- a) When the PHY senses activity on the medium, a PHY-CCA.indicate primitive with a value of BUSY shall be issued. This will normally occur during reception of the SYNC field of the PLCP Preamble.
- b) When the PHY senses that the medium is free, a PHY-CCA.indicate primitive with a value of IDLE shall be issued.
- c) At any time, the MAC may issue a PHY-CCARESET.request primitive, which will reset the PHY's internal CCA detection mechanism to the medium not-busy (IDLE) state. This primitive will be acknowledged with a PHY-CCARESET.confirm primitive.

16.2.5.4 PMD_SAP peer-to-peer service primitive parameters

Several service primitives include a parameter vector. This vector shall be a list of parameters that may vary depending on PHY type. Table 68 indicates the parameters required by the MAC or IR PHY in each of the parameter vectors used for peer-to-peer interactions.

Table 68—IR PMD_SAP peer-to-peer service primitives

Parameter	Associated primitive	Value
LENGTH	RXVECTOR, TXVECTOR	4 to $2^{16} - 1$
DATARATE	RXVECTOR, TXVECTOR	PHY dependent

16.3 IR PMD sublayer

The IR PMD sublayer does not define PMD SAPs. The mechanism for communications between the PLCP and PMD sublayers, as well as the distinction between these two sublayers, if any, is left to implementors. In particular, it is possible to design and implement, in a conformant way, a single sublayer that subsumes the functions of both the PLCP and PMD, presenting only the PHY-SAP.

16.3.1 Overview

The PMD functional, electrical, and optical characteristics required for interoperability of implementations conforming to this specification are described in this subclause. The relationship of this specification to the entire IR physical layer is shown in Figure 11.

16.3.2 PMD operating specifications, general

General specifications for the IR PMD sublayer are provided in this subclause. These specifications apply to both the receive and transmit functions and general operation of a compliant IR PHY.

16.3.2.1 Modulation and channel data rates

Two modulation formats and data rates are specified for the IR PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate is based on 1 Mbit/s 16-PPM modulation. The 16-PPM encoding is specified in Table 69. Each group of 4 data bits is mapped to one of the 16-PPM symbols. The enhanced access rate is based on 2 Mbit/s 4-PPM. The 4-PPM encoding is specified in Table 70. Each group of 2 data bits is mapped to one of the 4-PPM symbols. Transmission order of the symbol slots is from left to right, as shown in the table, where a 1 indicates in-band energy in the slot, and a 0 indicates the absence of in-band energy in the slot.

The data in Table 69 and Table 70 have been arranged (gray coded) so that a single out-of-position-by-one error in the medium, caused, for example, by intersymbol interference, results in only a single bit error in the received data, rather than in a multiple bit error.

Table 69—Sixteen-PPM basic rate mapping

Data	16-PPM symbol
0000	0000000000000001
0001	0000000000000010
0011	0000000000000100
0010	0000000000001000
0110	0000000000100000
0111	0000000000100000
0101	0000000001000000
0100	0000000010000000
1100	0000000100000000
1101	0000001000000000
1111	0000010000000000
1110	0000100000000000
1010	0001000000000000
1011	0010000000000000
1001	0100000000000000
1000	1000000000000000

Table 70—Four-PPM enhanced rate mapping

Data	4-PPM symbol
00	0001
01	0010
11	0100
10	1000

16.3.2.2 Octet partition and PPM symbol generation procedure

Since PPM is a block modulation method, with the block size less than a full octet, octets have to be partitioned prior to modulation (mapping into PPM symbols).

Octet partition depends on the PPM order being used.

Assume an octet is formed by eight bits numbered 7 6 5 4 3 2 1 0, where bit 0 is the lsb. Partition the octet as follows:

For 16-PPM, create two PPM symbols:

- The symbol using bits 3 2 1 0 shall be transmitted onto the medium first.
- The symbol using bits 7 6 5 4 shall be transmitted onto the medium last.

For 4-PPM, create four PPM symbols:

- The symbol using bits 1 0 shall be transmitted onto the medium first.
- The symbol using bits 3 2 shall be transmitted onto the medium second.
- The symbol using bits 5 4 shall be transmitted onto the medium third.
- The symbol using bits 7 6 shall be transmitted onto the medium last.

16.3.2.3 Operating environment

The IR PHY will operate only in indoor environments. IR PHY interfaces cannot be exposed to direct sunlight. The IR PHY relies on reflected infrared energy and does not require a line-of-sight between emitter and receiver in order to work properly. The range and bit error rate of the system may vary with the geometry of the environment and with natural and artificial illumination conditions.

16.3.2.4 Operating temperature range

The temperature range for full operation compliance with the IR PHY is specified as 0 °C to 40 °C.

16.3.3 PMD transmit specifications

The following subclauses describe the transmit functions and parameters associated with the PMD sublayer.

16.3.3.1 Transmitted peak optical power

The peak optical power of an emitted pulse shall be as specified in Table 71.

Table 71—Peak optical power as a function of emitter radiation pattern mask

Emitter radiation pattern mask	Peak optical power
Mask 1	2 W $\pm$ 20%
Mask 2	0.55 W $\pm$ 20%

16.3.3.2 Basic pulse shape and parameters

The basic pulse width, measured between the 50% amplitude points, shall be 250 ± 10 ns. The pulse rise time, measured between the 10% and 90% amplitude points, shall be no more than 40 ns. The pulse fall time, measured between the 10% and 90% amplitude points, shall be no more than 40 ns. The edge jitter, defined as the absolute deviation of the edge from its correct position, shall be no more than 10 ns. The basic pulse shape is shown in Figure 102.

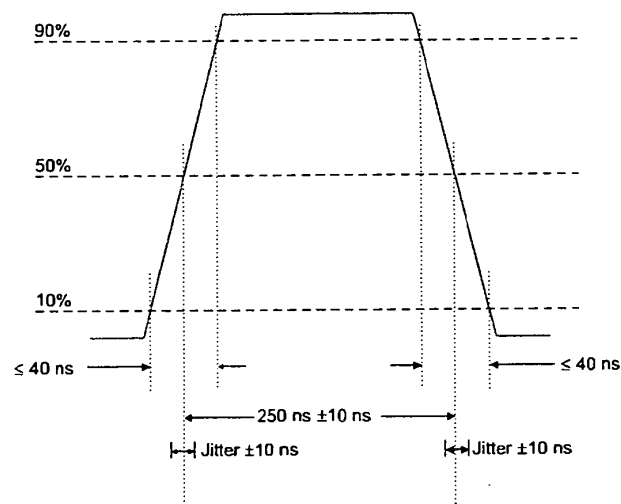


Figure 102—Basic pulse shape

16.3.3.3 Emitter radiation pattern mask

The standard contains two emitter radiation pattern masks. Mask 1 is defined in Table 72 and illustrated in Figure 103. Mask 2 is defined in Table 73 and illustrated in Figure 105.

Table 72—Definition of the emitter radiation pattern mask 1

Declination angle	Normalized irradiance
$\alpha \leq 60^\circ$	$> 3.5 \times 10^{-6}$
$\alpha \leq 29^\circ$	$\leq 2.2 \times 10^{-5}$
$29^\circ < \alpha \leq 43^\circ$	$\leq -1.06 \times 10^{-4} + (0.44 \times 10^{-5}) \alpha$
$43^\circ < \alpha \leq 57^\circ$	$\leq 1.15 \times 10^{-4} - (7.1 \times 10^{-7}) \alpha$
$57^\circ < \alpha \leq 74^\circ$	$\leq 2.98 \times 10^{-4} - (3.9 \times 10^{-6}) \alpha$
$74^\circ < \alpha \leq 90^\circ$	$\leq 4.05 \times 10^{-5} - (4.5 \times 10^{-7}) \alpha$

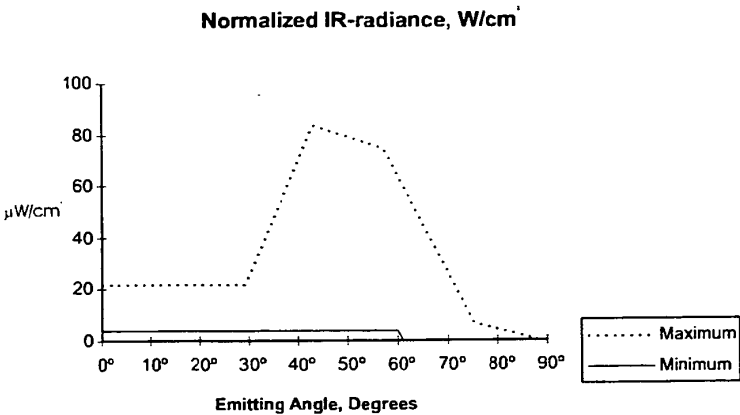


Figure 103—Emitter radiation pattern mask 1

Following is a description of how to interpret the Mask 1 table and figure. Position the conformant Mask 1 device in its recommended attitude. Define the conformant Mask 1 device axis as the axis passing through the emitter center and having the direction perpendicular to the floor. The mask represents the irradiance normalized to the total peak emitted power, as a function of the angle between the conformant Mask 1 device axis and the axis from the emitter center to the test receiver center (declination angle). The distance between emitter and test receiver is 1 m. The test receiver normal is always aimed at the emitter center. The azimuth angle is a rotation angle on the conformant device axis.

A device is conformant if for any azimuth angle its radiation pattern as a function of declination angle falls within the pattern mask.

Figure 104 is a description of how to interpret the Mask 2 table with reference to Figure 105.

Table 73—Definition of emitter radiation pattern mask 2

Declination angle	Pitch angle	Normalized irradiance
$\alpha \leq 60$	$\alpha = 0$	$0.05 \pm 15\%$
$\alpha \leq 90$	$\alpha = 0$	$0.025 \pm 15\%$
$\alpha \geq 100$	$\alpha = 0$	≤ 0.015
$0 \leq \alpha \leq 60$	$0 \leq \alpha \leq 10$	$0.035 \leq I \leq 0.055$
$0 \leq \alpha \leq 60$	$10 \leq \alpha \leq 20$	$0.0225 \leq I \leq 0.05$
$0 \leq \alpha \leq 60$	$\alpha \geq 30$	≤ 0.015

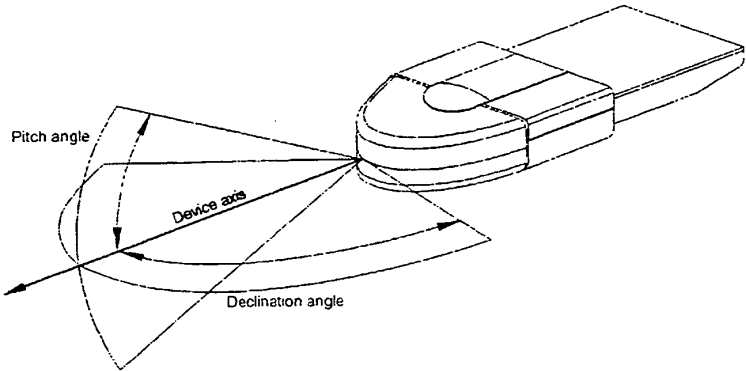


Figure 104—Mask 2 device orientation drawing

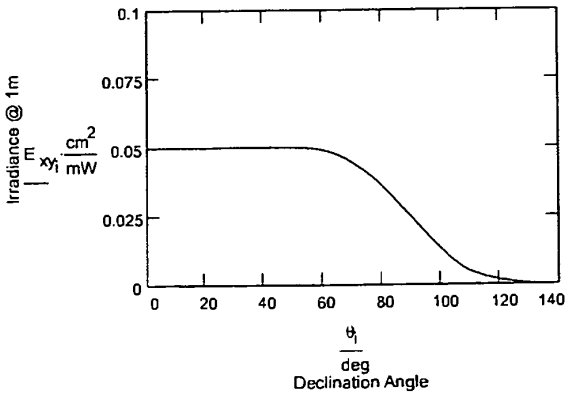


Figure 105—Emitter radiation pattern mask 2

Position the conformant Mask 2 device in its recommended attitude. Define the conformant Mask 2 device axis as passing through the emitter center and having the direction relative to the device as defined by the manufacturer. The declination angle plane is as defined by the manufacturer. The mask represents the irradiance normalized to the peak emitted power on the conformant Mask 2 device axis, as a function of the angle between the conformant device axis and the axis from the emitter center to the test receiver center (declination angle) in the declination plane. The distance between emitter and test receiver is 1 m. The test receiver normal is always aimed at the emitter center. The pitch angle is an angle relative to the conformant device axis which is perpendicular to the declination plane.

The device is conformant if, for a pitch angle of 0 degrees, at any declination angle from 0 to 100 degrees, and if, for any declination angle from 0 to 60 degrees, at any pitch angle from 0 to 20 degrees, its radiation pattern as a function of angle falls within the pattern mask.

Other radiation patterns are for future study.

16.3.3.4 Optical emitter peak wavelength

The optical emitter peak wavelength shall be between 850 nm and 950 nm.

16.3.3.5 Transmit spectrum mask

Define the transmit spectrum of a transmitter as the Fourier Transform, or equivalent, of a voltage (or current) signal whose amplitude, as a function of time, is proportional to the transmitted optical power.

The transmit spectrum of a conformant transmitter shall be 20 dB below its maximum for all frequencies above 15 MHz. The transmit spectrum mask is shown in Figure 106.

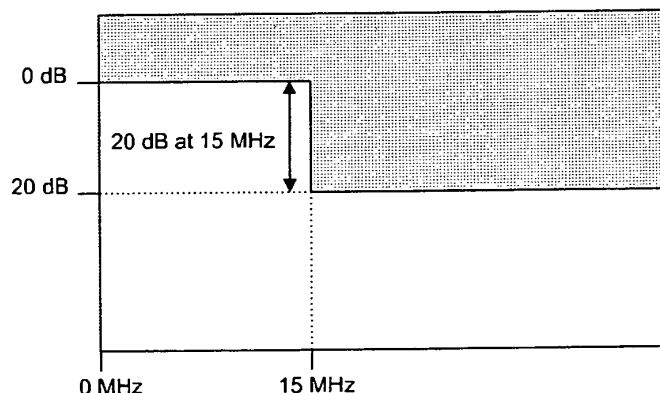


Figure 106—Transmit spectrum mask

16.3.4 PMD receiver specifications

The following subclauses describe the receive functions and parameters associated with the PMD sublayer.

16.3.4.1 Receiver sensitivity

The receiver sensitivity, defined as the minimum irradiance (in mW/cm²) at the photodetector plane required for a frame error ratio (FER) of 4×10^{-5} with a PLCS DU of 512 octets and with an unmodulated background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm², shall be

- 1 Mbit/s: 2×10^{-5} mW/cm²
- 2 Mbit/s: 8×10^{-5} mW/cm²

16.3.4.2 Receiver dynamic range

The receiver dynamic range, defined as the ratio between the maximum and minimum irradiance at the plane normal to the receiver axis that assures an FER lower than or equal to 4×10^{-5} with a PLCS DU of 512 octets and with an unmodulated background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm², shall be ≥ 30 dB.

16.3.4.3 Receiver field-of-view (FOV)

The receiver axis is defined as the direction of incidence of the optical signal at which the received optical power is maximum.

The received optical power shall be greater than the values given in Table 74, at the angles indicated, where "angle of incidence" is the angle of the optical signal relative to the receiver axis, and "received power" is the received optical power as a percentage of that measured at the receiver axis.

Table 74—Definition of the receiver field of view

Angle of incidence	Received power
$\alpha \leq 20^\circ$	$\geq 65\%$
$\alpha \leq 40^\circ$	$\geq 55\%$
$\alpha \leq 60^\circ$	$\geq 35\%$
$\alpha \leq 80^\circ$	$\geq 10\%$

16.3.5 Energy Detect, Carrier Sense, and CCA definitions

16.3.5.1 Energy Detect (ED) signal

The ED signal shall be set true when IR energy variations in the band between 1 MHz and 10 MHz exceed 0.001 mW/cm².

The ED shall operate independently of the CS. The ED shall not be asserted at the minimum signal level specified in 16.3.4.1, which is below the level specified in this subclause.

This signal is not directly available to the MAC.

16.3.5.2 Carrier Sense (CS) signal

The CS shall be asserted by the PHY when it detects and locks onto an incoming PLCP Preamble signal. Conforming PHYs shall assert this condition within the first 12 μ s of signal reception, at the minimum signal

level equal to the receiver sensitivity specified in 16.3.4.1, with a background IR level as specified in 16.3.4.1.

The CS shall be deasserted by the PHY when the receiving conformant device loses carrier lock.

NOTE—The 12 μ s specification is somewhat less than the minimum length of the PLCP SYNC interval, which is 14.25 μ s.

The CS shall operate independently of the ED and shall not require a prior ED before the acquisition and assertion of CS. This permits reception of signals at the minimum signal level specified in 16.3.4.1, even though these signals fall below the ED level.

This signal is not directly available to the MAC.

16.3.5.3 CCA

CCA shall be asserted "IDLE" by the PHY when the CS and the ED are both false, or when ED has been continuously asserted for a period of time defined by the product of `dot11CCAWatchdogTimerMax` and `dot11CCAWatchdogCountMax` without CS becoming active. When either CS or ED go true, CCA is indicated as "BUSY" to the MAC via the primitive `PHY-CCA.indicate`. CS and DE behavior are defined in 16.3.5.2.

Normally, CCA will be held "BUSY" throughout the period of the PLCP Header. After receiving the last PLCP bit and the first data octet, the PHY shall signal `PHY-RXSTART.indicate` with the parameters `LENGTH` and `RATE`. CCA shall be held "BUSY" until the number of octets specified in the decoded PLCP Header are received. At that time the PHY shall signal `PHY-RXEND.indicate`. The CCA may remain "BUSY" after the end of data if some form of energy is still being detected. The PHY will signal `PHY-CCA.indicate` with a value of `IDLE` only when the CCA goes "CLEAR."

The transition of CCA from "BUSY" to "IDLE" is indicated to the MAC via the primitive `PHY-CCA.indicate`.

If CS and ED go false before the PHY signals `PHY-RXSTART.indicate`, CCA is set to "IDLE" and *immediately* signaled to the MAC via `PHY-CCA.indicate` with a value of `IDLE`. If CS and ED go false after the PHY has signaled `PHY-RXSTART.indicate`, implying that the PLCP Header has been properly decoded, then the PHY shall not signal a change in state of CCA until the proper interval has passed for the number of octets indicated by the received PLCP `LENGTH`. At that time, the PHY shall signal `PHY-RXEND.indicate` with an `RXERROR` parameter of `CarrierLost` followed by `PHY-CCA.indicate` with a value of `IDLE`.

The transition of CCA from "CLEAR" to "BUSY" resets the CCA watchdog timer and CCA watchdog counter. `dot11CCAWatchdogTimerMax` and `dot11CCAWatchdogCountMax` are parameters available via MIB entries and can be read and set via the LME.

Rise and fall times of CCA relative to the OR'ing of the CS and ED signals shall be less than 30 ns. CS and ED are both internal signals to the PHY and are not available directly to the MAC, nor are they defined at any exposed interface.

16.3.5.4 CHNL_ID

For the IR PHY, `CHNL_ID = X'01'` is defined as the baseband modulation method. All other values are not defined.

16.4 PHY attributes

PHY attributes have allowed values and default values that are PHY dependent. Table 75 and Table 76 describe those values, and further specify whether they are permitted to vary from implementation to implementation.

Table 75 does not provide the definition of the attributes, but only provides the IR PHY-specific values for the attributes whose definitions are in Clause 13.

Table 75—IR PHY MIB attributes

PHY MIB object	Default value	Operational semantics	Operational behavior
dot11CCAWatchdogTimerMax	Implementation dependent	Dynamic	A conformant PHY may set this via the LME
dot11CCAWatchdogCountMax	Implementation dependent	Dynamic	A conformant PHY may set this via the LME
dot11CCAWatchdogTimerMin	22 μ s	Static	Identical for all conformant PHYs
dot11CCAWatchdogCountMin	1	Static	Identical for all conformant PHYs
dot11SupportedDataRatesTx	Implementation dependent	Static	All conformant PHYs must include the value X'02' (1 Mbit/s).
dot11SupportedDataRatesRx	Implementation dependent	Static	All conformant PHYs must include the values X'02' (1 Mbit/s) and X'04' (2 Mbit/s).
dot11PhyType	03	Static	Identical for all conformant PHYs
dot11PhyTempType	X'01'	Static	Identical for all conformant PHYs

The static IR PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 76. The definitions of these characteristics are in 10.4.3.

Table 76—IR PHY characteristics

Characteristic	Value
aSlotTime	8 μ s
aSIFSTime	10 μ s
aCCATime	5 μ s
aRxTxTurnaroundTime	0 μ s
aTxPLCPDelay	Implementors may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	1 μ s
aRxTxSwitchTime	0 μ s
aTxRampOnTime	0 μ s
aTxRampOffTime	0 μ s
aTxRFDelay	Implementors may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	Implementors may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μ s
aMACProcessingDelay	2 μ s
aPreambleLength	16 μ s (1 Mbit/s) 20 μ s (2 Mbit/s)
aPLCPHeaderLength	41 μ s (1 Mbit/s) 25 μ s (2 Mbit/s)
aMPDUDurationFactor	0
aMPDUMaxLength	2500
aCWmin	63
aCWmax	1023

Annex A

(normative)

Protocol Implementation Conformance Statement (PICS) proforma

A.1 Introduction

The supplier of a protocol implementation that is claimed to conform to ISO/IEC 8802.11: 1999 shall complete the following PICS proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can have a number of uses, including use

- a) By the protocol implementor, as a checklist to reduce the risk of failure to conform to the standard through oversight;
- b) By the supplier and acquirer, or potential acquirer, of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;
- c) By the user, or potential user, of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICS proformas);
- d) By a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A.2 Abbreviations and special symbols

A.2.1 Status symbols

M	mandatory
O	optional
O.<n>	optional, but support of at least one of the group of options labeled by the same numeral <n> is required
pred:	conditional symbol, including predicate identification

A.2.2 General abbreviations

N/A	not applicable
AD	address function capability
CF	implementation under test (IUT) configuration
FR	MAC frame capability
FS	frame sequence capability
PC	protocol capability
PICS	protocol implementation conformance statement

A.3 Instructions for completing the PICS proforma

A.3.1 General structure of the PICS proforma

The first part of the PICS proforma, Implementation identification and Protocol summary, is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed questionnaire, divided into subclauses, each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No) or by entering a value or a set or a range of values. (Note that there are some items where two or more choices from a set of possible answers may apply. All relevant choices are to be marked in these cases.)

Each item is identified by an item reference in the first column. The second column contains the question to be answered. The third column contains the reference or references to the material that specifies the item in the main body of ISO/IEC 8802-11: 1999. The remaining columns record the status of each item, i.e., whether support is mandatory, optional, or conditional, and provide the space for the answers (see also A.3.4). Marking an item as supported is to be interpreted as a statement that all relevant requirements of the subclauses and normative annexes, cited in the References column for the item, are met by the implementation.

A supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A</> or X</>, respectively, for cross-referencing purposes, where </> is any unambiguous identification for the item (e.g., simply a numeral). There are no other restrictions on its format or presentation.

The PICS proforma for a station consists of A.4.1 through A.4.4 inclusive, and at least one of A.4.5, A.4.6, or A.4.7 corresponding to the PHY implemented.

A completed PICS proforma, including any Additional Information and Exception Information, is the PICS for the implementation in question.

NOTE—Where an implementation is capable of being configured in more than one way, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's capabilities, if this makes for easier and clearer presentation of the information.

A.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist in the interpretation of the PICS. It is not intended or expected that a large quantity of information will be supplied, and a PICS can be considered complete without any such information. Examples of such Additional Information might be an outline of the ways in which an (single) implementation can be set up to operate in a variety of environments and configurations, or information about aspects of the implementation that are outside the scope of this standard but have a bearing upon the answers to some items.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

A.3.3 Exception information

It may happen occasionally that a supplier will wish to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will be found in the Support column for this. Instead, the supplier shall write the missing answer into the Support column, together with an X</> reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception Information item itself.

An implementation for which an Exception Information item is required in this way does not conform to ISO/IEC 8802-11: 1999.

NOTE—A possible reason for the situation described above is that a defect in ISO/IEC 8802-11: 1999 has been reported, a correction for which is expected to change the requirement not met by the implementation.

A.3.4 Conditional status

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply, mandatory or optional, are dependent upon whether or not certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the questionnaire if the Not Applicable (N/A) answer is selected. Otherwise, individual conditional items are indicated by a conditional symbol in the Status column.

A conditional symbol is of the form “<pred>:<S>”, where “<pred>” is a predicate as described below, and “<S>” is one of the status symbols M or O.

If the value of the predicate is true, the conditional item is applicable, and its status is given by S: the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the N/A answer is to be marked.

A predicate is one of the following:

- a) An item-reference for an item in the PICS proforma: the value of the predicate is true if the item is marked as supported, and is false otherwise.
- b) A boolean expression constructed by combining item-references using the boolean operator OR: the value of the predicate is true if one or more of the items is marked as supported, and is false otherwise.

Each item referenced in a predicate, or in a preliminary question for grouped conditional items, is indicated by an asterisk in the Item column.

A.4 PICS proforma—ISO/IEC 8802-11: 1999⁷

A.4.1 Implementation identification

Supplier	
Contact point for queries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification, e.g., name(s) and version(s) of the machines and/or operating systems(s), system names	

NOTES

1—Only the first three items are required for all implementations. Other information may be completed as appropriate in meeting the requirement for full identification.

2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).

A.4.2 Protocol summary, ISO/IEC 8802-11: 1999

Identification of protocol standard	ISO/IEC 8802-11: 1999
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	Amd. : Corrig. : Amd. : Corrig. :
Have any exception items been required? (See A.3.3; the answer Yes means that the implementation does not conform to ISO/IEC 8802-11: 1999.)	Yes ☐ No ☐
Date of statement (dd/mm/yy)	

⁷Copyright release for PICS proforma: Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

A.4.3 IUT configuration

Item	IUT configuration	References	Status	Support
	What is the configuration of the IUT?			
* CF1	Access Point (AP)	5.2	O.1	Yes ☐ No ☐
* CF2	Independent station (<i>not</i> an AP)	5.2	O.1	Yes ☐ No ☐
* CF3	Frequency-Hopping spread spectrum (FHSS) PHY for the 2.4 GHz band		O.2	Yes ☐ No ☐
* CF4	Direct Sequence Spread Spectrum (DSSS) PHY for the 2.4 GHz band		O.2	Yes ☐ No ☐
* CF5	Infrared PHY		O.2	Yes ☐ No ☐

A.4.4 MAC protocol

A.4.4.1 MAC protocol capabilities

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol capabilities supported?			
PC1	Authentication service	5.4.3.1, 5.4.3.2, 5.7.6, 5.7.7, 8.1, Annex C	M	Yes ☐ No ☐
PC1.1	Authentication state	5.5	M	Yes ☐ No ☐
PC1.2	Open System authentication	8.1.1	M	Yes ☐ No ☐
PC1.3	Shared Key authentication	8.1.2, 8.3	PC2:M	Yes ☐ No ☐ N/A ☐
* PC2	WEP algorithm	5.4.3.3, 8.2, Annex C	O	Yes ☐ No ☐
PC2.1	WEP Encryption procedure	8.2.3, 8.2.4, 8.2.5	PC2:M	Yes ☐ No ☐ N/A ☐
PC2.2	WEP Decryption procedure	8.2.3, 8.2.4, 8.2.5	PC2:M	Yes ☐ No ☐ N/A ☐
PC2.3	Security services management	8.3	M	Yes ☐ No ☐
PC3	Distributed Coordination function	9.1, 9.2, Annex C	M	Yes ☐ No ☐
PC3.1	Net Allocation Vector (NAV) function	9.2.1, 9.2.5, 9.3.2.2	M	Yes ☐ No ☐
PC3.2	Interframe space usage and timing	9.2.3, 9.2.5, 9.2.10	M	Yes ☐ No ☐
PC3.3	Random Backoff function	9.2.4	M	Yes ☐ No ☐
PC3.4	DCF Access procedure	9.2.5.1, 9.2.5.5	M	Yes ☐ No ☐
PC3.5	Random Backoff procedure	9.2.5.2	M	Yes ☐ No ☐
PC3.6	Recovery procedures and retransmit limits	9.2.5.3	M	Yes ☐ No ☐
PC3.7	RTS/CTS procedure	9.2.5.4, 9.2.5.6, 9.2.5.7	M	Yes ☐ No ☐

A.4.4.1 MAC protocol capabilities (continued)

Item	Protocol capability	References	Status	Support
PC3.8	Directed MPDU transfer	9.2.6	M	Yes ☐ No ☐
PC3.9	Broadcast and multicast MPDU transfer	9.2.7	M	Yes ☐ No ☐
PC3.10	MAC level acknowledgment	9.2.2, 9.2.8	M	Yes ☐ No ☐
PC3.11	Duplicate detection and recovery	9.2.9	M	Yes ☐ No ☐
* PC4	Point coordinator (PC)	9.1, 9.3, Annex C	CF1:O	Yes ☐ No ☐ N/A ☐
PC4.1	Maintenance of CFP structure and timing	9.3.1, 9.3.2	PC4:M	Yes ☐ No ☐ N/A ☐
PC4.2	PCF MPDU transfer from PC	9.3.3	PC4:M	Yes ☐ No ☐ N/A ☐
* PC4.3	PCF MPDU transfer to PC	9.3.3	PC4:O	Yes ☐ No ☐ N/A ☐
PC4.4	Overlapping PC provisions	9.3.3.2	PC4:M	Yes ☐ No ☐ N/A ☐
PC4.5	Polling list maintenance	9.3.4	PC4.3: M	Yes ☐ No ☐ N/A ☐
* PC5	CF-Pollable	9.1, 9.3, Annex C	CF2:O	Yes ☐ No ☐ N/A ☐
PC5.1	Interpretation of CFP structure and timing	9.3.1, 9.3.2	PC5:M	Yes ☐ No ☐ N/A ☐
PC5.2	PCF MPDU transfer to/from and CF-Pollable STA	9.3.3	PC5:M	Yes ☐ No ☐ N/A ☐
PC5.3	Polling list update	9.3.4	PC5:M	Yes ☐ No ☐ N/A ☐
PC6	Fragmentation	9.2, 9.4, Annex C	M	Yes ☐ No ☐
PC7	Defragmentation	9.2, 9.5, Annex C	M	Yes ☐ No ☐
PC8	MAC data service	9.1.5, 9.8, Annex C	M	Yes ☐ No ☐
PC8.1	Reorderable-Multicast service class	9.8	M	Yes ☐ No ☐
PC8.2	StrictlyOrdered service class	9.8	O	Yes ☐ No ☐
PC9	Multirate support	9.6, Annex C	M	Yes ☐ No ☐
* PC10	Multiple outstanding MSDU support	9.8, Annex C	O	Yes ☐ No ☐
PC10.1	Multiple outstanding MSDU transmission restrictions	9.8	PC10:M	Yes ☐ No ☐ N/A ☐
PC11	Timing synchronization	11.1, Annex C	M	Yes ☐ No ☐
PC11.1	Timing in an infrastructure network	11.1.1.1, 11.1.4	CF1:M	Yes ☐ No ☐ N/A ☐
PC11.2	Timing in an Independent BSS (IBSS)	11.1.1.2, 11.1.4	CF2:M	Yes ☐ No ☐ N/A ☐
PC11.3	Beacon Generation function	11.1.2	M	Yes ☐ No ☐ N/A ☐
PC11.5	TSF synchronization and accuracy	11.1.2	M	Yes ☐ No ☐
PC11.5	Infrastructure BSS initialization	11.1.3	CF1:M	Yes ☐ No ☐ N/A ☐

A.4.4.1 MAC protocol capabilities (continued)

Item	Protocol capability	References	Status	Support
PC11.6	Independent BSS initialization	11.1.3	CF2:M	Yes ☐ No ☐ N/A ☐
PC11.7	Passive scanning	11.1.3	CF2:M	Yes ☐ No ☐ N/A ☐
PC11.8	Active scanning	11.1.3	CF2:M	Yes ☐ No ☐ N/A ☐
PC11.9	Probe response	11.1.3	M	Yes ☐ No ☐
PC11.10	Hop Synchronization function	11.1.5	CF3:M	Yes ☐ No ☐ N/A ☐
PC12	Infrastructure power management	11.2.1, Annex C	M	Yes ☐ No ☐
PC12.1	Station power management modes	11.2.1.1, 11.2.1.8	CF2:M	Yes ☐ No ☐ N/A ☐
PC12.2	TIM transmission	11.2.1.2, 11.2.1.3	CF1:M	Yes ☐ No ☐ N/A ☐
PC12.3	AP function during CP	11.2.1.4	CF1:M	Yes ☐ No ☐ N/A ☐
PC12.4	AP function during CFP	11.2.1.5	PC4:M	Yes ☐ No ☐ N/A ☐
PC12.5	Receive function during CP	11.2.1.6	CF2:M	Yes ☐ No ☐ N/A ☐
PC12.6	Receive function during CFP	11.2.1.7	PC5:M	Yes ☐ No ☐ N/A ☐
PC12.7	Aging function	11.2.1.9	CF1:M	Yes ☐ No ☐ N/A ☐
PC13	IBSS power management	11.2.2, Annex C	CF2:M	Yes ☐ No ☐ N/A ☐
PC13.1	Initialization of power management	11.2.2.2	CF2:M	Yes ☐ No ☐ N/A ☐
PC13.2	STA power state transitions	11.2.2.3	CF2:M	Yes ☐ No ☐ N/A ☐
PC13.3	ATIM and frame transmission	11.2.2.4	CF2:M	Yes ☐ No ☐ N/A ☐
PC14	Association and reassociation	5.4, 5.7, 11.3, Annex C	M	Yes ☐ No ☐
PC14.1	Association state	5.5	M	Yes ☐ No ☐
PC14.2	STA association procedure	11.3.1	CF2:M	Yes ☐ No ☐ N/A ☐
PC14.3	AP association procedure	11.3.2	CF1:M	Yes ☐ No ☐ N/A ☐
PC14.4	STA reassociation procedure	11.3.3	CF2:M	Yes ☐ No ☐ N/A ☐
PC14.5	AP reassociation procedure	11.3.4	CF1:M	Yes ☐ No ☐ N/A ☐
PC15	Management information base (MIB)	Annex D	M	Yes ☐ No ☐
PC15.1	dot11SMtbase, dot11SMtAuthenticationAlgorithms	Annex D	M	Yes ☐ No ☐
* PC15.2	dot11SMtprivacy	Annex D	PC2:M	Yes ☐ No ☐ N/A ☐
PC15.3	dot11MACbase, dot11CountersGroup, dot11MacGroupAddresses	Annex D	M	Yes ☐ No ☐
* PC15.4	dot11MACStatistics	Annex D	O	Yes ☐ No ☐
PC15.5	dot11ResourceTypeID	Annex D	M	Yes ☐ No ☐

A.4.4.2 MAC frames

Item	MAC frame	References	Status	Support
	Is transmission of the following MAC frames supported?	7, Annex C		
FT1	Association request	7	CF2:M	Yes ☐ No ☐ N/A ☐
FT2	Association response	7	CF1:M	Yes ☐ No ☐ N/A ☐
FT3	Reassociation request	7	CF2:M	Yes ☐ No ☐ N/A ☐
FT4	Reassociation response	7	CF1:M	Yes ☐ No ☐ N/A ☐
FT5	Probe request	7	CF2:M	Yes ☐ No ☐ N/A ☐
FT6	Probe response	7	M	Yes ☐ No ☐
FT7	Beacon	7	M	Yes ☐ No ☐
FT8	ATIM	7	CF2:M	Yes ☐ No ☐ N/A ☐
FT9	Disassociation	7	M	Yes ☐ No ☐
FT10	Authentication	7	M	Yes ☐ No ☐
FT11	Deauthentication	7	M	Yes ☐ No ☐
FT12	PS-Poll	7	CF2:M	Yes ☐ No ☐ N/A ☐
FT13	RTS	7	M	Yes ☐ No ☐
FT14	CTS	7	M	Yes ☐ No ☐
FT15	ACK	7	M	Yes ☐ No ☐
FT16	CF-End	7	PC4:M	Yes ☐ No ☐ N/A ☐
FT17	CF End+CF-Ack	7	PC4:M	Yes ☐ No ☐ N/A ☐
FT18	Data	7	M	Yes ☐ No ☐
FT19	Data + CF-Ack	7	(PC4 OR PC5):M	Yes ☐ No ☐ N/A ☐
FT20	Data + CF-Poll	7	PC4.3:M	Yes ☐ No ☐ N/A ☐
FT21	Data + CF-Ack+CF-Poll	7	PC4.3:M	Yes ☐ No ☐ N/A ☐
FT22	Null	7	M	Yes ☐ No ☐
FT23	CF-Ack (no data)	7	(PC4 OR PC5):M	Yes ☐ No ☐ N/A ☐
FT24	CF-Poll (no data)	7	PC4.3:M	Yes ☐ No ☐ N/A ☐
FT25	CF-Ack+CF-Poll (no data)	7	PC4.3:M	Yes ☐ No ☐ N/A ☐
	Is reception of the following MAC frames supported?	7, Annex C		
FR1	Association request	7	CF1:M	Yes ☐ No ☐ N/A ☐
FR2	Association response	7	CF2:M	Yes ☐ No ☐ N/A ☐
FR3	Reassociation request	7	CF1:M	Yes ☐ No ☐ N/A ☐
FR4	Reassociation response	7	CF2:M	Yes ☐ No ☐ N/A ☐
FR5	Probe request	7	M	Yes ☐ No ☐
FR6	Probe response	7	M	Yes ☐ No ☐
FR7	Beacon	7	M	Yes ☐ No ☐
FR8	ATIM	7	CF2:M	Yes ☐ No ☐ N/A ☐
FR9	Disassociation	7	M	Yes ☐ No ☐
FR10	Authentication	7	M	Yes ☐ No ☐

A.4.4.2 MAC frames (continued)

Item	MAC frame	References	Status	Support
FR11	Deauthentication	7	M	Yes ☐ No ☐
FR12	PS-Poll	7	CF1:M	Yes ☐ No ☐ N/A ☐
FR13	RTS	7	M	Yes ☐ No ☐
FR14	CTS	7	M	Yes ☐ No ☐
FR15	ACK	7	M	Yes ☐ No ☐
FR16	CF-End	7	M	Yes ☐ No ☐
FR17	CF End+CF-Ack	7	M	Yes ☐ No ☐
FR18	Data	7	M	Yes ☐ No ☐
FR19	Data + CF-Ack	7	M	Yes ☐ No ☐
FR20	Data + CF-Poll	7	PC5:M	Yes ☐ No ☐ N/A ☐
FR21	Data + CF-Ack+CF-Poll	7	PC5:M	Yes ☐ No ☐ N/A ☐
FR22	Null	7	M	Yes ☐ No ☐
FR23	CF-Ack (no data)	7	(PC4 OR PC5):M	Yes ☐ No ☐ N/A ☐
FR24	CF-Poll (no data)	7	PC5:M	Yes ☐ No ☐ N/A ☐
FR25	CF-Ack+CF-Poll (no data)	7	PC5:M	Yes ☐ No ☐ N/A ☐

A.4.4.3 Frame exchange sequences

Item	Frame exchange sequence	References	Status	Support
	Are the following frame sequences supported?			
FS1	Basic frame sequences	9.7, Annex C	M	Yes ☐ No ☐
FS2	CF-Frame sequences	9.7, Annex C	(PC4 OR PC5):M	Yes ☐ No ☐ N/A ☐

A.4.4.4 MAC addressing functions

Item	MAC Address function	References	Status	Support
	Are the following MAC Addressing functions supported?			
AD1	STA universal individual IEEE 802 address	5.3.3, 7.1.3.3	M	Yes ☐ No ☐
AD2	BSS identifier generation	7.1.3.3, 11.1.3, Annex C	M	Yes ☐ No ☐
AD3	Receive address matching	7.1.3.3, 7.2.2, Annex C	M	Yes ☐ No ☐ N/A ☐

A.4.5 Frequency-Hopping PHY functions

Item	Protocol feature	References	Status	Support
	Which requirements and options does the PHY support?			
FH1	PHY service primitive parameters			
FH1.1	TXVECTOR parameter: LENGTH	14.2.2.1	M	Yes ☐ No ☐
FH1.2	TXVECTOR parameter: PLCPBITRATE	14.2.2.2	M	Yes ☐ No ☐
FH1.2.1	PLCPBITRATE = X'00' (1.0 Mbit/s)	14.2.2.2	M	Yes ☐ No ☐
* FH1.2.2	PLCPBITRATE = X'02' (2.0 Mbit/s)	14.2.2.2	O	Yes ☐ No ☐
FH1.3	RXVECTOR parameter: LENGTH	14.2.3.1	M	Yes ☐ No ☐
FH1.4	RXVECTOR parameter: RSSI	14.2.3.2	O	Yes ☐ No ☐
FH2	PLCP frame format			
FH2.1	PLCP Preamble: Sync	14.3.2.1.1	M	Yes ☐ No ☐
FH2.2	PLCP Preamble: Start Frame Delimiter	14.3.2.1.2	M	Yes ☐ No ☐
FH2.3	PLCP Header: Length Word	14.3.2.2.1	M	Yes ☐ No ☐
FH2.4	PLCP Header: Signaling field	14.3.2.2.2	M	Yes ☐ No ☐
FH2.5	PLCP Header: Header Error Check	14.3.2.2.3	M	Yes ☐ No ☐
FH2.6	PLCP Data Whitener: Scrambling and bias suppression encoding	14.3.2.3, 14.3.3.1.1	M	Yes ☐ No ☐
FH3	PLCP Transmit procedure			
FH3.1	Transmit: transmit on MAC request	14.3.3.1.1	M	Yes ☐ No ☐
FH3.2	Transmit: format and whiten frame	14.3.3.1.1	M	Yes ☐ No ☐
FH3.3	Transmit: Timing	14.3.3.1.1	M	Yes ☐ No ☐
FH4	PLCP CS/CCA procedure			
FH4.1	CS/CCA: perform on a minimum of one antenna	14.3.3.2.1	M	Yes ☐ No ☐
FH4.2	CS/CCA: Detect preamble starting up to 20 μ s after start of slot time	14.3.3.2.1	M	Yes ☐ No ☐
FH4.3	CS/CCA: Detect preamble starting at least 16 μ s prior to end of slot time	14.3.3.2.1	M	Yes ☐ No ☐
FH4.4	CS/CCA: Detect random data	14.3.3.2.1	M	Yes ☐ No ☐
FH4.5	CS/CCA: Perform on antenna with essentially same gain and pattern as transmit antenna	14.3.3.2.1	M	Yes ☐ No ☐
FH4.6	CS/CCA: Detect valid SFD and PLCP header	14.3.3.2.1	M	Yes ☐ No ☐
FH4.7	CS/CCA: Maintain BUSY indication until end of length contained in valid PLCP header	14.3.3.2.1	M	Yes ☐ No ☐
FH5	PLCP Receive procedure			
FH5.1	Receive: Receive and dewhiten frame	14.3.3.3.1	M	Yes ☐ No ☐
FH6	PHY LME			
FH6.1	PLME: Support FH sync	14.4.2.2	M	Yes ☐ No ☐
FH6.2	PLME: Support PLME primitives	14.4.3.2	O	Yes ☐ No ☐

A.4.5 Frequency-Hopping PHY functions (continued)

Item	Protocol feature	References	Status	Support
FH7	Geographic area specific requirements			
* FH7.1	Geographic areas			
FH7.1.1	North America	14.6.2	O.1	Yes ☐ No ☐
FH7.1.2	Most of Europe	14.6.2	O.1	Yes ☐ No ☐
FH7.1.3	Japan	14.6.2	O.1	Yes ☐ No ☐
FH7.1.4	Spain	14.6.2	O.1	Yes ☐ No ☐
FH7.1.5	France	14.6.2	O.1	Yes ☐ No ☐
FH7.2	Operating frequency range	14.6.3	FH7.1:M	Yes ☐ No ☐
FH7.3	Number of operating channels	14.6.4	FH7.1:M	Yes ☐ No ☐
FH7.4	Operating channel frequencies	14.6.5	FH7.1:M	Yes ☐ No ☐
FH7.5	Occupied channel bandwidth	14.6.6	FH7.1:M	Yes ☐ No ☐
FH7.6	Minimum hop rate	14.6.7	FH7.1:M	Yes ☐ No ☐
FH7.7	Hop sequences	14.6.8	FH7.1:M	Yes ☐ No ☐
FH7.8	Unwanted emissions	14.6.9	FH7.1:M	Yes ☐ No ☐
FH8	1 Mbit/s PMD			
FH8.1	Modulation 2GFSK, BT=0.5, 1=positive frequency deviation, 0=negative frequency deviation	14.6.10	M	Yes ☐ No ☐
FH8.2	Peak frequency deviation	14.6.10	M	Yes ☐ No ☐
FH8.3	Zero-Crossing error	14.6.10	M	Yes ☐ No ☐
FH8.4	Nominal channel data rate	14.6.11	M	Yes ☐ No ☐
FH8.5	Channel switching/settling time	14.6.12	M	Yes ☐ No ☐
FH8.6	Receive to transmit switch time	14.6.13	M	Yes ☐ No ☐
FH8.7	Nominal transmit power	14.6.14.1	M	Yes ☐ No ☐
FH8.8	Transmit power levels	14.6.14.2	M	Yes ☐ No ☐
FH8.9	Transmit power level control to <100 mW	14.6.14.3	M	Yes ☐ No ☐
FH8.10	Transmit spectrum shape	14.6.14.4	M	Yes ☐ No ☐
FH8.11	Transmit center frequency tolerance	14.6.14.5	M	Yes ☐ No ☐
FH8.12	Transmitter ramp periods	14.6.14.6	M	Yes ☐ No ☐
FH8.13	Receiver input dynamic range	14.6.15.1	M	Yes ☐ No ☐
FH8.14	Receiver center frequency acceptance range	14.6.15.2	M	Yes ☐ No ☐
FH8.15	Clear channel assessment power threshold for a probability of detection of 90% (preamble)/70% (random data) for 100 mW units	14.6.15.3	M	Yes ☐ No ☐
FH8.16	Clear channel assessment power threshold for units >100 mW; sensitivity threshold is 1/2 dB lower for every dB above 20 dBm	14.6.15.3	M	Yes ☐ No ☐
FH8.17	Minimum receiver sensitivity at FER=3% with 400 octet frames	14.6.15.4	M	Yes ☐ No ☐
FH8.18	Intermodulation protection	14.6.15.5	M	Yes ☐ No ☐

A.4.5 Frequency-Hopping PHY functions (continued)

Item	Protocol feature	References	Status	Support
FH8.19	Desensitization	14.6.15.6	M	Yes ☐ No ☐
FH8.20	Operating temperature range	14.6.16	M	Yes ☐ No ☐
FH8.20.1	Temperature type 1	14.6.16	O	Yes ☐ No ☐
FH8.20.2	Temperature type 2	14.6.16	O	Yes ☐ No ☐
FH8.20.3	Temperature type 3	14.6.16	O	Yes ☐ No ☐
FH9	2 Mbit/s PMD			
FH9.1	All 1M PMD requirements	14.7.1	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.2	Modulation 4GFSK, BT=0.5	14.7.2	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.3	Frame structure for 2M PHY	14.7.2.1	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.4	Nominal channel data rate	14.7.3	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.5	Input dynamic range	14.7.4	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.6	Minimum receiver sensitivity at FER=3% with 400 octet frames	14.7.5	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.7	Intermodulation protection	14.7.6	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH9.8	Desensitization	14.7.7	FH1.2.2:M	Yes ☐ No ☐ N/A ☐
FH10	MLB	13.1, 14.8, Annex D	M	Yes ☐ No ☐
FH10.1	dot11PhyFHSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	13.1, 14.8	M	Yes ☐ No ☐

A.4.6 Direct sequence PHY functions

Item	PHY feature	References	Status	Support
DS1	PLCP sublayer procedures	15.2		
	Preamble prepend on TX	15.2.1	M	Yes ☐ No ☐
DS1.1	PLCP frame format	15.2.2, 15.2.3	M	Yes ☐ No ☐
DS1.2	PLCP integrity check generation	15.2.3, 15.2.3.6	M	Yes ☐ No ☐
DS1.3	TX rate change capability	15.2.3.3, 15.2.5	M	Yes ☐ No ☐
DS1.4	Supported data rates	15.1, 15.2.3.3	M	Yes ☐ No ☐
DS1.5	Data whitener scrambler	15.2.4	M	Yes ☐ No ☐
DS1.6	Scrambler initialization	15.2.4	M	Yes ☐ No ☐
DS2	Preamble process on RX	15.2.1		
DS2.1	PLCP frame format	15.2.2, 15.2.3	M	Yes ☐ No ☐
DS2.2	PLCP integrity check verify	15.2.3, 15.2.3.6	M	Yes ☐ No ☐
DS2.3	RX Rate change capability	15.2.3.3, 15.2.5	M	Yes ☐ No ☐
DS2.4	Data whitener descrambler	15.2.4	M	Yes ☐ No ☐
DS3	PN code sequence	15.4.6.3	M	Yes ☐ No ☐
DS4	Chipping continue on power down	15.2.6	O	Yes ☐ No ☐
*DS5	Operating channel capability	15.2.6, 15.4.6.2		

A.4.6 Direct sequence PHY functions (continued)

Item	PHY feature	References	Status	Support
* DS5.1	North America (FCC)	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.1.1	channel 1	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.2	channel 2	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.3	channel 3	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.4	channel 4	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.5	channel 5	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.6	channel 6	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.7	channel 7	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.8	channel 8	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.9	channel 9	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.10	channel 10	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
DS5.1.11	channel 11	15.2.6, 15.4.6.2	DS5.1:M	Yes ☐ No ☐ N/A ☐
* DS5.2	Canada (IC)	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.2.1	channel 1	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.2	channel 2	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.3	channel 3	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.4	channel 4	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.5	channel 5	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.6	channel 6	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.7	channel 7	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.8	channel 8	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.9	channel 9	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.10	channel 10	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
DS5.2.11	channel 11	15.2.6, 15.4.6.2	DS5.2:M	Yes ☐ No ☐ N/A ☐
* DS5.3	Europe (ETSI)	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.3.1	channel 1	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.2	channel 2	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.3	channel 3	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.4	channel 4	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.5	channel 5	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.6	channel 6	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.7	channel 7	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.8	channel 8	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.9	channel 9	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.10	channel 10	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.11	channel 11	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.12	channel 12	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
DS5.3.13	channel 13	15.2.6, 15.4.6.2	DS5.3:M	Yes ☐ No ☐ N/A ☐
* DS5.4	France	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.4.1	channel 10	15.2.6, 15.4.6.2	DS5.4:M	Yes ☐ No ☐ N/A ☐

A.4.6 Direct sequence PHY functions (continued)

Item	PHY feature	References	Status	Support
DS5.4.2	channel 11	15.2.6, 15.4.6.2	DS5.4:M	Yes ☐ No ☐ N/A ☐
DS5.4.3	channel 12	15.2.6, 15.4.6.2	DS5.4:M	Yes ☐ No ☐ N/A ☐
DS5.4.4	channel 13	15.2.6, 15.4.6.2	DS5.4:M	Yes ☐ No ☐ N/A ☐
* DS5.5	Spain	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS5.5.1	channel 10	15.2.6, 15.4.6.2	DS5.5:M	Yes ☐ No ☐ N/A ☐
DS5.5.2	channel 11	15.2.6, 15.4.6.2	DS5.5:M	Yes ☐ No ☐ N/A ☐
* DS5.6	Japan (RCR)	15.2.6, 15.4.6.2	DS5:O.1	Yes ☐ No ☐ N/A ☐
DS6	Bits to symbol mapping	15.4.6.4		
DS6.1	1 Mbit/s	15.4.6.4	M	Yes ☐ No ☐
DS6.2	2 Mbit/s	15.4.6.4	M	Yes ☐ No ☐
*DS7	CCA functionality	15.4.8.4		
DS7.1	Energy Only (RSSI above threshold)	15.4.8.4	DS7:O.2	Yes ☐ No ☐
DS7.2	IEEE 802.11 DSSS correlation	15.4.8.4	DS7:O.2	Yes ☐ No ☐
DS7.3	Both methods	15.4.8.4	DS7:O.2	Yes ☐ No ☐
DS7.4	Hold CCA busy for packet duration of a correctly received PLCP but carrier lost during reception of MPDU	15.2.7	M	Yes ☐ No ☐
DS7.5	Hold CCA busy for packet duration of a correctly received but out of specification PLCP	15.2.7	M	Yes ☐ No ☐
DS8	Transmit antenna selection	15.4.5.5, 15.4.5.6	O	Yes ☐ No ☐
DS9	Receive antenna diversity	15.4.5.5, 15.4.5.6, 15.4.5.7	O	Yes ☐ No ☐
*DS10	Antenna port(s) availability	15.4.6.9	O	Yes ☐ No ☐
DS10.1	50 Ω impedance	15.4.6.9	DS10:M	Yes ☐ No ☐ N/A ☐
*DS11	Transmit power level support	15.4.5.8, 15.4.7.3	O	Yes ☐ No ☐
DS11.1	If greater than 100 mW capability	15.4.7.3	DS11:M	Yes ☐ No ☐ N/A ☐
*DS12	Radio type (temperature range)	15.4.6.10		
DS12.1	Type 1	15.4.6.10	DS12:O.3	Yes ☐ No ☐ N/A ☐
DS12.2	Type 2	15.4.6.10	DS12:O.3	Yes ☐ No ☐ N/A ☐
DS13	Spurious emissions conformance	15.4.6.5	M	Yes ☐ No ☐
DS14	TX-RX turnaround time	15.4.6.6	M	Yes ☐ No ☐
DS15	RX-TX turnaround time	15.4.6.7	M	Yes ☐ No ☐
DS16	Slot time	15.4.6.8	M	Yes ☐ No ☐
DS17	ED reporting time	15.4.6.8, 15.4.8.4	M	Yes ☐ No ☐
DS18	Minimum transmit power level	15.4.7.2	M	Yes ☐ No ☐
DS19	Transmit spectral mask conformance	15.4.7.4	M	Yes ☐ No ☐
DS20	Transmitted center frequency tolerance	15.4.7.5	M	Yes ☐ No ☐

A.4.6 Direct sequence PHY functions (continued)

Item	PHY feature	References	Status	Support
DS21	Chip clock frequency tolerance	15.4.7.6	M	Yes ☐ No ☐
DS22	Transmit power on ramp	15.4.7.7	M	Yes ☐ No ☐
DS23	Transmit power down ramp	15.4.7.7	M	Yes ☐ No ☐
DS24	RF carrier suppression	15.4.7.8	M	Yes ☐ No ☐
DS25	Transmit modulation accuracy	15.4.7.9	M	Yes ☐ No ☐
DS26	Receiver minimum input level sensitivity	15.4.8.1	M	Yes ☐ No ☐
DS27	Receiver maximum input level	15.4.8.2	M	Yes ☐ No ☐
DS28	Receiver adjacent channel rejection	15.4.8.3	M	Yes ☐ No ☐
DS29	MLB	13.1, 15.3.2, Annex D	M	Yes ☐ No ☐
DS29.1	dot11PhyDSSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	13.1, 15.3.2	M	Yes ☐ No ☐

A.4.7 Infrared baseband PHY functions

Item	Feature	References	Status	Support
IR1	Is the transmitted SYNC field length in the range of required number of PPM slots, with the absence of a pulse in the last slot of the field?	16.2.4.1	M	Yes ☐
IR2	Is the transmitted SYNC field entirely populated by alternating presence and absence of pulses in consecutive PPM slots, with the absence of a pulse in the last slot of the field?	16.2.4.1	M	Yes ☐
IR3	Is the transmitted SFD field the binary sequence 1001, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot?	16.2.4.2	M	Yes ☐
IR4	Is the transmitted DR field pulse sequence equal to the correct value for the data rate provided by the TXVECTOR parameter PLCP BITRATE, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot?	16.2.4.3	M	Yes ☐
IR5	Is the transmitted DCLA field 32 PPM slots long with the specified sequence for 1 Mbit/s, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot? 1 Mbit/s: 0000000010000000000000010000000	16.2.4.4	M	Yes ☐
* IR5a	Does the unit support 2 Mbit/s transmission?	16.2.4.4	O	Yes ☐ No ☐

A.4.7 Infrared baseband PHY functions (continued)

Item	Feature	References	Status	Support
IR5b	If the unit supports 2 Mbit/s transmission, is the transmitted DCLA field 32 PPM slots long with the specified sequence for 2 Mbit/s, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot? 2 Mbit/s: 0010001000100010001000100010	16.2.4.4	IR5a:M	Yes ☐ No ☐ N/A ☐
IR6	Is the transmitted LENGTH field the correct PPM representation of the unsigned 16-bit binary integer, lsb transmitted first, equal to the correct value provided by the TXVECTOR parameter LENGTH?	16.2.4.5	M	Yes ☐
IR7	Is the transmitted CRC field the correct PPM representation of the CRC value calculated as per reference subclause, transmitted lsb first?	16.2.4.6	M	Yes ☐
IR8	Is the transmitted PSDU field the correct PPM representation of the PSDU, transmitted lsb first?	16.2.4.7	M	Yes ☐
IR9	When the CCA is false does transmission begin based on PHYTXSTART.request?	16.2.5.1	M	Yes ☐
IR10	Does the PHY issue a PHYTXSTART.confirm after the transmission of the PLCP header?	16.2.5.1	M	Yes ☐
IR11	Does the PHY accept each octet of the PSDU in a PHYDATA.request and answer with a PHYDATA.confirm?	16.2.5.1	M	Yes ☐
IR12	Does the PHY cease transmission in response to a PHYTXEND.request and answer with a PHYTXEND.confirm?	16.2.5.1	M	Yes ☐
IR13	Does the PHY of a receiving STA send a PHYCCA.indicate during reception of the SYNC field?	16.2.5.2	M	Yes ☐
IR14	Does the PHY of a receiving STA properly receive a transmission that changes data rate according to the DR field?	16.2.5.2	M	Yes ☐
IR15	Does the PHY of a receiving STA properly reject an incorrect CRC?	16.2.5.2	M	Yes ☐
IR16	Does the PHY of a receiving STA properly reject a DR field other than those specified in reference subclause?	16.2.5.2, 16.2.4.3	M	Yes ☐
IR17	Does the PHY of a receiving STA send PHYRXSTART.indicate with correct RATE and LENGTH parameters after proper reception of PLCP preamble and PLCP header?	16.2.5.2	M	Yes ☐
IR18	Does the PHY of a receiving STA forward receive octets in PHYDATA.indicate primitives?	16.2.5.2	M	Yes ☐
IR19	Does the PHY of a receiving STA send a PHYRXEND.indicate after the final octet indicated by the LENGTH field?	16.2.5.2	M	Yes ☐

A.4.7 Infrared baseband PHY functions (continued)

Item	Feature	References	Status	Support
IR20	Does the PHY of a receiving STA send a PHYCCA.indicate with a state value of IDLE after the PHYRXEND.indicate?	16.2.5.2	M	Yes ☐
IR21	Does the PHY reset its CCA detection mechanism upon receiving a PHYC-CARST.request, and respond with a PHYCCARST.indicate?	16.2.5.3	M	Yes ☐
IR22	When transmitting at 1 Mbit/s does the PHY transmit PPM symbols according to the 16-PPM Basic Rate Mapping table, transmitting from left to right?	16.3.2.1, 16.3.2.2	M	Yes ☐
IR23	When transmitting at 2 Mbit/s does the PHY transmit PPM symbols according to the 4-PPM Enhanced Rate Mapping table, transmitting from left to right?	16.3.2.1, 16.3.2.2	IR5a:M	Yes ☐
IR24	Does the PHY operate over a temperature range of 0 °C to 40 °C?	16.3.2.4	M	Yes ☐
* IR25	If the unit is conformant to emitter radiation mask 1, is the peak optical power of an emitted pulse within the specification range averaged over the pulse width?	16.3.3.1	O.1	Yes ☐ No ☐ N/A ☐
* IR26	If the unit is conformant to emitter radiation mask 2, is the peak optical power of an emitted pulse within the specification range averaged over the pulse width?	16.3.3.1	O.1	Yes ☐ No ☐ N/A ☐
IR27	Does the transmitted pulse shape conform to the description of the reference subclause?	16.3.3.2	M	Yes ☐
IR28	Does the emitter radiation pattern as a function of angle conform to the requirements of the reference subclause as applicable based on conformance to emitter radiation mask 1?	16.3.3.3	IR25:M	Yes ☐ No ☐ N/A ☐
IR28a	Does the emitter radiation pattern as a function of angle conform to the requirements of the reference subclause as applicable based on conformance to emitter radiation mask 2?	16.3.3.3	IR26:M	Yes ☐ No ☐ N/A ☐
IR29	Is the peak emitter optical output as a function of wavelength in the range specified?	16.3.3.4	M	Yes ☐
IR30	Does the spectrum of the transmit signal amplitude as a voltage or current meet the requirements of the reference subclause?	16.3.3.5	M	Yes ☐
IR31	Does the receiver sensitivity meet the requirements of the reference subclause for receive signals of both 1 Mbit/s and 2 Mbit/s?	16.3.4.1	M	Yes ☐
IR32	Does the receiver exhibit a dynamic range as specified in reference subclause?	16.3.4.2	M	Yes ☐
IR33	Does the receiver field-of-view conform to the requirements of the reference subclause?	16.3.4.3	M	Yes ☐
IR34	When it is known that the conditions are such that the Carrier Detect Signal and the Energy Detect Signal are false is the CCA asserted IDLE?	16.3.5.1	M	Yes ☐

A.4.7 Infrared baseband PHY functions (continued)

Item	Feature	References	Status	Support
IR35	When the conditions are such that Energy Detect is true for greater than the time defined in reference subclause, does CCA become IDLE?	16.3.5.1	M	Yes ☐
IR36	When conditions are such that either Carrier Detect or Energy Detect go true, does CCA go BUSY?	16.3.5.1	M	Yes ☐
IR37	Are these compliance groups implemented? dot11PhyIRComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	16.4	M	Yes ☐

Annex B

(informative)

Hopping sequences

The following tables pertain to the hopping sequences for North America and ETSI.

Table B.1—Hopping sequence set 1

index	0	3	6	9	12	15	18	21	24	27	30	33	36
1	2	5	8	11	14	17	20	23	26	29	32	35	38
2	25	28	31	34	37	40	43	46	49	52	55	58	61
3	64	67	70	73	76	79	3	6	9	12	15	18	21
4	10	13	16	19	22	25	28	31	34	37	40	43	46
5	45	48	51	54	57	60	63	66	69	72	75	78	2
6	18	21	24	27	30	33	36	39	42	45	48	51	54
7	73	76	79	3	6	9	12	15	18	21	24	27	30
8	49	52	55	58	61	64	67	70	73	76	79	3	6
9	21	24	27	30	33	36	39	42	45	48	51	54	57
10	63	66	69	72	75	78	2	5	8	11	14	17	20
11	78	2	5	8	11	14	17	20	23	26	29	32	35
12	31	34	37	40	43	46	49	52	55	58	61	64	67
13	61	64	67	70	73	76	79	3	6	9	12	15	18
14	24	27	30	33	36	39	42	45	48	51	54	57	60
15	54	57	60	63	66	69	72	75	78	2	5	8	11
16	65	68	71	74	77	80	4	7	10	13	16	19	22
17	28	31	34	37	40	43	46	49	52	55	58	61	64
18	79	3	6	9	12	15	18	21	24	27	30	33	36
19	33	36	39	42	45	48	51	54	57	60	63	66	69
20	4	7	10	13	16	19	22	25	28	31	34	37	40
21	20	23	26	29	32	35	38	41	44	47	50	53	56
22	13	16	19	22	25	28	31	34	37	40	43	46	49
23	38	41	44	47	50	53	56	59	62	65	68	71	74
24	74	77	80	4	7	10	13	16	19	22	25	28	31
25	56	59	62	65	68	71	74	77	80	4	7	10	13
26	71	74	77	80	4	7	10	13	16	19	22	25	28
27	23	26	29	32	35	38	41	44	47	50	53	56	59
28	5	8	11	14	17	20	23	26	29	32	35	38	41
29	39	42	45	48	51	54	57	60	63	66	69	72	75
30	12	15	18	21	24	27	30	33	36	39	42	45	48
31	36	39	42	45	48	51	54	57	60	63	66	69	72
32	68	71	74	77	80	4	7	10	13	16	19	22	25
33	9	12	15	18	21	24	27	30	33	36	39	42	45
34	70	73	76	79	3	6	9	12	15	18	21	24	27
35	77	80	4	7	10	13	16	19	22	25	28	31	34
36	6	9	12	15	18	21	24	27	30	33	36	39	42
37	62	65	68	71	74	77	80	4	7	10	13	16	19
38	29	32	35	38	41	44	47	50	53	56	59	62	65
39	14	17	20	23	26	29	32	35	38	41	44	47	50

Table B.1—Hopping sequence set 1 (continued)

index	0	3	6	9	12	15	18	21	24	27	30	33	36
40	27	30	33	36	39	42	45	48	51	54	57	60	63
41	16	19	22	25	28	31	34	37	40	43	46	49	52
42	59	62	65	68	71	74	77	80	4	7	10	13	16
43	43	46	49	52	55	58	61	64	67	70	73	76	79
44	76	79	3	6	9	12	15	18	21	24	27	30	33
45	34	37	40	43	46	49	52	55	58	61	64	67	70
46	72	75	78	2	5	8	11	14	17	20	23	26	29
47	11	14	17	20	23	26	29	32	35	38	41	44	47
48	60	63	66	69	72	75	78	2	5	8	11	14	17
49	80	4	7	10	13	16	19	22	25	28	31	34	37
50	47	50	53	56	59	62	65	68	71	74	77	80	4
51	22	25	28	31	34	37	40	43	46	49	52	55	58
52	75	78	2	5	8	11	14	17	20	23	26	29	32
53	66	69	72	75	78	2	5	8	11	14	17	20	23
54	41	44	47	50	53	56	59	62	65	68	71	74	77
55	15	18	21	24	27	30	33	36	39	42	45	48	51
56	35	38	41	44	47	50	53	56	59	62	65	68	71
57	67	70	73	76	79	3	6	9	12	15	18	21	24
58	52	55	58	61	64	67	70	73	76	79	3	6	9
59	58	61	64	67	70	73	76	79	3	6	9	12	15
60	44	47	50	53	56	59	62	65	68	71	74	77	80
61	50	53	56	59	62	65	68	71	74	77	80	4	7
62	17	20	23	26	29	32	35	38	41	44	47	50	53
63	7	10	13	16	19	22	25	28	31	34	37	40	43
64	19	22	25	28	31	34	37	40	43	46	49	52	55
65	8	11	14	17	20	23	26	29	32	35	38	41	44
66	69	72	75	78	2	5	8	11	14	17	20	23	26
67	51	54	57	60	63	66	69	72	75	78	2	5	8
68	42	45	48	51	54	57	60	63	66	69	72	75	78
69	3	6	9	12	15	18	21	24	27	30	33	36	39
70	30	33	36	39	42	45	48	51	54	57	60	63	66
71	57	60	63	66	69	72	75	78	2	5	8	11	14
72	37	40	43	46	49	52	55	58	61	64	67	70	73
73	55	58	61	64	67	70	73	76	79	3	6	9	12
74	26	29	32	35	38	41	44	47	50	53	56	59	62
75	46	49	52	55	58	61	64	67	70	73	76	79	3
76	53	56	59	62	65	68	71	74	77	80	4	7	10
77	40	43	46	49	52	55	58	61	64	67	70	73	76
78	32	35	38	41	44	47	50	53	56	59	62	65	68
79	48	51	54	57	60	63	66	69	72	75	78	2	5

Table B.1—Hopping sequence set 1 (continued)

index	39	42	45	48	51	54	57	60	63	66	69	72	75
1	41	44	47	50	53	56	59	62	65	68	71	74	77
2	64	67	70	73	76	79	3	6	9	12	15	18	21
3	24	27	30	33	36	39	42	45	48	51	54	57	60
4	49	52	55	58	61	64	67	70	73	76	79	3	6
5	5	8	11	14	17	20	23	26	29	32	35	38	41
6	57	60	63	66	69	72	75	78	2	5	8	11	14
7	33	36	39	42	45	48	51	54	57	60	63	66	69
8	9	12	15	18	21	24	27	30	33	36	39	42	45
9	60	63	66	69	72	75	78	2	5	8	11	14	17
10	23	26	29	32	35	38	41	44	47	50	53	56	59
11	38	41	44	47	50	53	56	59	62	65	68	71	74
12	70	73	76	79	3	6	9	12	15	18	21	24	27
13	21	24	27	30	33	36	39	42	45	48	51	54	57
14	63	66	69	72	75	78	2	5	8	11	14	17	20
15	14	17	20	23	26	29	32	35	38	41	44	47	50
16	25	28	31	34	37	40	43	46	49	52	55	58	61
17	67	70	73	76	79	3	6	9	12	15	18	21	24
18	39	42	45	48	51	54	57	60	63	66	69	72	75
19	72	75	78	2	5	8	11	14	17	20	23	26	29
20	43	46	49	52	55	58	61	64	67	70	73	76	79
21	59	62	65	68	71	74	77	80	4	7	10	13	16
22	52	55	58	61	64	67	70	73	76	79	3	6	9
23	77	80	4	7	10	13	16	19	22	25	28	31	34
24	34	37	40	43	46	49	52	55	58	61	64	67	70
25	16	19	22	25	28	31	34	37	40	43	46	49	52
26	31	34	37	40	43	46	49	52	55	58	61	64	67
27	62	65	68	71	74	77	80	4	7	10	13	16	19
28	44	47	50	53	56	59	62	65	68	71	74	77	80
29	78	2	5	8	11	14	17	20	23	26	29	32	35
30	51	54	57	60	63	66	69	72	75	78	2	5	8
31	75	78	2	5	8	11	14	17	20	23	26	29	32
32	28	31	34	37	40	43	46	49	52	55	58	61	64
33	48	51	54	57	60	63	66	69	72	75	78	2	5
34	30	33	36	39	42	45	48	51	54	57	60	63	66
35	37	40	43	46	49	52	55	58	61	64	67	70	73
36	45	48	51	54	57	60	63	66	69	72	75	78	2
37	22	25	28	31	34	37	40	43	46	49	52	55	58
38	68	71	74	77	80	4	7	10	13	16	19	22	25
39	53	56	59	62	65	68	71	74	77	80	4	7	10

Table B.1—Hopping sequence set 1 (continued)

index	39	42	45	48	51	54	57	60	63	66	69	72	75
40	66	69	72	75	78	2	5	8	11	14	17	20	23
41	55	58	61	64	67	70	73	76	79	3	6	9	12
42	19	22	25	28	31	34	37	40	43	46	49	52	55
43	3	6	9	12	15	18	21	24	27	30	33	36	39
44	36	39	42	45	48	51	54	57	60	63	66	69	72
45	73	76	79	3	6	9	12	15	18	21	24	27	30
46	32	35	38	41	44	47	50	53	56	59	62	65	68
47	50	53	56	59	62	65	68	71	74	77	80	4	7
48	20	23	26	29	32	35	38	41	44	47	50	53	56
49	40	43	46	49	52	55	58	61	64	67	70	73	76
50	7	10	13	16	19	22	25	28	31	34	37	40	43
51	61	64	67	70	73	76	79	3	6	9	12	15	18
52	35	38	41	44	47	50	53	56	59	62	65	68	71
53	26	29	32	35	38	41	44	47	50	53	56	59	62
54	80	4	7	10	13	16	19	22	25	28	31	34	37
55	54	57	60	63	66	69	72	75	78	2	5	8	11
56	74	77	80	4	7	10	13	16	19	22	25	28	31
57	27	30	33	36	39	42	45	48	51	54	57	60	63
58	12	15	18	21	24	27	30	33	36	39	42	45	48
59	18	21	24	27	30	33	36	39	42	45	48	51	54
60	4	7	10	13	16	19	22	25	28	31	34	37	40
61	10	13	16	19	22	25	28	31	34	37	40	43	46
62	56	59	62	65	68	71	74	77	80	4	7	10	13
63	46	49	52	55	58	61	64	67	70	73	76	79	3
64	58	61	64	67	70	73	76	79	3	6	9	12	15
65	47	50	53	56	59	62	65	68	71	74	77	80	4
66	29	32	35	38	41	44	47	50	53	56	59	62	65
67	11	14	17	20	23	26	29	32	35	38	41	44	47
68	2	5	8	11	14	17	20	23	26	29	32	35	38
69	42	45	48	51	54	57	60	63	66	69	72	75	78
70	69	72	75	78	2	5	8	11	14	17	20	23	26
71	17	20	23	26	29	32	35	38	41	44	47	50	53
72	76	79	3	6	9	12	15	18	21	24	27	30	33
73	15	18	21	24	27	30	33	36	39	42	45	48	51
74	65	68	71	74	77	80	4	7	10	13	16	19	22
75	6	9	12	15	18	21	24	27	30	33	36	39	42
76	13	16	19	22	25	28	31	34	37	40	43	46	49
77	79	3	6	9	12	15	18	21	24	27	30	33	36
78	71	74	77	80	4	7	10	13	16	19	22	25	28
79	8	11	14	17	20	23	26	29	32	35	38	41	44

Table B.2—Hopping sequence set 2

index	1	4	7	10	13	16	19	22	25	28	31	34	37
1	3	6	9	12	15	18	21	24	27	30	33	36	39
2	26	29	32	35	38	41	44	47	50	53	56	59	62
3	65	68	71	74	77	80	4	7	10	13	16	19	22
4	11	14	17	20	23	26	29	32	35	38	41	44	47
5	46	49	52	55	58	61	64	67	70	73	76	79	3
6	19	22	25	28	31	34	37	40	43	46	49	52	55
7	74	77	80	4	7	10	13	16	19	22	25	28	31
8	50	53	56	59	62	65	68	71	74	77	80	4	7
9	22	25	28	31	34	37	40	43	46	49	52	55	58
10	64	67	70	73	76	79	3	6	9	12	15	18	21
11	79	3	6	9	12	15	18	21	24	27	30	33	36
12	32	35	38	41	44	47	50	53	56	59	62	65	68
13	62	65	68	71	74	77	80	4	7	10	13	16	19
14	25	28	31	34	37	40	43	46	49	52	55	58	61
15	55	58	61	64	67	70	73	76	79	3	6	9	12
16	66	69	72	75	78	2	5	8	11	14	17	20	23
17	29	32	35	38	41	44	47	50	53	56	59	62	65
18	80	4	7	10	13	16	19	22	25	28	31	34	37
19	34	37	40	43	46	49	52	55	58	61	64	67	70
20	5	8	11	14	17	20	23	26	29	32	35	38	41
21	21	24	27	30	33	36	39	42	45	48	51	54	57
22	14	17	20	23	26	29	32	35	38	41	44	47	50
23	39	42	45	48	51	54	57	60	63	66	69	72	75
24	75	78	2	5	8	11	14	17	20	23	26	29	32
25	57	60	63	66	69	72	75	78	2	5	8	11	14
26	72	75	78	2	5	8	11	14	17	20	23	26	29
27	24	27	30	33	36	39	42	45	48	51	54	57	60
28	6	9	12	15	18	21	24	27	30	33	36	39	42
29	40	43	46	49	52	55	58	61	64	67	70	73	76
30	13	16	19	22	25	28	31	34	37	40	43	46	49
31	37	40	43	46	49	52	55	58	61	64	67	70	73
32	69	72	75	78	2	5	8	11	14	17	20	23	26
33	10	13	16	19	22	25	28	31	34	37	40	43	46
34	71	74	77	80	4	7	10	13	16	19	22	25	28
35	78	2	5	8	11	14	17	20	23	26	29	32	35
36	7	10	13	16	19	22	25	28	31	34	37	40	43
37	63	66	69	72	75	78	2	5	8	11	14	17	20
38	30	33	36	39	42	45	48	51	54	57	60	63	66
39	15	18	21	24	27	30	33	36	39	42	45	48	51

Table B.2—Hopping sequence set 2 (continued)

index	1	4	7	10	13	16	19	22	25	28	31	34	37
40	28	31	34	37	40	43	46	49	52	55	58	61	64
41	17	20	23	26	29	32	35	38	41	44	47	50	53
42	60	63	66	69	72	75	78	2	5	8	11	14	17
43	44	47	50	53	56	59	62	65	68	71	74	77	80
44	77	80	4	7	10	13	16	19	22	25	28	31	34
45	35	38	41	44	47	50	53	56	59	62	65	68	71
46	73	76	79	3	6	9	12	15	18	21	24	27	30
47	12	15	18	21	24	27	30	33	36	39	42	45	48
48	61	64	67	70	73	76	79	3	6	9	12	15	18
49	2	5	8	11	14	17	20	23	26	29	32	35	38
50	48	51	54	57	60	63	66	69	72	75	78	2	5
51	23	26	29	32	35	38	41	44	47	50	53	56	59
52	76	79	3	6	9	12	15	18	21	24	27	30	33
53	67	70	73	76	79	3	6	9	12	15	18	21	24
54	42	45	48	51	54	57	60	63	66	69	72	75	78
55	16	19	22	25	28	31	34	37	40	43	46	49	52
56	36	39	42	45	48	51	54	57	60	63	66	69	72
57	68	71	74	77	80	4	7	10	13	16	19	22	25
58	53	56	59	62	65	68	71	74	77	80	4	7	10
59	59	62	65	68	71	74	77	80	4	7	10	13	16
60	45	48	51	54	57	60	63	66	69	72	75	78	2
61	51	54	57	60	63	66	69	72	75	78	2	5	8
62	18	21	24	27	30	33	36	39	42	45	48	51	54
63	8	11	14	17	20	23	26	29	32	35	38	41	44
64	20	23	26	29	32	35	38	41	44	47	50	53	56
65	9	12	15	18	21	24	27	30	33	36	39	42	45
66	70	73	76	79	3	6	9	12	15	18	21	24	27
67	52	55	58	61	64	67	70	73	76	79	3	6	9
68	43	46	49	52	55	58	61	64	67	70	73	76	79
69	4	7	10	13	16	19	22	25	28	31	34	37	40
70	31	34	37	40	43	46	49	52	55	58	61	64	67
71	58	61	64	67	70	73	76	79	3	6	9	12	15
72	38	41	44	47	50	53	56	59	62	65	68	71	74
73	56	59	62	65	68	71	74	77	80	4	7	10	13
74	27	30	33	36	39	42	45	48	51	54	57	60	63
75	47	50	53	56	59	62	65	68	71	74	77	80	4
76	54	57	60	63	66	69	72	75	78	2	5	8	11
77	41	44	47	50	53	56	59	62	65	68	71	74	77
78	33	36	39	42	45	48	51	54	57	60	63	66	69
79	49	52	55	58	61	64	67	70	73	76	79	3	6

Table B.2—Hopping sequence set 2 (continued)

index	40	43	46	49	52	55	58	61	64	67	70	73	76
1	42	45	48	51	54	57	60	63	66	69	72	75	78
2	65	68	71	74	77	80	4	7	10	13	16	19	22
3	25	28	31	34	37	40	43	46	49	52	55	58	61
4	50	53	56	59	62	65	68	71	74	77	80	4	7
5	6	9	12	15	18	21	24	27	30	33	36	39	42
6	58	61	64	67	70	73	76	79	3	6	9	12	15
7	34	37	40	43	46	49	52	55	58	61	64	67	70
8	10	13	16	19	22	25	28	31	34	37	40	43	46
9	61	64	67	70	73	76	79	3	6	9	12	15	18
10	24	27	30	33	36	39	42	45	48	51	54	57	60
11	39	42	45	48	51	54	57	60	63	66	69	72	75
12	71	74	77	80	4	7	10	13	16	19	22	25	28
13	22	25	28	31	34	37	40	43	46	49	52	55	58
14	64	67	70	73	76	79	3	6	9	12	15	18	21
15	15	18	21	24	27	30	33	36	39	42	45	48	51
16	26	29	32	35	38	41	44	47	50	53	56	59	62
17	68	71	74	77	80	4	7	10	13	16	19	22	25
18	40	43	46	49	52	55	58	61	64	67	70	73	76
19	73	76	79	3	6	9	12	15	18	21	24	27	30
20	44	47	50	53	56	59	62	65	68	71	74	77	80
21	60	63	66	69	72	75	78	2	5	8	11	14	17
22	53	56	59	62	65	68	71	74	77	80	4	7	10
23	78	2	5	8	11	14	17	20	23	26	29	32	35
24	35	38	41	44	47	50	53	56	59	62	65	68	71
25	17	20	23	26	29	32	35	38	41	44	47	50	53
26	32	35	38	41	44	47	50	53	56	59	62	65	68
27	63	66	69	72	75	78	2	5	8	11	14	17	20
28	45	48	51	54	57	60	63	66	69	72	75	78	2
29	79	3	6	9	12	15	18	21	24	27	30	33	36
30	52	55	58	61	64	67	70	73	76	79	3	6	9
31	76	79	3	6	9	12	15	18	21	24	27	30	33
32	29	32	35	38	41	44	47	50	53	56	59	62	65
33	49	52	55	58	61	64	67	70	73	76	79	3	6
34	31	34	37	40	43	46	49	52	55	58	61	64	67
35	38	41	44	47	50	53	56	59	62	65	68	71	74
36	46	49	52	55	58	61	64	67	70	73	76	79	3
37	23	26	29	32	35	38	41	44	47	50	53	56	59
38	69	72	75	78	2	5	8	11	14	17	20	23	26
39	54	57	60	63	66	69	72	75	78	2	5	8	11

Table B.2—Hopping sequence set 2 (continued)

index	40	43	46	49	52	55	58	61	64	67	70	73	76
40	67	70	73	76	79	3	6	9	12	15	18	21	24
41	56	59	62	65	68	71	74	77	80	4	7	10	13
42	20	23	26	29	32	35	38	41	44	47	50	53	56
43	4	7	10	13	16	19	22	25	28	31	34	37	40
44	37	40	43	46	49	52	55	58	61	64	67	70	73
45	74	77	80	4	7	10	13	16	19	22	25	28	31
46	33	36	39	42	45	48	51	54	57	60	63	66	69
47	51	54	57	60	63	66	69	72	75	78	2	5	8
48	21	24	27	30	33	36	39	42	45	48	51	54	57
49	41	44	47	50	53	56	59	62	65	68	71	74	77
50	8	11	14	17	20	23	26	29	32	35	38	41	44
51	62	65	68	71	74	77	80	4	7	10	13	16	19
52	36	39	42	45	48	51	54	57	60	63	66	69	72
53	27	30	33	36	39	42	45	48	51	54	57	60	63
54	2	5	8	11	14	17	20	23	26	29	32	35	38
55	55	58	61	64	67	70	73	76	79	3	6	9	12
56	75	78	2	5	8	11	14	17	20	23	26	29	32
57	28	31	34	37	40	43	46	49	52	55	58	61	64
58	13	16	19	22	25	28	31	34	37	40	43	46	49
59	19	22	25	28	31	34	37	40	43	46	49	52	55
60	5	8	11	14	17	20	23	26	29	32	35	38	41
61	11	14	17	20	23	26	29	32	35	38	41	44	47
62	57	60	63	66	69	72	75	78	2	5	8	11	14
63	47	50	53	56	59	62	65	68	71	74	77	80	4
64	59	62	65	68	71	74	77	80	4	7	10	13	16
65	48	51	54	57	60	63	66	69	72	75	78	2	5
66	30	33	36	39	42	45	48	51	54	57	60	63	66
67	12	15	18	21	24	27	30	33	36	39	42	45	48
68	3	6	9	12	15	18	21	24	27	30	33	36	39
69	43	46	49	52	55	58	61	64	67	70	73	76	79
70	70	73	76	79	3	6	9	12	15	18	21	24	27
71	18	21	24	27	30	33	36	39	42	45	48	51	54
72	77	80	4	7	10	13	16	19	22	25	28	31	34
73	16	19	22	25	28	31	34	37	40	43	46	49	52
74	66	69	72	75	78	2	5	8	11	14	17	20	23
75	7	10	13	16	19	22	25	28	31	34	37	40	43
76	14	17	20	23	26	29	32	35	38	41	44	47	50
77	80	4	7	10	13	16	19	22	25	28	31	34	37
78	72	75	78	2	5	8	11	14	17	20	23	26	29
79	9	12	15	18	21	24	27	30	33	36	39	42	45

Table B.3—Hopping sequence set 3

index	2	5	8	11	14	17	20	23	26	29	32	35	38
1	4	7	10	13	16	19	22	25	28	31	34	37	40
2	27	30	33	36	39	42	45	48	51	54	57	60	63
3	66	69	72	75	78	2	5	8	11	14	17	20	23
4	12	15	18	21	24	27	30	33	36	39	42	45	48
5	47	50	53	56	59	62	65	68	71	74	77	80	4
6	20	23	26	29	32	35	38	41	44	47	50	53	56
7	75	78	2	5	8	11	14	17	20	23	26	29	32
8	51	54	57	60	63	66	69	72	75	78	2	5	8
9	23	26	29	32	35	38	41	44	47	50	53	56	59
10	65	68	71	74	77	80	4	7	10	13	16	19	22
11	80	4	7	10	13	16	19	22	25	28	31	34	37
12	33	36	39	42	45	48	51	54	57	60	63	66	69
13	63	66	69	72	75	78	2	5	8	11	14	17	20
14	26	29	32	35	38	41	44	47	50	53	56	59	62
15	56	59	62	65	68	71	74	77	80	4	7	10	13
16	67	70	73	76	79	3	6	9	12	15	18	21	24
17	30	33	36	39	42	45	48	51	54	57	60	63	66
18	2	5	8	11	14	17	20	23	26	29	32	35	38
19	35	38	41	44	47	50	53	56	59	62	65	68	71
20	6	9	12	15	18	21	24	27	30	33	36	39	42
21	22	25	28	31	34	37	40	43	46	49	52	55	58
22	15	18	21	24	27	30	33	36	39	42	45	48	51
23	40	43	46	49	52	55	58	61	64	67	70	73	76
24	76	79	3	6	9	12	15	18	21	24	27	30	33
25	58	61	64	67	70	73	76	79	3	6	9	12	15
26	73	76	79	3	6	9	12	15	18	21	24	27	30
27	25	28	31	34	37	40	43	46	49	52	55	58	61
28	7	10	13	16	19	22	25	28	31	34	37	40	43
29	41	44	47	50	53	56	59	62	65	68	71	74	77
30	14	17	20	23	26	29	32	35	38	41	44	47	50
31	38	41	44	47	50	53	56	59	62	65	68	71	74
32	70	73	76	79	3	6	9	12	15	18	21	24	27
33	11	14	17	20	23	26	29	32	35	38	41	44	47
34	72	75	78	2	5	8	11	14	17	20	23	26	29
35	79	3	6	9	12	15	18	21	24	27	30	33	36
36	8	11	14	17	20	23	26	29	32	35	38	41	44
37	64	67	70	73	76	79	3	6	9	12	15	18	21
38	31	34	37	40	43	46	49	52	55	58	61	64	67
39	16	19	22	25	28	31	34	37	40	43	46	49	52

Table B.3—Hopping sequence set 3 (continued)

index	2	5	8	11	14	17	20	23	26	29	32	35	38
40	29	32	35	38	41	44	47	50	53	56	59	62	65
41	18	21	24	27	30	33	36	39	42	45	48	51	54
42	61	64	67	70	73	76	79	3	6	9	12	15	18
43	45	48	51	54	57	60	63	66	69	72	75	78	2
44	78	2	5	8	11	14	17	20	23	26	29	32	35
45	36	39	42	45	48	51	54	57	60	63	66	69	72
46	74	77	80	4	7	10	13	16	19	22	25	28	31
47	13	16	19	22	25	28	31	34	37	40	43	46	49
48	62	65	68	71	74	77	80	4	7	10	13	16	19
49	3	6	9	12	15	18	21	24	27	30	33	36	39
50	49	52	55	58	61	64	67	70	73	76	79	3	6
51	24	27	30	33	36	39	42	45	48	51	54	57	60
52	77	80	4	7	10	13	16	19	22	25	28	31	34
53	68	71	74	77	80	4	7	10	13	16	19	22	25
54	43	46	49	52	55	58	61	64	67	70	73	76	79
55	17	20	23	26	29	32	35	38	41	44	47	50	53
56	37	40	43	46	49	52	55	58	61	64	67	70	73
57	69	72	75	78	2	5	8	11	14	17	20	23	26
58	54	57	60	63	66	69	72	75	78	2	5	8	11
59	60	63	66	69	72	75	78	2	5	8	11	14	17
60	46	49	52	55	58	61	64	67	70	73	76	79	3
61	52	55	58	61	64	67	70	73	76	79	3	6	9
62	19	22	25	28	31	34	37	40	43	46	49	52	55
63	9	12	15	18	21	24	27	30	33	36	39	42	45
64	21	24	27	30	33	36	39	42	45	48	51	54	57
65	10	13	16	19	22	25	28	31	34	37	40	43	46
66	71	74	77	80	4	7	10	13	16	19	22	25	28
67	53	56	59	62	65	68	71	74	77	80	4	7	10
68	44	47	50	53	56	59	62	65	68	71	74	77	80
69	5	8	11	14	17	20	23	26	29	32	35	38	41
70	32	35	38	41	44	47	50	53	56	59	62	65	68
71	59	62	65	68	71	74	77	80	4	7	10	13	16
72	39	42	45	48	51	54	57	60	63	66	69	72	75
73	57	60	63	66	69	72	75	78	2	5	8	11	14
74	28	31	34	37	40	43	46	49	52	55	58	61	64
75	48	51	54	57	60	63	66	69	72	75	78	2	5
76	55	58	61	64	67	70	73	76	79	3	6	9	12
77	42	45	48	51	54	57	60	63	66	69	72	75	78
78	34	37	40	43	46	49	52	55	58	61	64	67	70
79	50	53	56	59	62	65	68	71	74	77	80	4	7

Table B.3—Hopping sequence set 3 (continued)

index	41	44	47	50	53	56	59	62	65	68	71	74	77
1	43	46	49	52	55	58	61	64	67	70	73	76	79
2	66	69	72	75	78	2	5	8	11	14	17	20	23
3	26	29	32	35	38	41	44	47	50	53	56	59	62
4	51	54	57	60	63	66	69	72	75	78	2	5	8
5	7	10	13	16	19	22	25	28	31	34	37	40	43
6	59	62	65	68	71	74	77	80	4	7	10	13	16
7	35	38	41	44	47	50	53	56	59	62	65	68	71
8	11	14	17	20	23	26	29	32	35	38	41	44	47
9	62	65	68	71	74	77	80	4	7	10	13	16	19
10	25	28	31	34	37	40	43	46	49	52	55	58	61
11	40	43	46	49	52	55	58	61	64	67	70	73	76
12	72	75	78	2	5	8	11	14	17	20	23	26	29
13	23	26	29	32	35	38	41	44	47	50	53	56	59
14	65	68	71	74	77	80	4	7	10	13	16	19	22
15	16	19	22	25	28	31	34	37	40	43	46	49	52
16	27	30	33	36	39	42	45	48	51	54	57	60	63
17	69	72	75	78	2	5	8	11	14	17	20	23	26
18	41	44	47	50	53	56	59	62	65	68	71	74	77
19	74	77	80	4	7	10	13	16	19	22	25	28	31
20	45	48	51	54	57	60	63	66	69	72	75	78	2
21	61	64	67	70	73	76	79	3	6	9	12	15	18
22	54	57	60	63	66	69	72	75	78	2	5	8	11
23	79	3	6	9	12	15	18	21	24	27	30	33	36
24	36	39	42	45	48	51	54	57	60	63	66	69	72
25	18	21	24	27	30	33	36	39	42	45	48	51	54
26	33	36	39	42	45	48	51	54	57	60	63	66	69
27	64	67	70	73	76	79	3	6	9	12	15	18	21
28	46	49	52	55	58	61	64	67	70	73	76	79	3
29	80	4	7	10	13	16	19	22	25	28	31	34	37
30	53	56	59	62	65	68	71	74	77	80	4	7	10
31	77	80	4	7	10	13	16	19	22	25	28	31	34
32	30	33	36	39	42	45	48	51	54	57	60	63	66
33	50	53	56	59	62	65	68	71	74	77	80	4	7
34	32	35	38	41	44	47	50	53	56	59	62	65	68
35	39	42	45	48	51	54	57	60	63	66	69	72	75
36	47	50	53	56	59	62	65	68	71	74	77	80	4
37	24	27	30	33	36	39	42	45	48	51	54	57	60
38	70	73	76	79	3	6	9	12	15	18	21	24	27
39	55	58	61	64	67	70	73	76	79	3	6	9	12

Table B.3—Hopping sequence set 3 (continued)

index	41	44	47	50	53	56	59	62	65	68	71	74	77
40	68	71	74	77	80	4	7	10	13	16	19	22	25
41	57	60	63	66	69	72	75	78	2	5	8	11	14
42	21	24	27	30	33	36	39	42	45	48	51	54	57
43	5	8	11	14	17	20	23	26	29	32	35	38	41
44	38	41	44	47	50	53	56	59	62	65	68	71	74
45	75	78	2	5	8	11	14	17	20	23	26	29	32
46	34	37	40	43	46	49	52	55	58	61	64	67	70
47	52	55	58	61	64	67	70	73	76	79	3	6	9
48	22	25	28	31	34	37	40	43	46	49	52	55	58
49	42	45	48	51	54	57	60	63	66	69	72	75	78
50	9	12	15	18	21	24	27	30	33	36	39	42	45
51	63	66	69	72	75	78	2	5	8	11	14	17	20
52	37	40	43	46	49	52	55	58	61	64	67	70	73
53	28	31	34	37	40	43	46	49	52	55	58	61	64
54	3	6	9	12	15	18	21	24	27	30	33	36	39
55	56	59	62	65	68	71	74	77	80	4	7	10	13
56	76	79	3	6	9	12	15	18	21	24	27	30	33
57	29	32	35	38	41	44	47	50	53	56	59	62	65
58	14	17	20	23	26	29	32	35	38	41	44	47	50
59	20	23	26	29	32	35	38	41	44	47	50	53	56
60	6	9	12	15	18	21	24	27	30	33	36	39	42
61	12	15	18	21	24	27	30	33	36	39	42	45	48
62	58	61	64	67	70	73	76	79	3	6	9	12	15
63	48	51	54	57	60	63	66	69	72	75	78	2	5
64	60	63	66	69	72	75	78	2	5	8	11	14	17
65	49	52	55	58	61	64	67	70	73	76	79	3	6
66	31	34	37	40	43	46	49	52	55	58	61	64	67
67	13	16	19	22	25	28	31	34	37	40	43	46	49
68	4	7	10	13	16	19	22	25	28	31	34	37	40
69	44	47	50	53	56	59	62	65	68	71	74	77	80
70	71	74	77	80	4	7	10	13	16	19	22	25	28
71	19	22	25	28	31	34	37	40	43	46	49	52	55
72	78	2	5	8	11	14	17	20	23	26	29	32	35
73	17	20	23	26	29	32	35	38	41	44	47	50	53
74	67	70	73	76	79	3	6	9	12	15	18	21	24
75	8	11	14	17	20	23	26	29	32	35	38	41	44
76	15	18	21	24	27	30	33	36	39	42	45	48	51
77	2	5	8	11	14	17	20	23	26	29	32	35	38
78	73	76	79	3	6	9	12	15	18	21	24	27	30
79	10	13	16	19	22	25	28	31	34	37	40	43	46

Annex C

(normative)

Formal description of MAC operation

This annex contains formal descriptions of the behavior of MAC station (STA) and access point (AP) entities. These descriptions also describe the frame formats and the generation and interpretation of information encoded in MAC frames, in the parameters of service primitives supported by the MAC, and in MIB attributes used or generated by the MAC. The MAC is described using the 1992 version of the ITU Specification and Description Language (SDL-92). SDL-92 is defined in ITU-T Recommendation Z.100 (03/93). An update to Z.100 was approved in 1996 (SDL-96), but none of the SDL facilities used in this annex were modified. An introduction to the MAC formal description is provided in Clause C.1. Definitions of the data types and operators used by the MAC state machines are provided in Clause C.2. An SDL system describing MAC operation at an IEEE 802.11 station is contained in Clause C.3. Finally, a subset of an SDL system describing the aspects of MAC operation at an IEEE 802.11 AP that differ from operation at a non-AP station is provided in Clause C.4.

In Annex D, the MAC and PHY management information bases are described in Abstract Syntax Notation One (ASN.1), defined in ISO/IEC 8824: 1990 and ISO/IEC 8825: 1990. ITU-T Recommendation Z.105 (03/95) defines the use of SDL in conjunction with ASN.1, allowing system behavior to be defined using SDL and data types to be defined using ASN.1. Incomplete tool support precluded the use of ITU-T Recommendation Z.105 in this annex. However, within the limits of ITU-T Recommendation Z.100 (referred to subsequently as Z.100), the data types in Clause C.2 are defined in a similar manner to ITU-T Recommendation Z.105 (referred to subsequently as Z.105). Annex E contains a listing of available documentation.

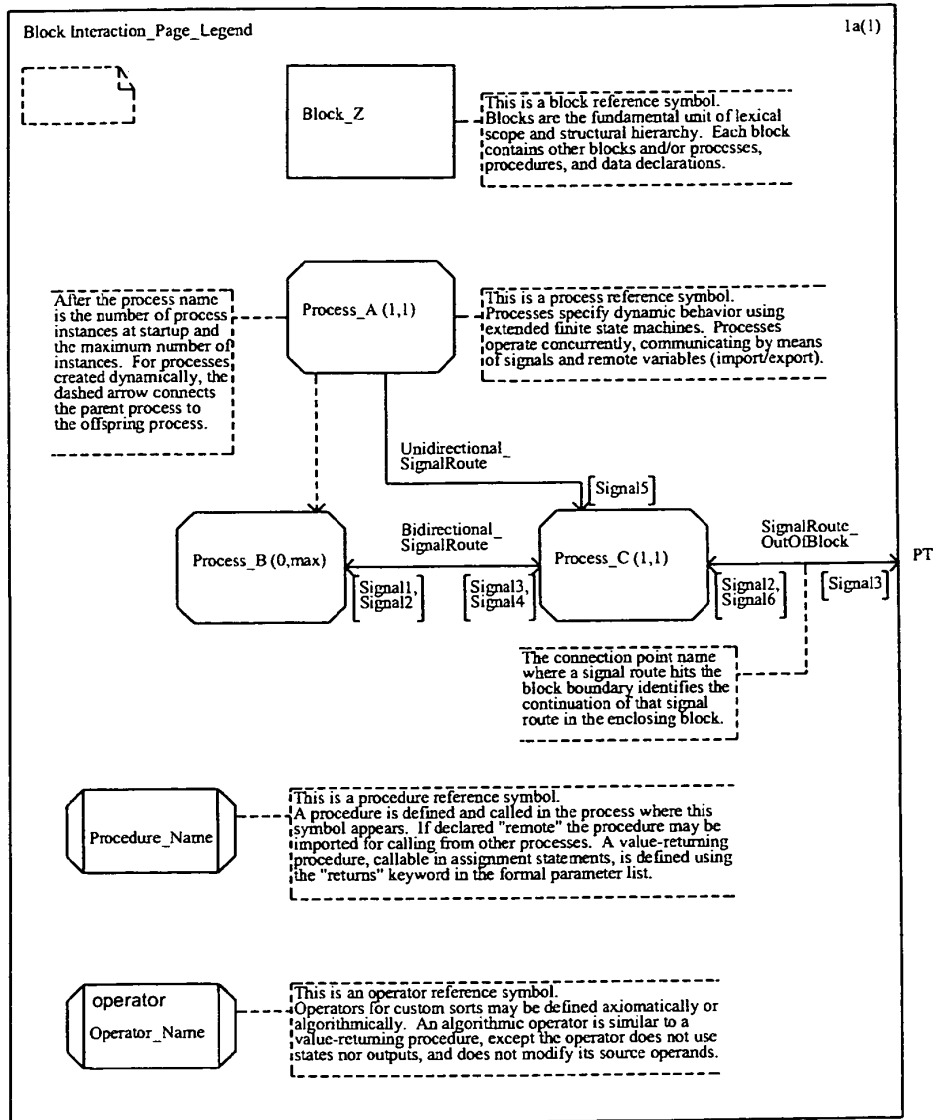
NOTES

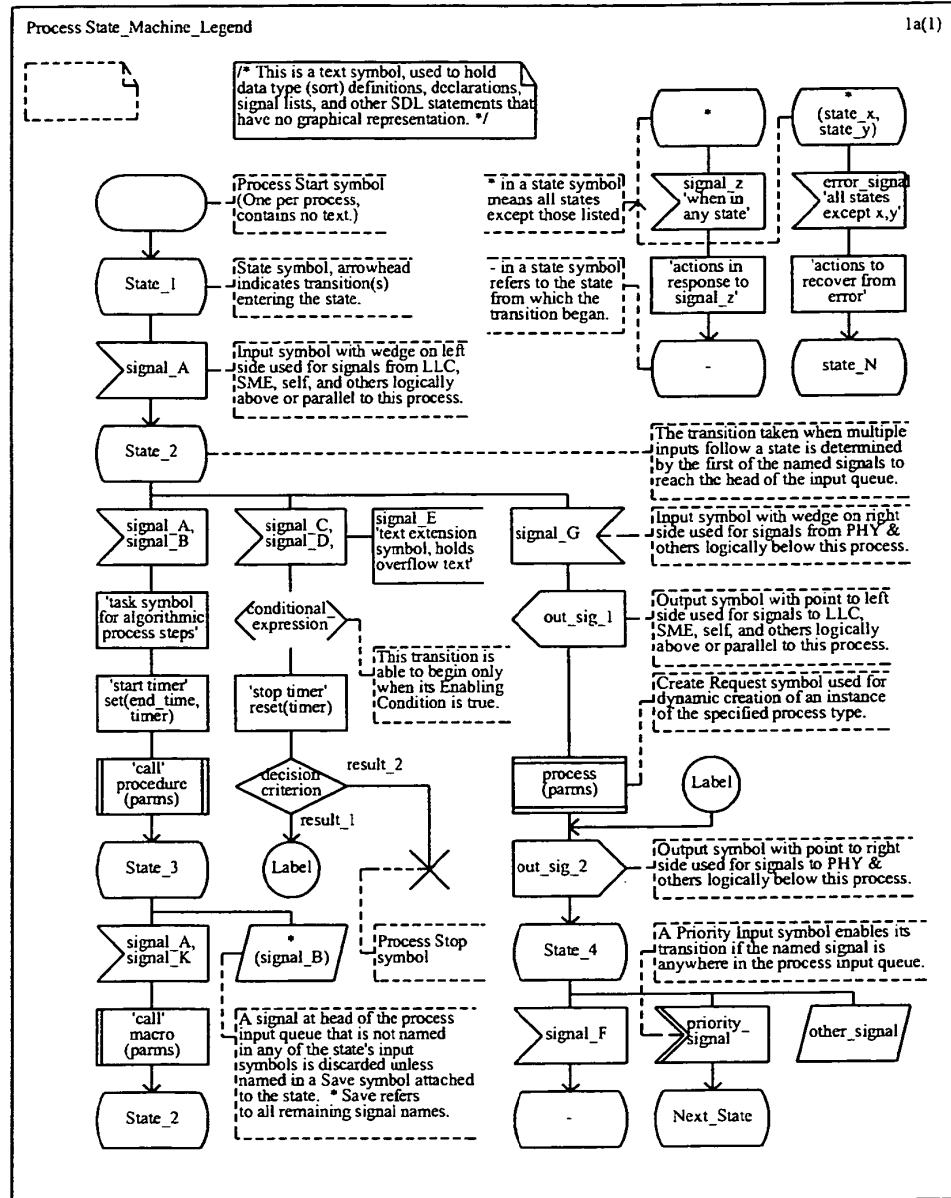
1—The SDL definitions in this annex should be usable with any SDL tool that supports the 1993 version or 1996 update of ITU-T Recommendation Z.100. Software for generating, analyzing, verifying, and simulating SDL system descriptions is available from several sources.

2—The SDL code in this annex was generated using *SDT/PC version 3.02*; from Telelogic AB, Malmö, Sweden (+46-40-174700; internet: telelogic.se); USA office in Princeton, NJ (+1-609-520-1935; internet: telelogic.com). Telelogic offers SDT for several workstation platforms in addition to SDT/PC.

3—The use of Telelogic's product to prepare this annex does not constitute an endorsement of SDT by the IEEE LAN MAN Standards Committee or by the IEEE.

4—The diagrams on the next two pages show most of the symbols of SDL graphical syntax (SDL-GR) used in the MAC formal description. The symbols in these diagrams have labels and comments that explain their meanings. These diagrams are intended to serve as a legend for the SDL-GR symbols that comprise most of the process interaction and state transition diagrams. These diagrams are neither a complete SDL system, nor a complete presentation of SDL-GR symbology. Also, this state machine fragment exists to illustrate the SDL graphical syntax, and does not describe any useful behavior.





C.1 Introduction to the MAC formal description

This formal description defines the behavior of IEEE 802.11 MAC entities. The MAC protocol functional decomposition used herein facilitates explicit description of the reference points and durations of the various timed intervals; the bases for generation and/or validation of header fields, service parameters, and MIB attributes; and the interpretation of each value in cases where enumerated data types are used in service parameters.

C.1.1 Fundamental assumptions

The MAC protocol is described as an SDL system, which is a set of extended finite state machines. Each state machine is a set of independent processes, all of which operate concurrently. All variable data-holding entities and procedures exist solely within the context of a single process. In SDL all interprocess communication is done with signals (there are no global variables). Signals may be sent and received explicitly, using SDL's output and input symbols, or implicitly, using SDL's export/import mechanism (only if the variables or procedures are declared "remote"). By default, signals incur delays when traversing channels between blocks; however, only nondelaying channels and signal routes are used in the MAC state machines, and all remote variables and procedures are declared with the "nodelay" property.

State transitions, procedure calls, and tasks (assignment statements and other algorithmic processing steps) are assumed to require zero time. This permits the time intervals that are part of the normative MAC behavior to be defined explicitly, using SDL timers. One unit of system time (a 1.0 change in the value of "now") is assumed to represent one microsecond of real time. Usec (microsecond) and TU (time unit) data types are defined, with operators to convert Usec and TU values to SDL time or duration when necessary.

The SDL system boundary encloses the MAC entities. The LLC, SME, PHY, and distribution system are part of the environment. SDL generally assumes that entities in the environment operate as specified; however, the MAC state machines that communicate with the various SAPs attempt to validate inputs from the environment, and to handle cases where a pair of communicating entities, one within the system and the other outside the system boundary, have different local views of the medium, station, or service state. All stations in an IEEE 802.11 service set are assumed to exhibit the behaviors described herein. Nevertheless, because of the open nature of the wireless medium, the MAC state machines check for error cases that can arise only when an entity on the wireless medium is transmitting IEEE 802.11 PDUs, but is not obeying the communication protocols specified by this standard.

C.1.2 Notation conventions

When practical, names used in the clauses of this standard are spelled identically in this annex. The principal exceptions are those names that conflict with one of SDL's reserved words (such as power management mode "active," which is renamed "sta_active" in SDL). To help fit the SDL text into the graphic symbols, acronyms with multiple, sequential capital letters are written with only the first letter capitalized (e.g., "MSDU" is written "Msdu" and "MLMEJoin.request" is written "MlmeJoin.request").

SDL reserved words and the names of variables and synonyms (named constants) begin with lowercase letters. The names of sorts (data types), signals, signal routes, channels, blocks, and processes begin with uppercase letters. The names of certain groups of variables and/or synonyms begin with a particular lowercase letter, followed by the remainder of the name, beginning with an uppercase letter. These groups are

"aNameOfAttribute"	PHY operational parameters.
"cNameOfCapability"	Capability bits, also used for internal values exported as MIB counters.
"dNameOfDuration"	Duration (relative time) values, declared as Usec, TU, or Duration.
"dot11NameOfAttribute"	MIB attributes.

"eNameOfElement"	Element ID values.
"mNameOfVariable"	Remote variables used for intra-MAC communication, but not part of the MIB. Most of these variables are exported from the MLME block.
"sNameOfStaticValue"	Synonyms for static data values used within the MAC.
"tNameOfTime"	Time (absolute time) values, declared as Usec, TU, or Time. The names of timers begin with "T."

C.1.3 Modeling techniques

State machines are grouped according to defined function sets that are visible, directly or indirectly, at an exposed interface. The emphasis in the organization of the state machines is explicitly to show initiation of and response to events at the exposed interfaces, and time-related actions, including those dependent on the absence of external events (e.g., response timeouts) and intervals measured in derived units (e.g., backoff "time" in units of slots during which the wireless medium is idle). The operations associated with the various state transitions emphasize communication functions. Most of the details regarding insertion, extraction, and encoding of information in fields of the PDUs is encapsulated with the definitions of those fields. This approach, which relies heavily on SDL's abstract data type and inheritance mechanisms, permits the behavior of the data-holding entities to be precisely defined, without obscuring process flow by adding in-line complexity to the individual state transitions.

The modeling of PDUs and SDUs requires sorts such as octet strings, and operators such as bitwise boolean functions, which are not predefined in SDL. These sorts and operators are defined in Package macsorts, which appears in Clause C.2.

Protocol and service data unit sorts are based on the **Bit** sort. Bit is a subtype of SDL's predefined Boolean sort. As a result, Bit literals "0" and "1" are alternative names for "false" and "true," and have no numeric significance. To use "0" or "1" as integer values requires a conversion operation. Items of the **Bitstring** sort are 0-origin, variable-length strings of Bits. With Bitstring operands, operators "and," "or," "xor," and "not" operate bitwise, with the length of the result equal to the length of the longest (or only) source string. The **Octet** sort is a subtype of Bitstring that adds conversion operators to and from Integer. Each item of the Octet sort has length=8 {by usage convention in Z.100, enforced in Z.105}. Items of the **Octetstring** sort are 0-origin, variable-length strings of Octets. The **Frame** sort is a subtype of Octetstring that adds operators to extract and to modify all MAC header fields and most other MAC frame fields and elements. Most MAC fields and elements that contain named values with specific value assignments or enumerations are defined as subtypes of Frame, Octetstring, or Bitstring with the names added as literals or synonyms, so that the state machines can refer to the names without introducing ambiguity about the value encodings.

Where communication at a SAP or between processes is strictly first in first out (FIFO), the (implicit) input queue of the SDL processes is used. When more sophisticated queue management is needed, a queue whose entries are instances of one, specified sort is created using the **Queue** generator. Entries on Queue sorts may be added and removed at either the tail or the head, and the number of queue entries may be determined. The contents of a Queue may also be searched to locate entries with particular parameter values.

Clause C.2 contains an SDL-92 Package (a named collection of SDL definitions that can be included by reference into an SDL System specification), which is a formal description of the formats and data encodings used in IEEE 802.11 SDUs, PDUs, and the parameters of the service primitives used at each of the SAPs supported by the IEEE 802.11 MAC. This package also contains definitions for some data structures and operators used internally by one or more of the MAC state machines.

The behaviors of many intra-MAC operators are part of the normative description of the MAC protocol because results of the specified operations are visible, directly or indirectly, at exposed interfaces. For example, custom operators are used to define the generation of the CRC-32 value used in the FCS field (operator `crc32`, page 301), the calculation of frame transmission time used as part of the value in the Duration/ID field

in certain types of frames (operator calcDur, page 316), the comparison of the values of particular fields of a received MAC header with cached data values as part of the procedure for detecting duplicate frames (operator searchTupleCache, page 289), and numerous other aspects of frame formats and information encoding. On the other hand, data structures used solely for intra-MAC storage or for transferring of information between different state machines of a single station or access point, are only normative to the extent that they define items of internal state and the temporal sequence necessary for proper operation of the MAC protocol. The specific structures and encodings used for internal data storage and communication functions in this formal description do *not* constrain MAC implementations, provided those implementations exhibit the specified behaviors at the defined SAPs and, in conjunction with an appropriate PHY, on the wireless medium.

C.2 Data type and operator definitions for the MAC state machines

This clause is in SDL/PR (phrase notation), with the exception of procedural operators, which are defined in SDL/GR (graphic notation). Package macsorts contains the definitions of the sorts (data types with associated operators and literals) and synonyms (named constants) used by the MAC state machines. Package macmib defines data types for attributes in the MAC MIB, and portions of the PHY MIB, accessed by the MAC state machines. Package macmib exists solely to satisfy SDL's strong type checking in the absence of an SDL tool that fully supports Z.105 (the combined use of SDL with ASN.1).

Package macsorts

3101_dMacEnum(31)

/* PACKAGE MACSORTS */
/* This package contains definitions of the custom sorts (data types), operators,
literals, and synonyms (named constants) used by the MAC state machines. */

```

.....
* Enumerated types used within the MAC state machines
.....
newtype ChangeType /* type of change due at the next boundary */
literals dwell, /* dwell (only with FH PHY) */
        mocc; /* medium occupancy (only with PCF) */
endnewtype ChangeType;
newtype lmed /* priority for queuing MMPDUs, relative to MSDUs */
literals head, /* place MMPDU at head of transmit queue */
        norm; /* place MMPDU at tail of transmit queue */
endnewtype lmed;
newtype NavSrc /* source of duration in SetNav & ClearNav signals */
literals rts, /* RTS frame */
        cfpBss, cfendBss, /* start/end of CFP in own BSS */
        cfpOther, cfendOther, /* start/end of CFP in other BSS */
        cswitch, /* channel switch */
        misc, /* durld from other frame types */
        nosrc; /* non-reception events */
endnewtype NavSrc;
newtype PsMode /* power save mode of a station (PsResponse signal) */
literals sta_active, power_save, unknown; endnewtype PsMode;
newtype PsState /* power save state of this station */
literals awake, doze; endnewtype PsState;
newtype StateErr /* requests disassoc or deauth (MmIndicate signal) */
literals noerr, class2, class3; endnewtype StateErr;
newtype StationState /* assoc/auth state of sta (SsResponse signal) */
literals not_auth, auth_open, auth_key, assoc, dis_assoc;
endnewtype StationState;
newtype TxResult /* transmission attempt status (PduConfirm signal) */
literals successful, partial, retryLimit, txLifetime,
        atimAck, atimNak; endnewtype TxResult;

```

```

.....
* Enumerated types used in PHY service primitives
.....
newtype CcaStatus /* <state> parameter of PhyCca.indication */
literals busy, idle; endnewtype CcaStatus;
newtype PhyRxStat /* <xerror> parameter of PhyRxEnd.indication */
literals no_error, fmt_violation, carrier_lost, unsupt_rate;
endnewtype PhyRxStat;

```

```

.....
* Placeholders for Mlme/Pime GeVSet Parameter Values
.....
/* MibAtrib (placeholder in MlmeGet/Set definitions) */
syntype MibAtrib = Charstring endsyntype MibAtrib;
/* MibValue (placeholder in MlmeGet/Set definitions) */
syntype MibValue = Integer endsyntype MibValue;

```

Package macsorts

3102_dLmeEnum(31)

```

* Enumerated types used in Mac and Mlme service primitives
*
newtype AuthType /* <authentication type> parm in Mlme primitives */
inherits Octetstring operators all;
adding literals open_system, shared_key;
axioms open_system == mkOS(0, 2); shared_key == mkOS(1, 2);
endnewtype AuthType;
newtype AuthTypeSet powerset( AuthType); endnewtype AuthTypeSet;
newtype BssType /* <BSS type> parameter & BSS description element */
literals infrastructure, independent, any_bss; endnewtype BssType;
newtype BssTypeSet powerset( BssType); endnewtype BssTypeSet;
newtype CfPriority /* <priority> parameter of various requests */
literals contention, contentionFree; endnewtype CfPriority;
newtype MibStatus /* <status> parm of Mlme/Plme Get/Set.confirm */
literals success, invalid, write_only, read_only;
endnewtype MibStatus;
newtype MlmeStatus /* <status> parm of Mlme operation confirm */
literals success, invalid, timeout, refused,
tomany_req, already_bss; endnewtype MlmeStatus;
newtype PwrSave /* <power save mode> parameter of MlmePowerMgt */
literals sta_active, power_save; endnewtype PwrSave;
newtype Routing /* <routing info> parameter for MAC data service */
literals null_rt; endnewtype Routing;
newtype RxStatus /* <reception status> parm of MaUnitdata indication */
literals rx_success, rx_failure; endnewtype RxStatus;
newtype ScanType /* <scan type> parameter of MlmeScan.request */
literals active_scan, passive_scan; endnewtype ScanType;
newtype ServiceClass /* <service class> parameter for MaUnitdata */
literals reorderable, strictlyOrdered; endnewtype ServiceClass;
newtype TxStatus /* <transmission status> parm of MaUnitdataStatus */
literals successful, retryLimit, txLifetime, noBss,
excessiveDataLength, nonNullSourceRouting,
unsupportedPriority, unavailablePriority,
unsupportedServiceClass, unavailableServiceClass,
unavailableKeyMapping; endnewtype TxStatus;

```



Package macsorts

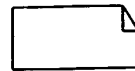
3103_eIntraMac(31)



```

* Intra-MAC remote variables (names of form mXYZ)
*-----*/
remote mActingAsAp Boolean nodelay; /* =true if STA started BSS */
remote mAld AsocId nodelay; /* AID assigned to STA by AP */
remote mAssoc Boolean nodelay; /* =true if STA associated w/BSS */
remote mAtimW Boolean nodelay; /* =true if ATIM window in prog */
remote mBkIP Boolean nodelay; /* =true if backoff in prog */
remote mBates Ratestring nodelay; /* basic rate set for this sta */
remote mBssId MacAddr nodelay; /* identifier of current (I)BSS */
remote mCap Octetstring nodelay; /* capability info from MlmeJoin */
remote mCfp Boolean nodelay; /* =true if CF period in progress */
remote mDisable Boolean nodelay; /* =true if not in any BSS; then */
/* TX only sends probe_req; RX only accepts beacon, probe_rsp */
remote mDtimCount Integer nodelay; /* =0 at Tbt of Beacon with DTIM */
remote mFxlP Boolean nodelay; /* =true during frame exchange seq */
remote mlbss Boolean nodelay; /* =true if STA is member of IBSS */
remote mListenInt Integer nodelay; /* beacons between wake up @TBTT */
remote mNavEnd Time nodelay; /* NAV end Time, <=now when idle */
remote mNextBdry Time nodelay; /* next boundary Time; =0 if none */
remote mNextTbtt Time nodelay; /* Time next beacon due to occur */
remote mPcAvail Boolean nodelay; /* =true if point coord in BSS */
remote mPcDlvr Boolean nodelay; /* =true if CF delivery only */
remote mPcPoll Boolean nodelay; /* =true if CF delivery & polling */
remote mPdy Usec nodelay; /* probe delay from start or join */
remote mPss PsState nodelay; /* power save state of STA */
remote mReceiveDTIMs Boolean nodelay; /* =true if DTIMs received */
remote mRxA Boolean nodelay; /* =true if RX indicated by PHY */
remote mSsId Octetstring nodelay; /* name of the current (I)BSS */
remote procedure TSF nodelay; /* read & update 64-bit TSF timer */
fpar Integer, Boolean; returns Integer;

```



Package macsorts

3104_dStaticData(31)

```

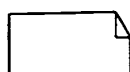
/*****
 *      Named static data values   (names of form sXYZ)
 *****/
synonym sMaxMsduLng Integer = 2304; /* max octets in an MSDU */
synonym sMacHdrLng Integer = 24; /* octets in data header, no WEP */
synonym sWepHdrLng Integer = 28; /* octets in data header with WEP */
synonym sWepAddLng Integer = 8; /* octets added for WEP */
synonym sWdsAddLng Integer = 6; /* octets added for WDS (addr4) */
synonym sCrcLng Integer = 4; /* octets for crc32 (FCS, ICV) */
synonym sMaxMpduLng Integer = /* max octets in an MPDU */
(sMaxMsduLng + sMacHdrLng + sWdsAddLng + sWepAddLng + sCrcLng);
syntype FrameIndexRange = Integer /* index range for octets in MPDU */
constants 0 : sMaxMpduLng endsyntype FrameIndexRange;
synonym sTsOctet Integer = 24; /* first octet of Timestamp field */
synonym sMinFragLng Integer = 256; /* min value for aMpduMaxLength */
synonym sMaxFragNum Integer = /* maximum fragment number */
(sMaxMsduLng / (sMinFragLng - sMacHdrLng - sCrcLng));
synonym sAckCtsLng Integer = 112; /* bits in ACK and CTS frames */

```

```

/*****
 *      Station configuration flags (static, supplementary to MIB)
 *****/
synonym sVersion Integer = 0; /* supported Protocol Version */
synonym sCanBeAp Boolean = false; /* =true if STA can operate as AP */
synonym sCanBePc Boolean = false; /* =true if AP can be Point Coord */
synonym sCfPollable Boolean = true; /* =true if responds to CF-polls */

```



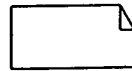
Package macsorts

3105_d\Usec_TU(31)

```

* Discrete microsecond and Time Unit sorts
*****
/* SDL does not define the relationship between its concept */
/* of Time and physical time in the system being described. */
/* An abstraction is needed to establish this relationship. */
/* because Time in SDL uses the semantics of Real, whereas */
/* time in the MAC protocol is discrete, with the semantics */
/* of Natural and a step size (resolution) of 1 microsecond. */
/* Most MAC times are defined using the subtypes of Integer */
/* Usec and TU. These have operators for explicit conversion */
/* to SDL Time (tUsec, tTU), SDL Duration (dUsec, dTU), and */
/* from SDL Time (uTime, tuTime) as needed to comply with SDL's */
/* strong type checking. Where the MAC state machines need to */
/* access the contents of the TSF timer, SDL's 'now' (current */
/* time) is used. This yields readable time-dependent code, */
/* but the value of 'now' cannot be modified by an SDL program, */
/* so adopting the TSF time from timestamps in received Beacons */
/* or Probe Responses is shown as an informal task symbol. */
/* Microsecond sort -- also has operators tmin and tmax */
newtype Usec inherits Integer operators all;
adding operators
dUsec : Usec -> Duration;
tUsec : Usec -> Time;
uTime : Time -> Usec;
tmax : Usec, Usec -> Usec;
tmin : Usec, Usec -> Usec;
axioms for all u, w in Usec(
  u >= w ==> tmax(u, w) == u;    u < w ==> tmax(u, w) == w;
  u >= w ==> tmin(u, w) == w;    u < w ==> tmin(u, w) == u;
  for all t in Time( for all r in Real(
    r = float(u) ==> tUsec(u) == Time!(Duration!(r));
    t = Time!(Duration!(r)) and u = fix(r) ==> u == uTime(t));
  for all d in Duration( for all r in Real(
    r = float(u) ==> dUsec(u) == Duration!(r); ));
constants >= 0 /* constrain value range to be non-negative */
endnewtype Usec;
/* Time Unit sort -- (1 * TU) = (1024 * Usec) */
newtype TU inherits Integer operators all;
adding operators
dTU : TU -> Duration;
tTU : TU -> Time;
tuTime : Time -> TU;
u2TU : Usec -> TU;
tu2U : TU -> Usec;
axioms for all k in TU( for all t in Time( for all r in Real(
  r = float(k) ==> tTU(k) == Time!(Duration!(1024 * r));
  t = Time!(Duration!(r)) and k = (fix(r) / 1024) ==> k == tuTime(t));
  for all d in Duration( for all r in Real(
    r = float(k) ==> dTU(k) == Duration!(1024 * r));
  for all u in Usec( u2TU(u) == u / 1024; tu2U(k) == k * 1024; ));
constants >= 0 /* constrain value range to be non-negative */
endnewtype TU;

```



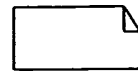
Package macsorts

3106_dString0(31)

```

.....
* Generator for 0-origin String sorts (adapted from Z.105, Annex A)
.....
/* String0(sort, nullSymbol) can define strings of any sort. */
/* These strings are indexed starting from 0 rather than 1. */
/* Sorts defined by String0 have the normal String operators, plus */
/* Tail (all but first item), Head (all but last item), and */
/* aggregators S2, S3, S4, S6, S8 (make fixed length strings). */
generator String0(type Item, literal Emptystring)
  literals Emptystring;
  operators
    MkString : Item -> String0; /* make a string from an item */
    Length : String0 -> Integer; /* length of string */
    First : String0 -> Item; /* first item in string */
    Tail : String0 -> String0; /* all but first item in string */
    Last : String0 -> Item; /* last item in string */
    head : String0 -> String0; /* all but last item in string */
    "/" : String0, String0 -> String0; /* concatenation */
    Extract! : String0, Integer -> Item; /* get item from string */
    Modify! : String0, Integer, Item -> String0; /* modify string */
    SubStr : String0, Integer, Integer -> String0;
    /* SubStr(s,i,j) is string0 of length j starting at string0(i) */
    S2 : Item, Item -> String0; S3 : Item, Item, Item -> String0;
    S4 : Item, Item, Item, Item -> String0;
    S6 : Item, Item, Item, Item, Item, Item -> String0;
    S8 : Item, Item, Item, Item, Item, Item, Item, Item -> String0;
    /* axioms continued on next page... */
endgenerator String0;

```



Package macros

3107_aString0(31)

```

/* String0 axioms */
/* for all item0,item1,item2,item3,item4,item5,item6,item7 in Item(
   for all s, s1, S2, S3 in String0( for all i, j in Integer(
   constructors are Emptystring, MkString, and "/*";
   equalities between constructor terms
   s // Emptystring == s;      Emptystring // s == s;
   (s1 // S2) // S3 == s1 // (S2 // S3);
   definition of Length by applying it to all constructors
   type String Length(Emptystring) == 0;
   type String Length(MkString(item0)) == 1;
   type String Length(s1 // S2) == Length(s1) + Length(S2);
   definition of Extract! by applying it to all constructors.
   Extract!(MkString(item0), 0) == item0;
   i < Length(s1) ==> Extract!(s1 // S2, i) == Extract!(s1, i);
   i >= Length(s1) ==> Extract!(s1 // S2, i) == Extract!(S2, i - Length(s1));
   i < 0 or i >= Length(s) ==> Extract!(s, i) == error!;
   definition of First and Last by other operations
   First(s) == Extract!(s, 0);
   Last(s) == Extract!(s, Length(s) - 1);
   definition of substr(s,i,j) by induction on j,
   i >= 0 and i <= Length(s) ==> SubStr(s, i, 0) == Emptystring;
   i >= 0 and j > 0 and i + j <= Length(s) ==> SubStr(s, i, j) ==
       SubStr(s, i, j - 1) // MkString(Extract!(s, i + j - 1));
   i < 0 or j < 0 or i + j > Length(s) ==> SubStr(s, i, j) == error!;
   definition of Modify!, Head, Tail, Sx by other operations
   Modify!(s, i, item0) == SubStr(s, 0, i) // MkString(item0) //
       SubStr(s, i + 1, Length(s) - i - 1);
   head(s) == SubStr(s, 0, Length(s) - 1);
   Tail(s) == SubStr(s, 1, Length(s) - 1);
   S2(item0, item1) == MkString(item0) // MkString(item1);
   S3(item0, item1, item2) ==
       MkString(item0) // MkString(item1) // MkString(item2);
   S4(item0, item1, item2, item3) ==
       MkString(item0) // MkString(item1) // MkString(item2) //
       MkString(item3);
   S6(item0, item1, item2, item3, item4, item5) ==
       MkString(item0) // MkString(item1) // MkString(item2) //
       MkString(item3) // MkString(item4) // MkString(item5);
   S8(item0, item1, item2, item3, item4, item5, item6, item7) ==
       MkString(item0) // MkString(item1) // MkString(item2) //
       MkString(item3) // MkString(item4) // MkString(item5) //
       MkString(item6) // MkString(item7); ));
*/

```

Package macros

3108_dBitstring(31)

```

*      ASN.1-style BIT sort   (from Z.105, Annex A)
.....
/* Bit is a subtype of Boolean -- bit values 0 and 1 are
/* not numerals and cannot be used with Integer operators */
newtype Bit inherits Boolean
  literals 0 = false, 1 = true; operators all; endnewtype Bit;

```

```

*      ASN.1-style BIT STRING sort   (adapted from Z.105, Annex A)
.....
/* Bitstrings are 0-origin strings of Bit. Z.105 uses ASN.1-style */
/* literals in binary ('1011'B) or hexadecimal ('D3'H), but this */
/* syntax is not accepted for Z.100 string literals. Therefore, */
/* this version provides only hexadecimal literals 0x00-0xFF. */
/* Bitstring operators '=' , 'not', 'and', 'or', and 'xor' act */
/* bitwise, with the length of the result string equal to the */
/* length of the longest (or only) source string. */
newtype Bitstring String0(Bit, ")
  adding literals macro Hex_Literals;
  operators
    "not" : Bitstring -> Bitstring;
    "and" : Bitstring, Bitstring -> Bitstring;
    "or" : Bitstring, Bitstring -> Bitstring;
    "xor" : Bitstring, Bitstring -> Bitstring;
    "==" : Bitstring, Bitstring -> Bitstring;  noequality;
  axioms macro Hex_Axioms;
  for all s, s1, S2, S3 in Bitstring(
    s = s == true;    s1 = S2 == S2 = s1;
    s1 /= S2 == not (s1 = S2);    s1 = S2 == true ==> s1 == S2;
    ((s1 = S2) and (S2 = S3)) ==> s1 = S3 == true;
    ((s1 = S2) and (S2 /= S3)) ==> s1 = S3 == false;
    for all b, b1, b2 in Bit(
      not ("") == "";
      not (MkString(b) // s) == MkString(not (b)) // not (s);
      " and " == "";
      Length(s) > 0 ==> " and s == MkString(0) and s;
      Length(s) > 0 ==> s and " == s and MkString(0);
      (MkString(b1) // s1) and (MkString(b2) // S2) ==
        MkString(b1 and b2) // (s1 and S2);
      s1 or S2 == not (not s1 and not S2);
      s1 xor S2 == (s1 or S2) and not (s1 and S2);
      s1 => S2 == not (not s1 and S2);));
  map for all b1, b2 in Bitstring literals(
    for all bs1, bs2 in Charstring literals(
/* connection to the String generator */
      for all b in Bit literals(
        spelling(b1) = "" // bs1 // bs2 // "",
        spelling(b2) = "" // bs2 // "", spelling(b) = bs1
        ==> b1 == MkString(b) // b2; ));
endnewtype Bitstring;

```




Package macsorts

3109_dIOctetstring(31)

```

* OCTET sort (influenced by Z.105, Annex A)
-----
/* Octet is a subtype of Bitstring where length always =8. */
/* Z.105 adds a "size" keyword to SDL and defines Octet with */
/* "... constants size (8) ..." to impose this length constraint. */
/* Here Octet relies on proper use maintain lengths as multiples */
/* of 8. Proper length strings are created by the hexadecimal */
/* Bitstring literals (e.g. 0xD5) and operator mkOctet: */
/* o := mkOctet(i) converts a non-negative Integer (mod 256) */
/* to an Octet (exactly 8 bits) */
/* i := octetVal(o) converts an Octet to an Integer (0:255) */
/* o := flip(o) reverses bit order of the Octet */
/* (0<-->7, 1<-->6, 2<-->5, 3<-->4) */
newtype Octet inherits Bitstring operators all;
adding operators
mkOctet : Integer -> Octet;
octetVal : Octet -> Integer;
flip : Octet -> Octet;
axioms
for all i in Integer( for all z in Octet(
i = 0 ==> mkOctet(i) == S8(0, 0, 0, 0, 0, 0, 0, 0);
i = 1 ==> mkOctet(i) == S8(1, 0, 0, 0, 0, 0, 0, 0);
i > 1 and i <= 255 ==> mkOctet(i) ==
SubStr((First(mkOctet(i mod 2)) // mkOctet(i / 2)), 0, 8);
i > 255 ==> mkOctet(i) == mkOctet(i mod 256);
i < 0 ==> mkOctet(i) == error!;
z = MkString(0) ==> octetVal(z) == 0;
z = MkString(1) ==> octetVal(z) == 1;
Length(z) > 1 and Length(z) <= 8 ==>
octetVal(z) == octetVal(First(z)) +
(2 * (octetVal(SubStr(z, 1, Length(z) - 1))));
Length(z) > 8 ==> octetVal(z) == error!;
flip(z) == S8(z(7),z(6),z(5),z(4),z(3),z(2),z(1),z(0)); ));
endnewtype Octet;

```



Package macsorts

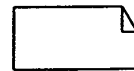
3109.1_aOctetstring(31)



```

-----
*   OCTET STRING sort (somewhat influenced by Z.105, Annex A)
-----
/* Octetstrings are 0-ORIGIN strings of Octet, NOT 1-ORIGIN */
/* strings like Octet_String in Z.105 (hence the name change). */
/* Octetstring has conversion operators to and from Bitstring. */
/* and integer to Octetstring. Octetstring literals are "null" */
/* and 1-4, 6, 8 item 0x00 strings O1, O2, O3, O4, O6, O8. */
newtype Octetstring String0(Octet, null)
adding literals O1, O2, O3, O4, O6, O8;
operators
  B_S : Octetstring -> Bitstring; /* name changed from Z.105 */
  O_S : Bitstring -> Octetstring; /* name changed from Z.105 */
  mkOS : Integer, Integer -> Octetstring; /* mkOS(i1,i2) returns */
      /* mkstring(mkOctet(i1)) padded (0x00) to length i2 */
  mk2octets : Integer -> Octetstring; /* 16-bit int to 2-octets */
axioms
for all b, b1, b2 in Bitstring(
  for all s in Octetstring(
    for all o in Octet(
      B_S(null) == null;    O_S(null) == null;
      B_S(MkString(o) // s) == o // B_S(s);
      Length(b1) > 0, Length(b1) < 8 ==>
        O_S(b1) == MkString(b1 or 0x00); /* expand b1 to 8 bits */
      b == b1 // b2, Length(b1) = 8 ==>
        O_S(b) == MkString(b1) // O_S(b2);
      for all i, k in Integer(
        k = 1 ==> mkOS(i, k) == MkString(mkOctet(i));
        k > 1 ==> mkOS(i, k) == mkOS(i, k - 1) // MkString(0x00);
        k <= 0 ==> error!;
        mk2octets(i) == MkString(mkOctet(i mod 256)) //
          MkString(mkOctet(i / 256)); );
      O1 == MkString(0x00);    O2 == O1 // O1;
      O3 == O2 // O1;    O4 == O2 // O2;
      O6 == O4 // O2;    O8 == O4 // O4; ));
map for all O1, O2 in Octetstring literals(
  for all b1, b2 in Bitstring literals(
    spelling(O1) = spelling(b1), spelling(O2) = spelling(b2)
    ==> O1 = O2 == b1 = b2; ));
endnewtype Octetstring;

```



Package macsorts

3110_dMacAddr(31)

```

*
*   MAC Address sorts
*
*-----*/
/* MacAddr is a subtype of Octetstring with added operators: */
/* isGroup(m) =true if given a group address */
/* isBcst(m) =true if given the broadcast address */
/* isLocal(m) =true if given a locally-administered address */
/* adrOs(m) converts MacAddr to Octetstring */
/* MAC addresses must be defined to be exactly 6 octets long. */
/* typically using the S6 operator or nullAddr synonym. */
newtype MacAddr inherits Octetstring operators all;
adding operators
  isGroup : MacAddr -> Boolean;
  isBcst : MacAddr -> Boolean;
  isLocal : MacAddr -> Boolean;
  adrOs : MacAddr -> Octetstring;
axioms
  for all m in MacAddr(
    (Length(m) = 6) and ((Extract!(m,0) and 0x01) = 0x01) ==> isGroup(m) == true;
    (Length(m) = 6) and ((Extract!(m,0) and 0x01) = 0x00) ==> isGroup(m) == false;
    (Length(m) = 6) and (m = S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF)) ==> isBcst == true;
    (Length(m) = 6) and (m /= S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF)) ==> isBcst == false;
    (Length(m) = 6) and ((Extract!(m,0) and 0x02) = 0x02) ==> isLocal == true;
    (Length(m) = 6) and ((Extract!(m,0) and 0x02) = 0x00) ==> isLocal == false;
    Length(m) /= 6 ==> error! /* common error! term */;
    for all o in Octetstring(m = MacAddr!(o) == adrOs(m) = o; ));
endnewtype MacAddr;
newtype MacAddrSet powerset( MacAddr) endnewtype MacAddrSet;
synonym bcstAddr MacAddr = /* Broadcast Address */
  <<type MacAddr>> S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF);
synonym nullAddr MacAddr = /* Null Address */
  << type MacAddr>> S6(0x00,0x00,0x00,0x00,0x00,0x00);

```

```

*
*   BSS description sorts
*
*-----*/
/* BssDscr is used with MlmeScan.confirm and MlmeJoin.request */
newtype BssDscr struct
  bdBssid MacAddr;
  bdSsid Octetstring; /* 1 <= length <= 32 */
  bdType BssType;
  bdBcnPer TU; /* beacon period in Time Units */
  bdDtimPer Integer; /* DTIM period in beacon periods */
  bdTstamp Octetstring; /* 8 Octets from ProbeRsp/Beacon */
  bdStartTs Octetstring; /* 8 Octets TSF when rx Tstamp */
  bdPhyParms PhyParms; /* empty if not needed by PHY */
  bdCfParms CfParms; /* empty if not CfPollable/no PCF */
  bdIbssParms IbssParms; /* empty if infrastructure BSS */
  bdCap Capability; /* capability information */
  bdRates Ratestring; /* BSS basic rate set */
endnewtype BssDscr;
newtype BssDscrSet powerset( BssDscr) endnewtype BssDscrSet;

```

Package macsorts

3111_dTupleCache(31)

```

.....
* Duplicate filtering support sorts
...../
syntype FragNum = Integer /* Range of possible fragment numbers */
constants 0:sMaxFragNum endsyntype FragNum;
syntype SeqNum = Integer /* Range of possible sequence numbers */
constants 0:4095 endsyntype SeqNum;
newtype Tuple struct /* for duplicate filtering & defragmentation */
full Boolean; /* =true if Tuple contains valid info */
ta MacAddr; /* transmitting station address (Addr2) */
sn SeqNum; /* Msdu/Mmpdu sequence number */
fn FragNum; /* most recent Mpdv fragment number */
tRx Time; /* reception time (endRx of fragment) */
default (. false, nullAddr, 0, 0, 0.);
endnewtype Tuple;

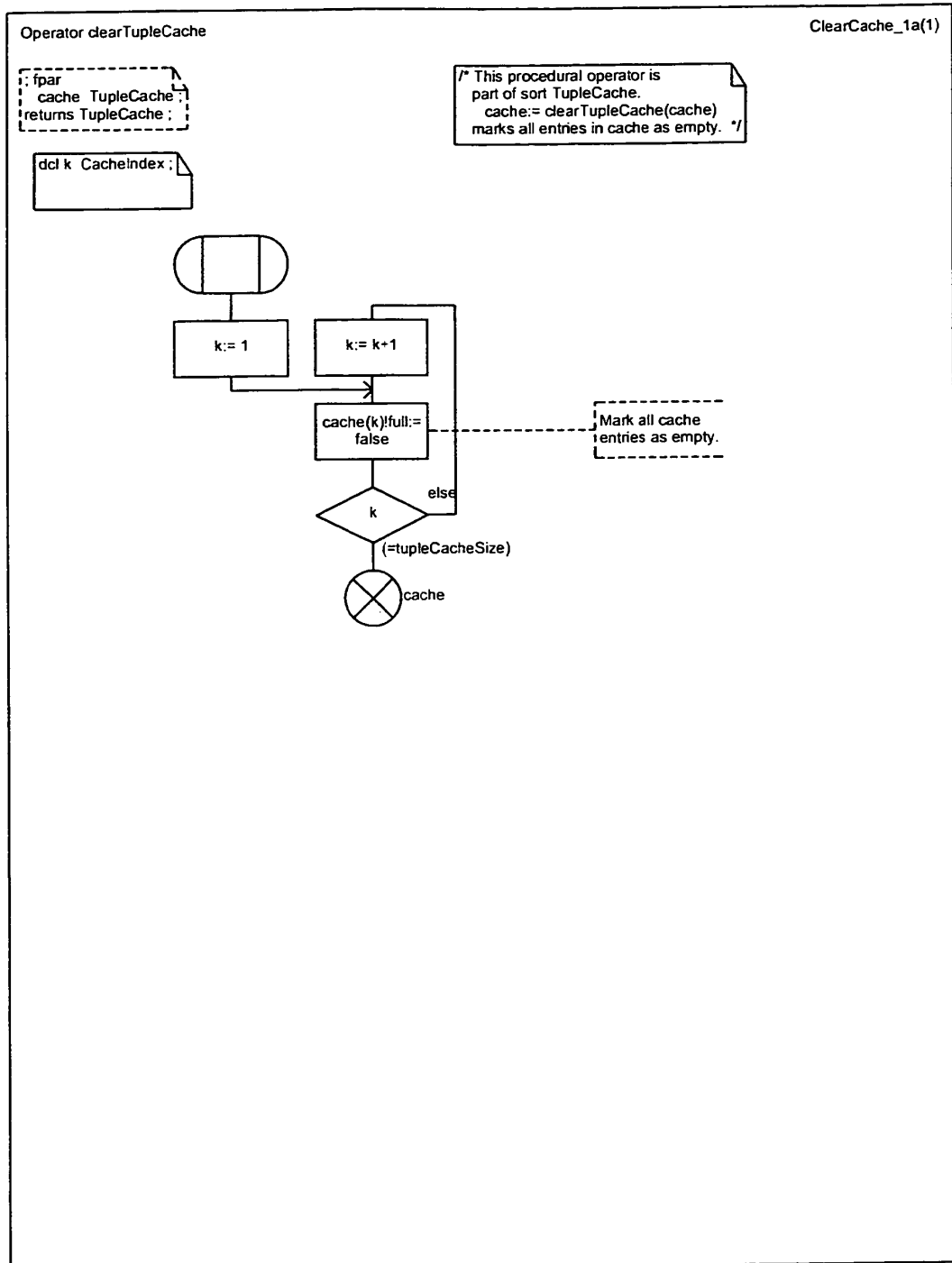
```

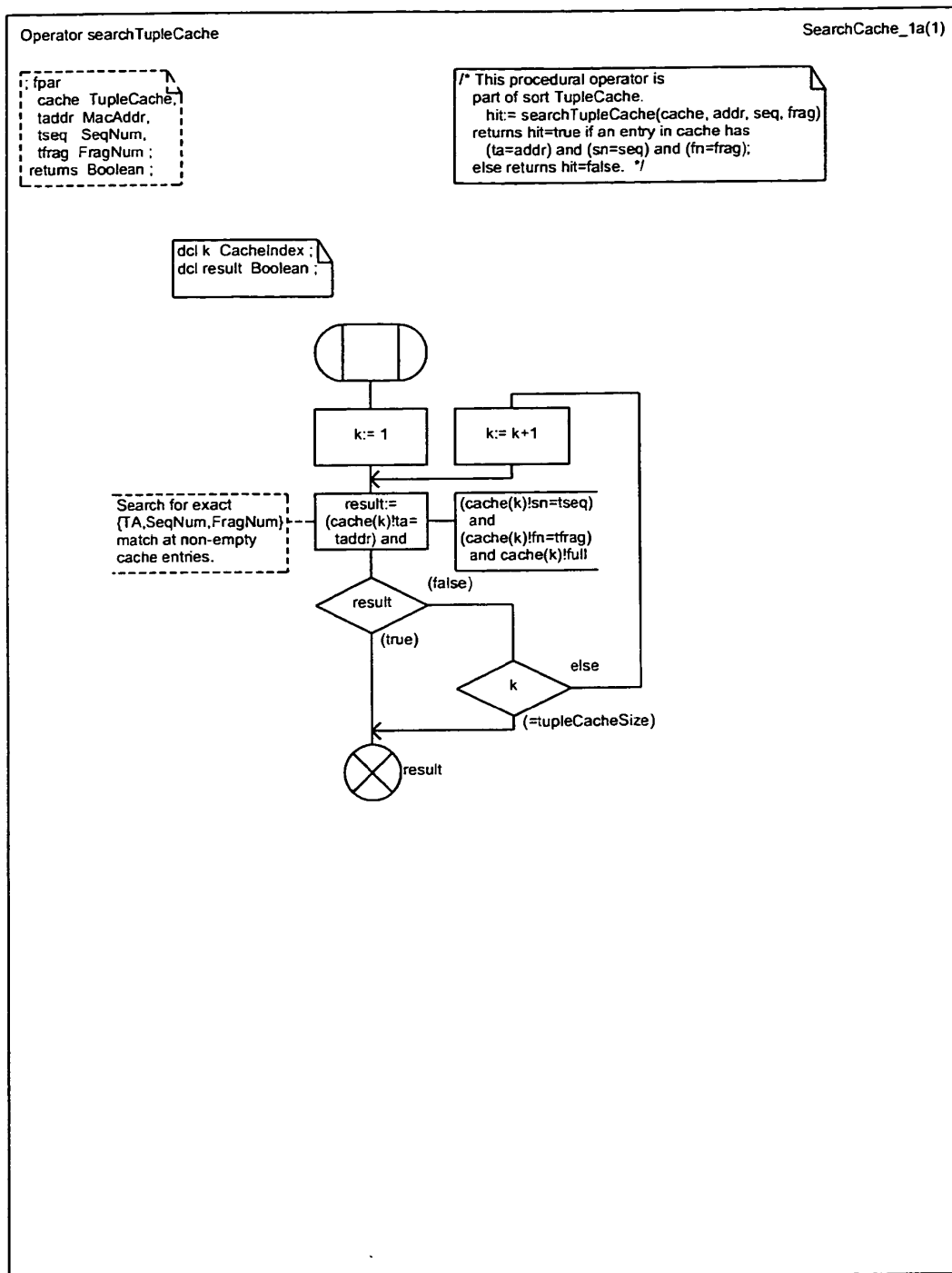
operator
clearTupleCacheoperator
searchTupleCacheoperator
updateTupleCache

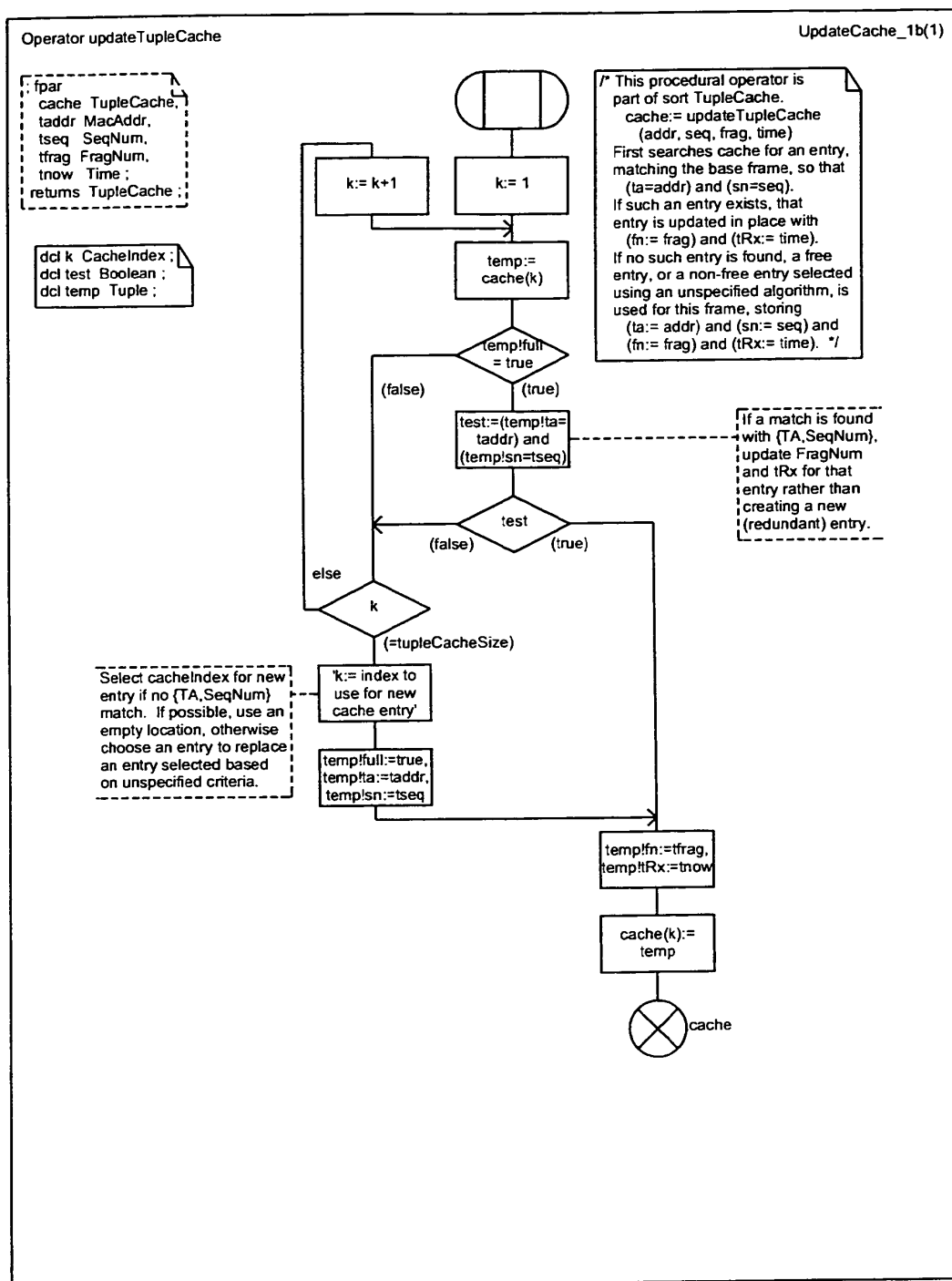
```

.....
* TupleCache support sorts
...../
/* Number of TupleCache entries and associated index range */
synonym tupleCacheSize Integer = 32; /* this value is an example.
/* TupleCache size is implementation dependent */
syntype CacheIndex = Integer constants 1:tupleCacheSize
endsyntype CacheIndex;
/* TupleCache array */
/* cache:= ClearTupleCache(cache) to initialize cache */
/* cache:= UpdateTupleCache(cache, addr, seq, frag, endRx) */
/* if <addr,seq> is already cached, updates frag */
/* if <addr,seq> not cached, fills an empty entry */
/* or replaces an entry using an unspecified algorithm */
/* SearchTupleCache(cache, addr, seq, frag) */
/* returns true if specified <addr,seq,frag> in cache */
newtype TupleCache Array( CacheIndex, Tuple);
adding operators
ClearTupleCache : TupleCache -> TupleCache;
SearchTupleCache : TupleCache, MacAddr, SeqNum, FragNum -> Boolean;
UpdateTupleCache : TupleCache, MacAddr, SeqNum, FragNum, Time ->
TupleCache;
operator ClearTupleCache;
fpar cache TupleCache; returns TupleCache; referenced;
operator SearchTupleCache;
fpar cache TupleCache, taddr MacAddr, tseq SeqNum, tfrag FragNum;
returns Boolean; referenced;
operator UpdateTupleCache;
fpar cache TupleCache, taddr MacAddr, tseq SeqNum, tfrag FragNum,
tnow Time; returns TupleCache; referenced;
endnewtype TupleCache;

```









Package macsorts

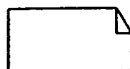
3112_d\Counter(31)

```

-----
*      32-bit Counter sort and Integer string sort
-----
/* This sort used for MIB counters, needed because SDL Integers */
/* have no specified maximum value. inc(counter) increments the */
/* counter value by 1, with wraparound from (2^32)-1 to 0. */

newtype Counter32 inherits Integer operators all;
adding operators
inc : Counter32 -> Counter32;
axioms
for all c in Counter32 (
  c < 4294967295 ==> inc(c) == c + 1;
  c >= 4294967295 ==> inc(c) == 0; );
endnewtype Counter32;
/* String (1-origin) of Integer */
newtype Intstring String( Integer, noInt); endnewtype Intstring;

```

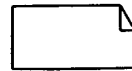
Package macsorts

3113_d1Queue(31)

```

Generator for Queue sorts
-----
/* The Queue generator is derived from the String0 generator */
/* to create Queues of any sort. Queues operators are: */
/* Qfirst(queue,item) adds item as the first queue element */
/* Qlast(queue,item) adds item as the last queue element */
/* and the String0 operators Length, //, First, Last, Head, Tail */
/* Because operators can only return a single value, removing an */
/* element from a queue is a 2-step process: */
/* dequeue first: item:=First(queue); queue:=Tail(queue); */
/* dequeue last: item:=Last(queue); queue:=Head(queue); */
generator Queue(type Item, literal Emptyqueue)
literals Emptyqueue;
operators
MkQ : Item -> Queue; /* make a queue from an item */
Length : Queue -> Integer; /* number of items on queue */
First : Queue -> Item; /* first item on queue */
Qfirst : Queue,Item -> Queue; /* add item as first on queue */
Tail : Queue -> Queue; /* all but first item on queue */
Last : Queue -> Item; /* last item on queue */
Qlast : Queue,Item -> Queue; /* add item as last on queue */
head : Queue -> Queue; /* all but last item on queue */
"/" : Queue, Queue -> Queue; /* concatenation */
Extract! : Queue,Integer -> Item; /* copy item from queue */
Modify! : Queue,Integer,Item -> Queue; /* modify item in queue */
SubQ : Queue,Integer,Integer -> Queue;
/* SubQ(q,i,j) queue of length j starting from queue(i) */
axioms
for all item0 in Item( for all q, q1, q2, q3 in Queue(
for all i, j in Integer(
/* constructors are Emptyqueue, MkQueue, and "/"; */
/* equalities between constructor terms */
q // Emptyqueue == q; Emptyqueue // q == q;
(q1 // q2) // q3 == q1 // (q2 // q3);
/* definition of Length by applying it to all constructors */
type Queue Length(Emptyqueue) == 0;
type Queue Length(MkQueue(item0)) == 1;
type Queue Length(q1 // q2) == Length(q1) + Length(q2);
/* definition of Extract! by applying it to all constructors, */
Extract!(MkQueue(item0), 0) == item0;
i < Length(q1) ==> Extract!(q1 // q2, i) == Extract!(q1, i);
i >= Length(q1) ==> Extract!(q1 // q2, i) == Extract!(q2, i - Length(q1));
i < 0 or i >= Length(q) ==> Extract!(q, i) == error!;
/* definition of First and Last by other operations */
First(q) == Extract!(q, 0); Last(q) == Extract!(q, Length(q) - 1);
/* definition of SubQ(q,i,j) by induction on j. */
i >= 0 and i <= Length(q) ==> SubQ(q, i, 0) == Emptyqueue;
i >= 0 and j > 0 and i + j <= Length(q) ==> SubQ(q, i, j) ==
SubQ(q, i, j - 1) // MkQueue(Extract!(q, i + j - 1));
i < 0 or j < 0 or i + j > Length(q) ==> SubQ(q,i,j) == error!;
/* define Modify!, Head, Tail, Qfirst, Qlast by other ops */
Modify!(q, i, item0) == SubQ(q, 0, i) //
MkQueue(item0) // SubQ(q, i + 1, Length(q) - i - 1);
head(q) == SubQ(q, 0, Length(q) - 1);
Tail(q) == SubQ(q, 1, Length(q) - 1);
Qfirst(q, item0) == MkQueue(item0) // q;
Qlast(q, item0) == q // MkQueue(item0); )))
endgenerator Queue;

```



Package macsorts

3114_dFragment(31)

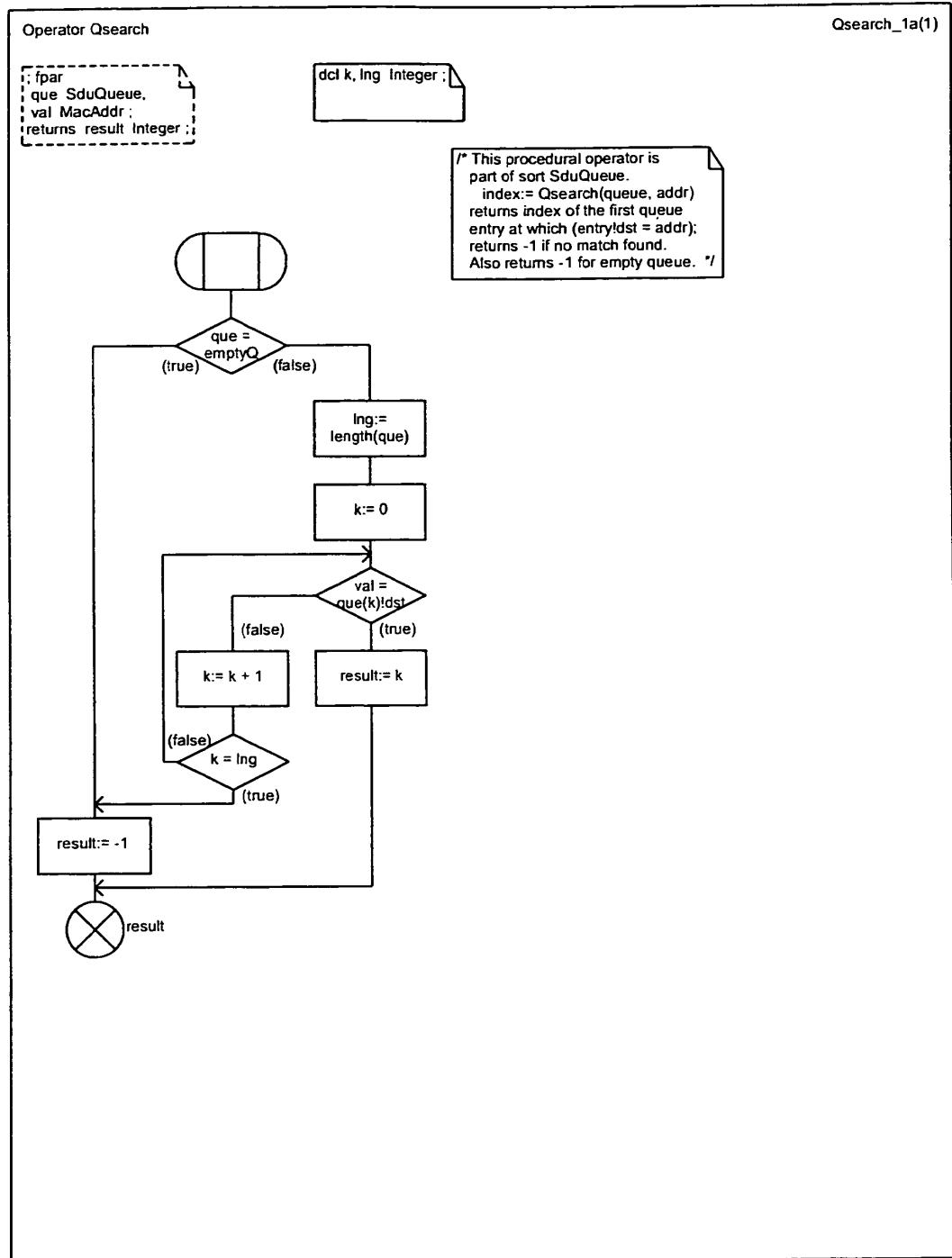


operator
qSearch

```

-----
*
Fragmentation support sorts
-----
/* Array to hold up to FragNum fragments of an Msdu/Mmpdu */
newtype FragArray Array(FragNum, Frame); endnewtype FragArray;
/* FragSdu structure is for OUTGOING MSDUs/MMPDUs (called SDUs) */
/* Each SDU, even if not fragmented, is held in an instance of */
/* this structure awaiting its (re)transmission attempt(s). */
/* Transmit queue(s) are ordered lists of FragSdu instances. */
newtype FragSdu struct
  fTot FragNum; /* number of fragments in pdu FragArray */
  fCur FragNum; /* next fragment number to send */
  fAnc FragNum; /* next fragment to announce in ATIM or TIM
    when fAnc > fCur, pdu(fCur)+ may be sent */
  eol Time; /* set to (now + dUsec(aMaxTxMsdLifetime))
    when the entry is created */
  sqf SeqNum; /* SDU sequence number, set at 1st Tx attempt */
  src Integer; /* short retry counter for this SDU */
  lrc Integer; /* long retry counter for this SDU */
  dst MacAddr; /* destination address */
  grpa Boolean; /* =true if RA (not DA) is a group address */
  psm Boolean; /* =true if RA (not DA) may be in pwr_save */
  resume Boolean; /* =true if fragment burst being resumed */
  cnfTo Pld; /* address to which confirmation is sent */
  txrate Rate; /* data rate used for initial fragment */
  cf CfPriority; /* requested priority (from LLC) */
  pdu FragArray; /* array of Frame to hold fragments */
endnewtype FragSdu;
/* Queue of FragSdu */
/* for power save buffers, etc., searchable with Qsearch operator: */
/* index:= Qsearch(queue, addr) where queue is an SduQueue, */
/* index identifies the first queue entry at which */
/* entry!dst = addr; or as -1 if no match (or queue empty). */
newtype SduQueue Queue(FragSdu, emptyQ);
adding operators
  qSearch : SduQueue, MacAddr -> Integer;
operator qSearch;
  fpar que SduQueue, val MacAddr; returns Integer; referenced;
endnewtype SduQueue;

```





Package macsorts

3115_dDefragment(31)

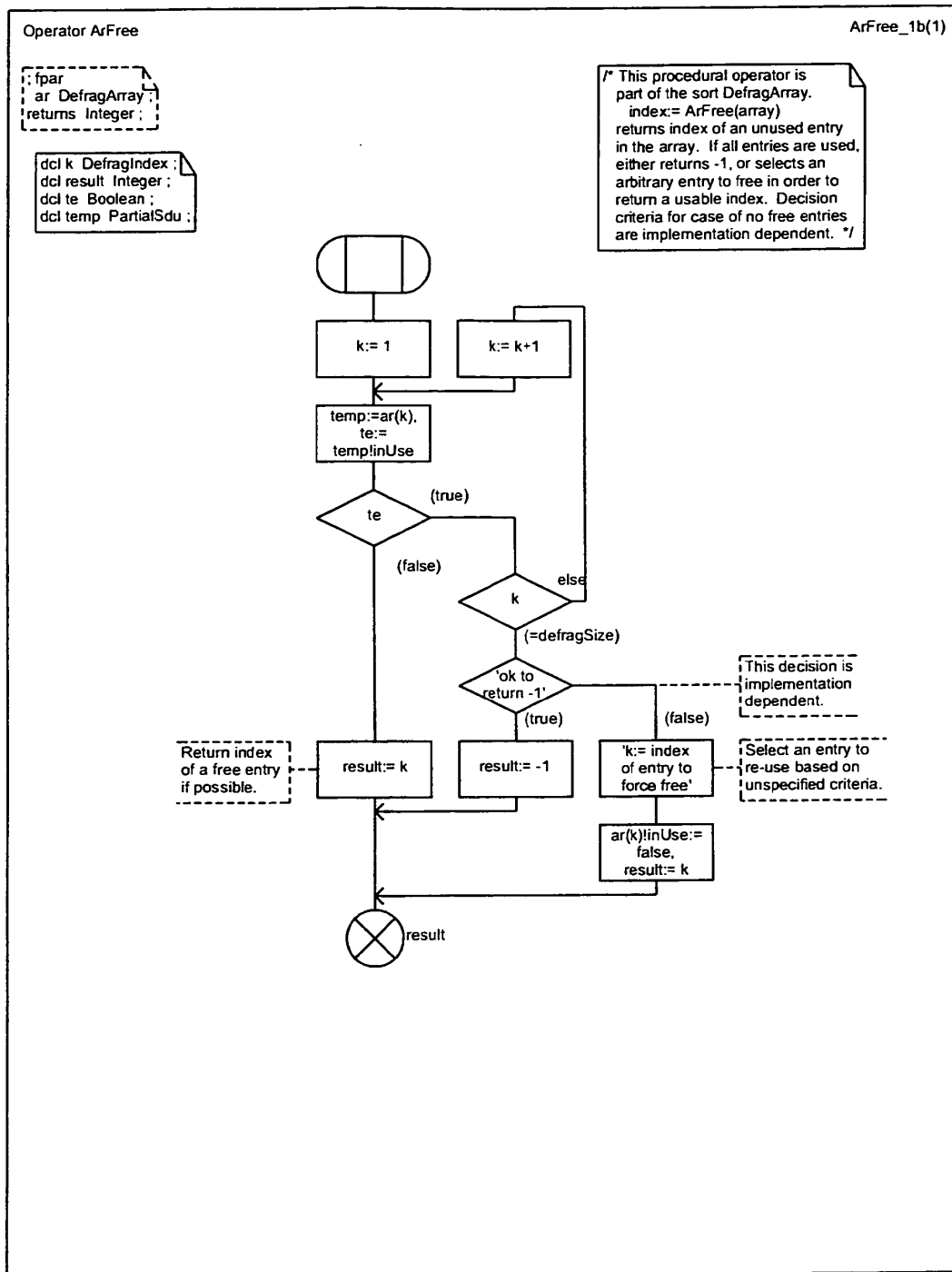
operator
ArAgeoperator
ArFreeoperator
ArSearch

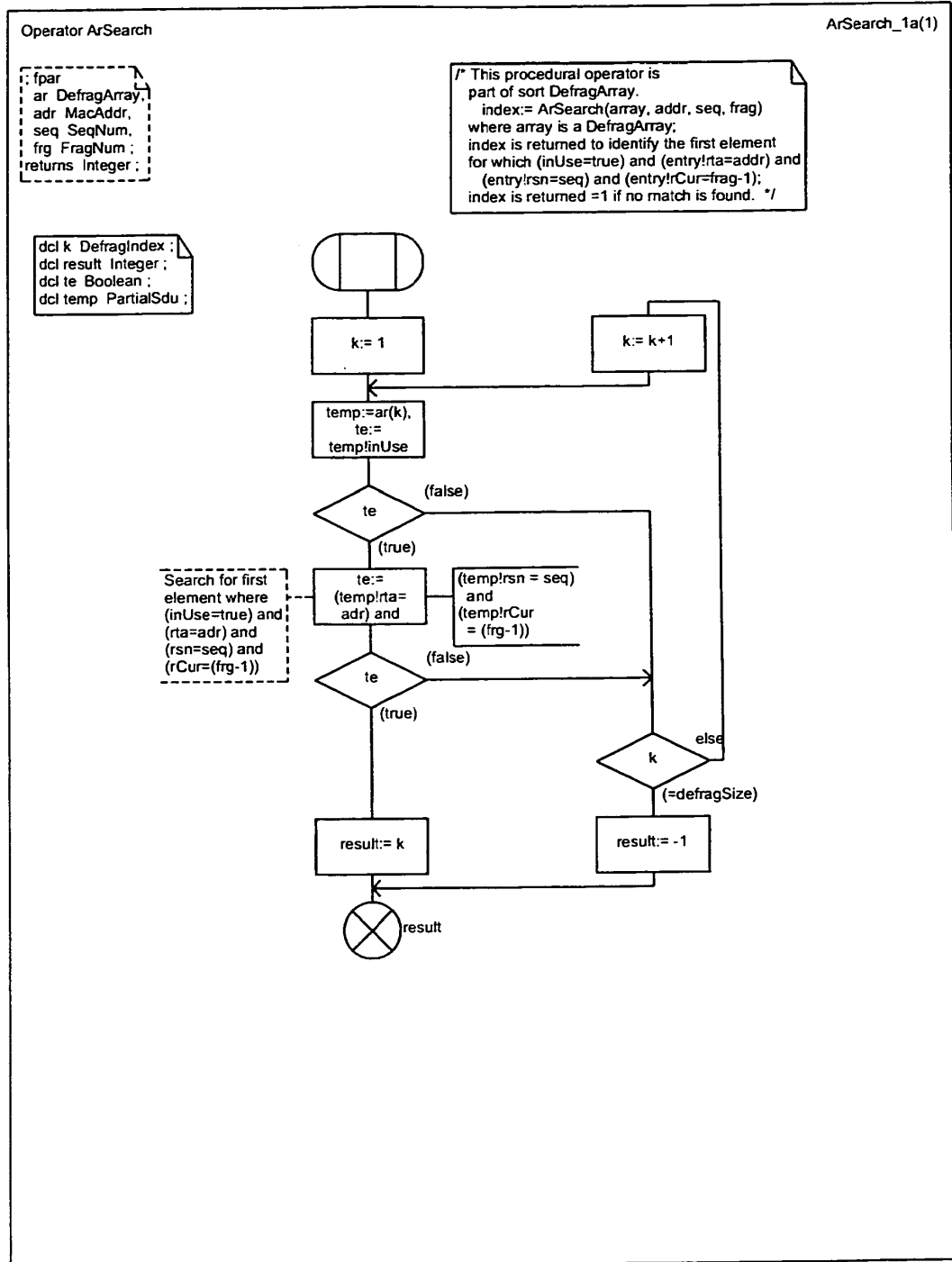
```

*****
*   Defragmentation support sorts
*****
/* The PartialSdu structure is for INCOMPLETE MSDUs/MMPDUs */
/* (generally SDUs) for which at least 1 fragment has been */
/* received. Unfragmented SDUs are reported upward immediately, */
/* and are never stored in instances of this structure. */
newtype PartialSdu struct
  inUse Boolean; /* =true if this instance holds any fragments */
  rta MacAddr; /* transmitting station (Addr2) */
  rsn SeqNum; /* SDU sequence number */
  rCur FragNum; /* fragment number of most recent Mpdus */
  reol Time; /* (now+dUse(aMaxReceiveLifetime) @ 1st Mpdus */
  rsdu Frame; /* buffer where Mpdus are concatenated */
  default (, false, nullAddr, 0, 0, 0, null.);
endnewtype PartialSdu;
newtype PartialSduKeys struct /* if aPrivacyOptionImplemented=true */
  wDefKeys KeyVector; /* default keys when 1st frag received */
  wKeyMap KeyMapArray; /* key mappings when 1st frag received */
  wExclude Boolean; /* aExcludeUnencrypted @ 1st frag rx */
endnewtype PartialSduKeys;
/* Number of entries in defragmentation array at this station. */
/* The value is implementation dependent (min=3, see 9.5). */
synonym defragSize Integer = 6;
syntype defragIndex = Integer constants 1: defragSize
endsyntype defragIndex;
/* Array of PartialSdu for use defragmenting Msdus and Mmpdus. */
/* Searchable using the ArSearch operator */
/* index:= ArSearch(array, addr, seq, frag) */
/* where index is returned to identify the first element for which */
/* ((inUse = true) and (entry.rta = addr) and (entry.rsn = seq) */
/* and (entry.rCur = (frag-1)); or as =1 if no match found. */
/* index:= ArFree(array) returns the index of a free entry, */
/* or -1 if no entries free. May free an entry, selected using */
/* an unspecified algorithm, to avoid returning -1. */
/* array:= ArAge(array, age) */
/* frees where (entry.reol < age), also used to clear array. */
newtype DefragArray Array( defragIndex, PartialSdu);
adding operators
  ArSearch : DefragArray, MacAddr, SeqNum, FragNum -> Integer;
  ArFree : DefragArray -> Integer;
  ArAge : DefragArray, Time -> DefragArray;
operator ArSearch;
  fpar ar DefragArray, adr MacAddr, seq SeqNum, frg FragNum;
  returns Integer; referenced;
operator ArFree; fpar ar DefragArray; returns Integer; referenced;
operator ArAge; fpar ar DefragArray, age Time;
  returns DefragArray; referenced;
endnewtype DefragArray;
newtype DefragKeysArray Array( defragIndex, PartialSduKeys);
endnewtype DefragKeysArray;

```









Package macsorts
3116_d\Crc_Wep(31)

operator
crc32

```

* CRC-32 sorts (for FCS and ICV)
-----
/* Crc is a subtype of Octetstring with added operators: */
/* crc:= Crc32(crc,octet) */
/* updates the crc value to include the new octet, and */
/* Mirror(crc), which returns a Crc value with the order */
/* of the octets, and of the bits in each octet, reversed for */
/* MSb-first transmission (see 7.1.1). Crc variables must have */
/* exactly 4 octets, which is done using initCrc or S4. */
newtype Crc inherits Octetstring operators all;
adding operators
  Crc32 : Crc, Octet -> Crc;
  mirror : Crc -> Octetstring;
operator Crc32: fpar crcin Crc, val Octet; returns Crc; referenced;
axioms for all c in Crc{
  mirror(c) == S4(flip(c(3)),flip(c(2)),flip(c(1)), flip(c(0))); };
endnewtype Crc;
synonym initCrc Crc = /* Initial Crc value (all 1s) */
  << type Crc>> S4(0xFF,0xFF,0xFF,0xFF);
synonym goodCrc Crc = /* Unique remainder for valid CRC-32 */
  << type Crc>> S4(0x7B,0xDD,0x04,0xC7);

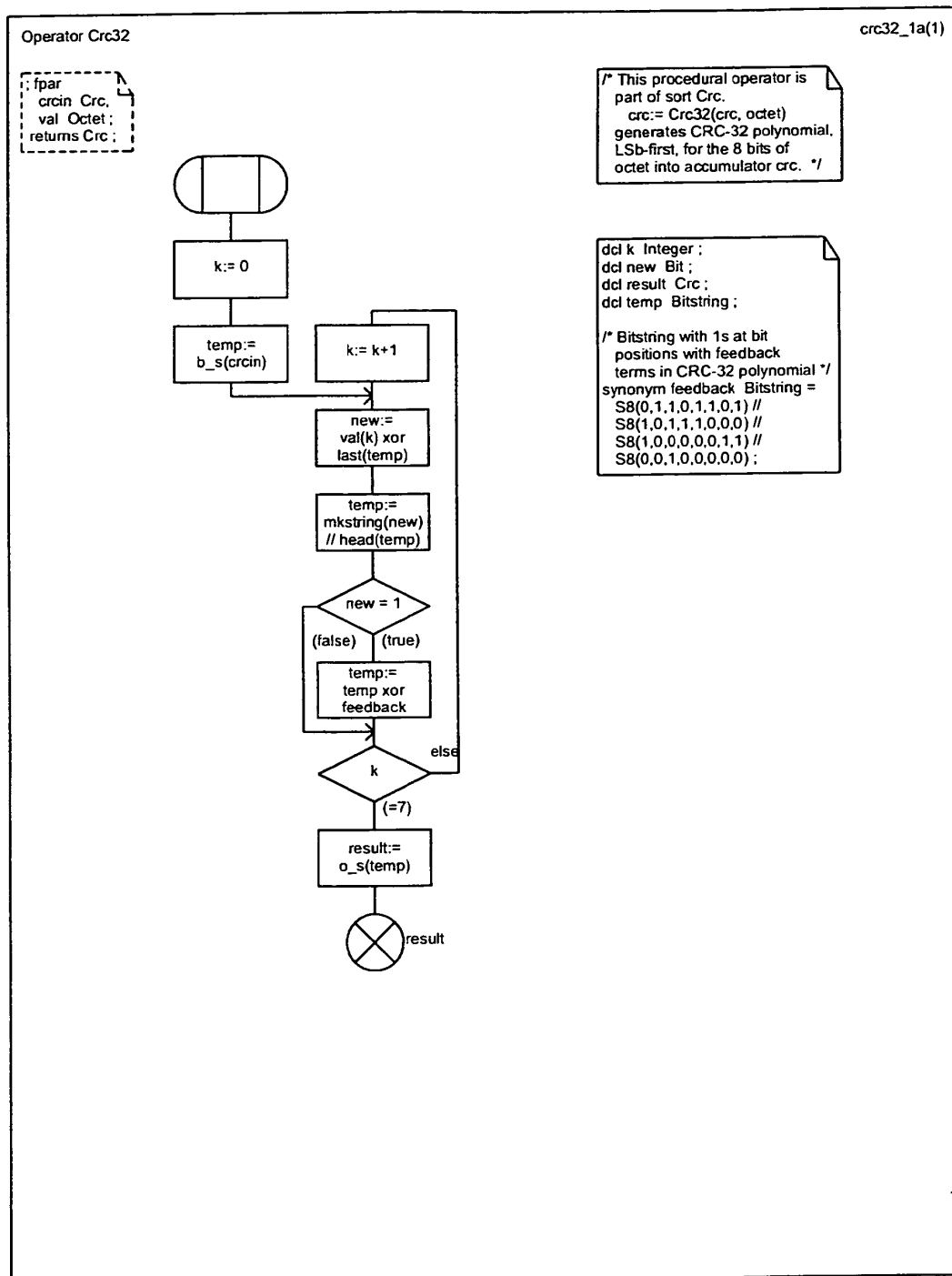
```

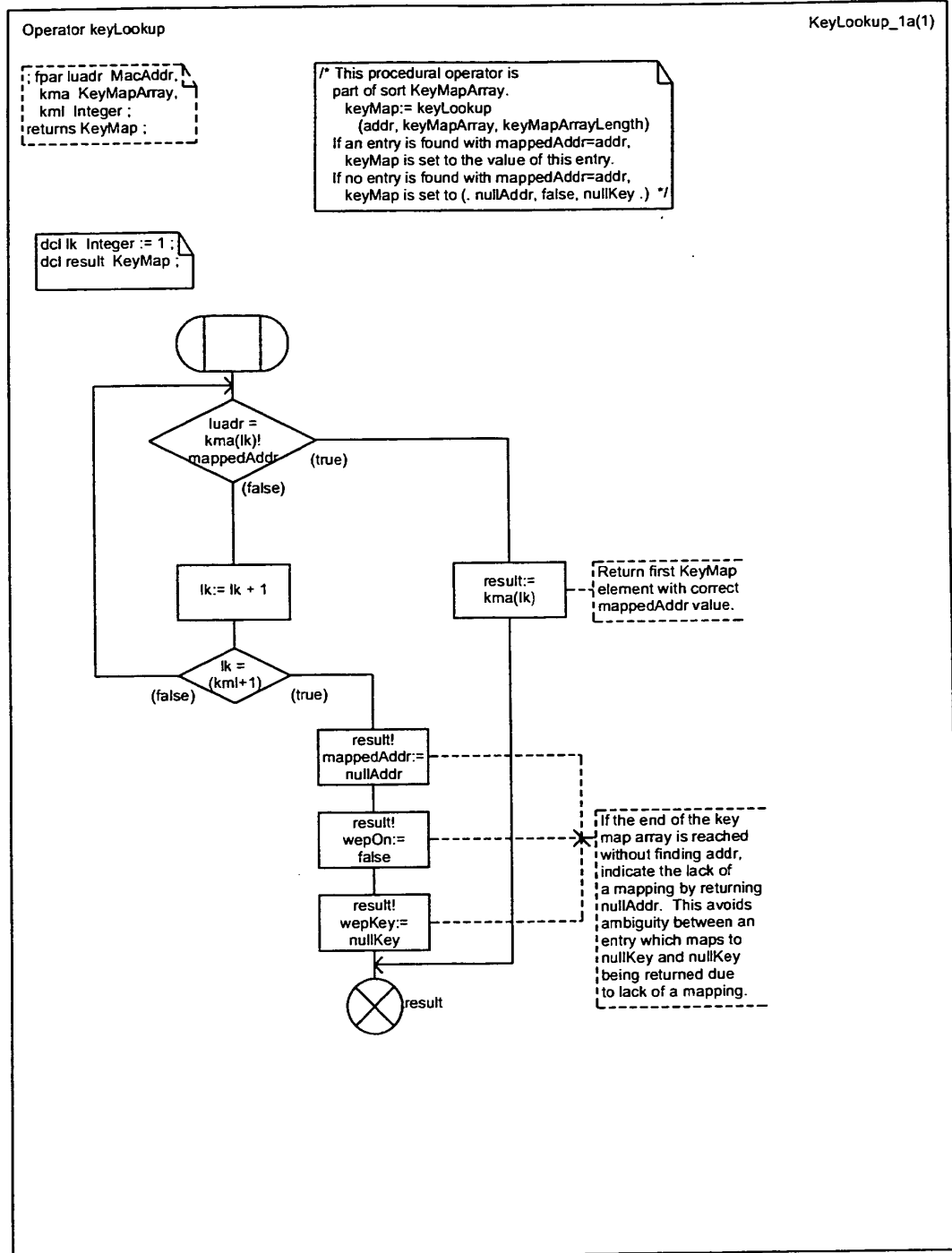
operator
keyLookup

```

* WEP support sorts
-----
syntype KeyIndex = Integer constants 0:3 endsyntype KeyIndex;
newtype PmgKey inherits Octetstring operators all;
adding literals nullKey; /* nullKey is not any of 2^40 key values */
axioms nullKey == null; default nullKey; endnewtype PmgKey;
newtype KeyVector /* vector of default WEP keys */
  Array( KeyIndex, PmgKey); endnewtype KeyVector;
/* Number of entries in aWepKeyMappings array at this station.
/* implementation dependent value, minimum=10 (see 8.3.2). */
synonym sWepKeyMappingLength Integer = 10;
syntype KeyMappingRange = Integer
  constants 1:sWepKeyMappingLength endsyntype KeyMappingRange;
newtype KeyMap struct /* structure used for entries in KeyMapArray */
  mappedAddr MacAddr;
  wepOn Boolean;
  wepKey PmgKey;
endnewtype KeyMap;
/* KeyMapArray -- used for aWepKeyMapping table; */
/* an array of KeyMap indexed by KeyMappingRange, with operator */
/* KeyMap := keyLookup(addr, keyMapArray, keyMapArrayLength) */
/* returns the KeyMap entry for the specified addr, or */
/* (. nullAddr, false, nullKey .) if no mapping for addr. */
newtype KeyMapArray Array( KeyMappingRange, KeyMap);
adding operators
  keyLookup : MacAddr, KeyMapArray, Integer -> KeyMap;
operator keyLookup;
  fpar luadr MacAddr, kma KeyMapArray, kml Integer;
  returns KeyMap; referenced;
endnewtype KeyMapArray;

```





Package macsorts

3117_dIFrame_1(31)

```

/*
 * FRAME sort (the basic definition of fields in MAC frames)
 */
/* Frame is a subtype of Octetstring with operators for creating
 * MAC headers, extracting each of the header fields and some
 * management frame fields, and modifying most of these fields.
 * There are operators to create and extract management frame
 * elements, but no operators for the frame body, IV, ICV, and FCS
 * fields, which are handled directly as Octetstrings. */
newtype Frame inherits Octetstring operators all;
adding operators
mkFrame : TypeSubtype, MacAddr, MacAddr, Octetstring -> Frame;
mkCtl : TypeSubtype, Octetstring, MacAddr -> Frame;
protocolVer : Frame -> Integer; /* Protocol version (2 bits) */
basetype : Frame -> BasicType; /* Type field (2 bits) */
ftype : Frame -> TypeSubtype; /* Type & Subtype (6 bits) */
setType : Frame, TypeSubtype -> Frame;
toDs : Frame -> Bit; /* To DS bit (1 bit) */
setToDs : Frame, Bit -> Frame;
frDs : Frame -> Bit; /* From DS bit (1 bit) */
setFrDs : Frame, Bit -> Frame;
moreFrag : Frame -> Bit; /* More Fragments bit (1 bit) */
setMoreFrag : Frame, Bit -> Frame;
retryBit : Frame -> Bit; /* Retry bit (1 bit) */
setRetryBit : Frame, Bit -> Frame;
pwrMgt : Frame -> Bit; /* Power Management bit (1 bit) */
setPwrMgt : Frame, Bit -> Frame;
moreData : Frame -> Bit; /* More Data bit (1 bit) */
setMoreData : Frame, Bit -> Frame;
wepBit : Frame -> Bit; /* WEP bit (1 bit) */
setWepBit : Frame, Bit -> Frame;
orderBit : Frame -> Bit; /* (strictly)Order(ed) (1 bit) */
setOrderBit : Frame, Bit -> Frame;
durId : Frame -> Integer; /* Duration/ID field (2) */
setDurId : Frame, Integer -> Frame;
addr1 : Frame -> MacAddr; /* Address 1 [DA/RA] field (6) */
setAddr1 : Frame, MacAddr -> Frame;
addr2 : Frame -> MacAddr; /* Address 2 [SA/TA] field (6) */
setAddr2 : Frame, MacAddr -> Frame;
addr3 : Frame -> MacAddr; /* Address 3 [Bss/DA/SA] field */
setAddr3 : Frame, MacAddr -> Frame;
addr4 : Frame -> MacAddr; /* Address 4 [WDS-SA] field (6) */
insAddr4 : Frame, MacAddr -> Frame;
seq : Frame -> SeqNum; /* Sequence Number (12 bits) */
setSeq : Frame, SeqNum -> Frame;
frag : Frame -> FragNum; /* Fragment Number (4 bits) */
setFrag : Frame, FragNum -> Frame;
ts : Frame -> Time; /* Timestamp field (8) */
setTs : Frame, Time -> Frame;
mkElem : ElementID, Octetstring -> Frame; /* make element */
GetElem : Frame, ElementID -> Frame; /* get element if avail */
status : Frame -> StatusCode; /* Status Code field (2) */
setStatus : Frame, StatusCode -> Frame;
authStat : Frame -> StatusCode; /* Status Code in Auth frame */
reason : Frame -> ReasonCode; /* Reason Code field (2) */

/* Frame operators continued on next page ... */

```

operator
getElem

Gets element
from body of
Management
frame. If the
target element
is not present
an Octetstring
of length zero
is returned.



Package macrosorts 3118_dVFrame_2(31)

```

/* ...Frame Sort Operators continued */
authSeqNum : Frame -> Integer; /* Auth Sequence Number (2) */
authAlg : Frame -> AuthType; /* Auth Algorithm field (2) */
beaconInt : Frame -> TU; /* Beacon Interval field (2) */
listenInt : Frame -> TU; /* Listen Interval field (2) */
Aid : Frame -> AsocId; /* Association ID field (2) */
setAid : Frame, AsocId -> Frame;
curApAddr : Frame -> MacAddr; /* Current AP Addr field (6) */
capA : Frame, Capability -> Bit; /* Capability (Re)Asoc */
setCapA : Frame, Capability, Bit -> Frame;
capB : Frame, Capability -> Bit; /* Capability Bcn/Probe */
setCapB : Frame, Capability, Bit -> Frame;
keyId : Frame -> KeyIndex; /* Key ID subfield (2 bits) */
setKeyId : Frame, KeyIndex -> Frame;
operator GetElem;
fpar fr Frame, el ElementID; returns Frame; referenced;

/* Frame Sort Axioms */
axioms
for all f in Frame( for all a, sa, da, ra, ta, bssa in MacAddr(
for all body, dur, sid, info in Octetstring(
addr1(f) == SubStr(f,4,6);
setAddr1(f,a) == SubStr(f,0,4) // a // SubStr(f,10,Length(f)-10);
addr2(f) == SubStr(f,10,6);
setAddr2(f,a) == SubStr(f,0,10) // a // SubStr(f,16,Length(f)-16);
addr3(f) == SubStr(f,16,6);
setAddr3(f,a) == SubStr(f,0,16) // a // SubStr(f,22,Length(f)-22);
addr4(f) == SubStr(f,24,6);
insAddr4(f,a) == SubStr(f,0,24) // a // SubStr(f,24,Length(f)-24);
curApAddr(f) == SubStr(f,28,6);
for all ft in TypeSubtype(
mkFrame(ft, da, bssa, body) ==
ft // O3 // da // dot11MacAddress // bssa // O2 // body;
(ft = rts) ==> mkCtl(ft, dur, ra) ==
ft // O1 // dur // ra // aStationID;
(ft = ps_poll) ==> mkCtl(ft, sid, bssa) ==
ft // O1 // sid // bssa // aStationID;
(ft = cts) or (ft = ack) ==> mkCtl(ft, dur, ra) ==
ft // O1 // dur // ra;
(ft = cfend) or (ft = cfend_ack) ==> mkCtl(ft, bssa, ra) ==
ft // O3 // ra // bssa;
ftype(f) == MkString(f(0) and 0xFC);
setFtype(f, ft) == Modify(f, 0, MkString((f(0) and 0x03) or
ft)); );
for all bt in BaseType( basetype(f) == f(0) and 0x0C; );
for all i in Integer(
protocolVer(f) == octetVal(f(0) and 0x03);
authSeqNum(f) == octetVal(f(26)) + (octetVal(f(27)) * 256);
durId(f) == octetVal(f(2)) + (octetVal(f(3)) * 256);
setDurId(f, i) == SubStr(f, 0, 2) // mkOS(i mod 256, 1) //
mkOS(i / 256, 1) // SubStr(f, 4, Length(f) - 4); );
for all e in ElementID(
mkElem(e, info) == e // mkOS(Length(info) + 2, 1) // info; );

/* Frame Sort Axioms continued on next page ... */

```

Package macsorts

3119_d1Frame_3(31)

```

/* ... Frame Sort Axioms continued */
for all b in Bit(
  toDs(f) == if (f(1) and 0x01) then 1 else 0 fi;
  setToDs(f, b) ==
    Modify!(f, 1, (f(1) and 0xFE) or S8(0,0,0,0,0,0,b,0));
  frDs(f) == if (f(1) and 0x02) then 1 else 0 fi;
  setFrDs(f, b) ==
    Modify!(f, 1, (f(1) and 0xFD) or S8(0,0,0,0,0,0,b,0));
  moreFrag(f) == if (f(1) and 0x04) then 1 else 0 fi;
  setMoreFrag(f, b) ==
    Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,0,0,0,0,b,0));
  retryBit(f) == if (f(1) and 0x08) then 1 else 0 fi;
  setRetryBit(f, b) ==
    Modify!(f, 1, (f(1) and 0xF7) or S8(0,0,0,0,0,0,b,0));
  pwrMgt(f) == if (f(1) and 0x10) then 1 else 0 fi;
  setPwrMgt(f, b) ==
    Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,0,0,0,0,b,0));
  moreData(f) == if (f(1) and 0x20) then 1 else 0 fi;
  setMoreData(f, b) ==
    Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,b,0,0,0,0,0));
  wepBit(f) == if (f(1) and 0x40) then 1 else 0 fi;
  setWepBit(f, b) ==
    Modify!(f, 1, (f(1) and 0xFB) or S8(0,b,0,0,0,0,0,0));
  orderBit(f) == if (f(1) and 0x80) then 1 else 0 fi;
  setOrderBit(f, b) ==
    Modify!(f, 1, (f(1) and 0xFB) or S8(b,0,0,0,0,0,0,0));
  for all c in Capability(
    capA(f,c) == if (B_S(SubStr(f,24,2)) and c) then 1 else 0 fi;
    setCapA(f,c,b) == SubStr(f,0,24) // (B_S(SubStr(f,24,2) and
      (not c)) or (if b then c else 02 fi)) //
      SubStr(f,26,Length(f) - 26);
    capB(f,c) == if (B_S(SubStr(f,34,2)) and c) then 1 else 0 fi;
    setCapB(f,c,b) == SubStr(f,0,34) // (B_S(SubStr(f,34,2) and
      (not c)) or (if b then c else 02 fi)) //
      SubStr(f,36,Length(f) - 36); );
  for all sq in SeqNum(
    seq(f) == (octetVal(f(22) and 0xF0)/16)*(octetVal(f(23)*16));
    setSeq(f, sq) == SubStr(f, 0, 22) // MkString(((f(22) and 0xF0)
      or mkOctet((sq mod 16) * 16)) // mkOS(sq / 16, 1) //
      SubStr(f, 24, Length(f) - 24); );
  for all fr in FragNum(
    frag(f) == octetVal(f(22) and 0x0F);
    setFrag(f, fr) ==
      SubStr(f, 0, 22) // MkString(((f(22) and 0xF0) or
      mkOctet(fr)) // SubStr(f, 23, Length(f) - 23); );
  for all tm in Time(
    ts(f) == tUsec( Usec!(octetVal(f(24)) +
      (256 * (octetVal(f(25)) +
        (256 * (octetVal(f(26)) +
          (256 * (octetVal(f(27)) +
            (256 * (octetVal(f(28)) +
              (256 * (octetVal(f(29)) +
                (256 * (octetVal(f(30)) +
                  (256 * octetVal(f(31)))))))))))))) ) );

/* Frame Sort Axioms continued on next page ... */

```

Package macsorts

3120_dVFrame_4(31)

```

/* ... Frame Sort Axioms continued */
setTs(f, tm) == SubStr(f, 0, 24) // mkOS(fix(tm), 1) //
mkOS((fix(tm) / 256), 1) // mkOS((fix(tm) / 65536), 1) //
mkOS((fix(tm) / 16777216), 1) //
mkOS((fix(tm) / 4294967296), 1) //
mkOS((fix(tm) / 4294967296) / 256), 1) //
mkOS((fix(tm) / 4294967296) / 65536), 1) //
mkOS((fix(tm) / 4294967296) / 16777216), 1) //
SubStr(f, 32, Length(f) - 32);
for all stat in StatusCode(
  status(f) == SubStr(f, 26, 2);
  setStatus(f, stat) ==
    SubStr(f, 0, 26) // stat // SubStr(f, 28, Length(f) - 28);
  authStat(f) == SubStr(f, 28, 2); );
for all rea in ReasonCode( reason(f) == SubStr(f, 24, 2); );
for all alg in AuthType( AuthType(f) == SubStr(f, 24, 2); );
for all u in TU(
  beaconInt(f) == octetVal(f(32)) + (octetVal(f(33)) * 256);
  listenInt(f) == octetVal(f(26)) + (octetVal(f(27)) * 256); );
for all sta in AssocId(
  Aid(f) == octetVal(f(28)) + (octetVal(f(29)) * 256);
  setAid(f, sta) == SubStr(f, 0, 28) // mkOS(sta mod 256, 1) //
  mkOS(sta / 256, 1) // SubStr(f, 30, Length(f) - 30); );
for all kid in KeyIndexRange(
  keyId(f) == octetVal(f(27)) / 64;
  setKeyId(f, kid) == Modify!(f, 27, mkOS(kid * 64)); );
endnewtype Frame;

```

```

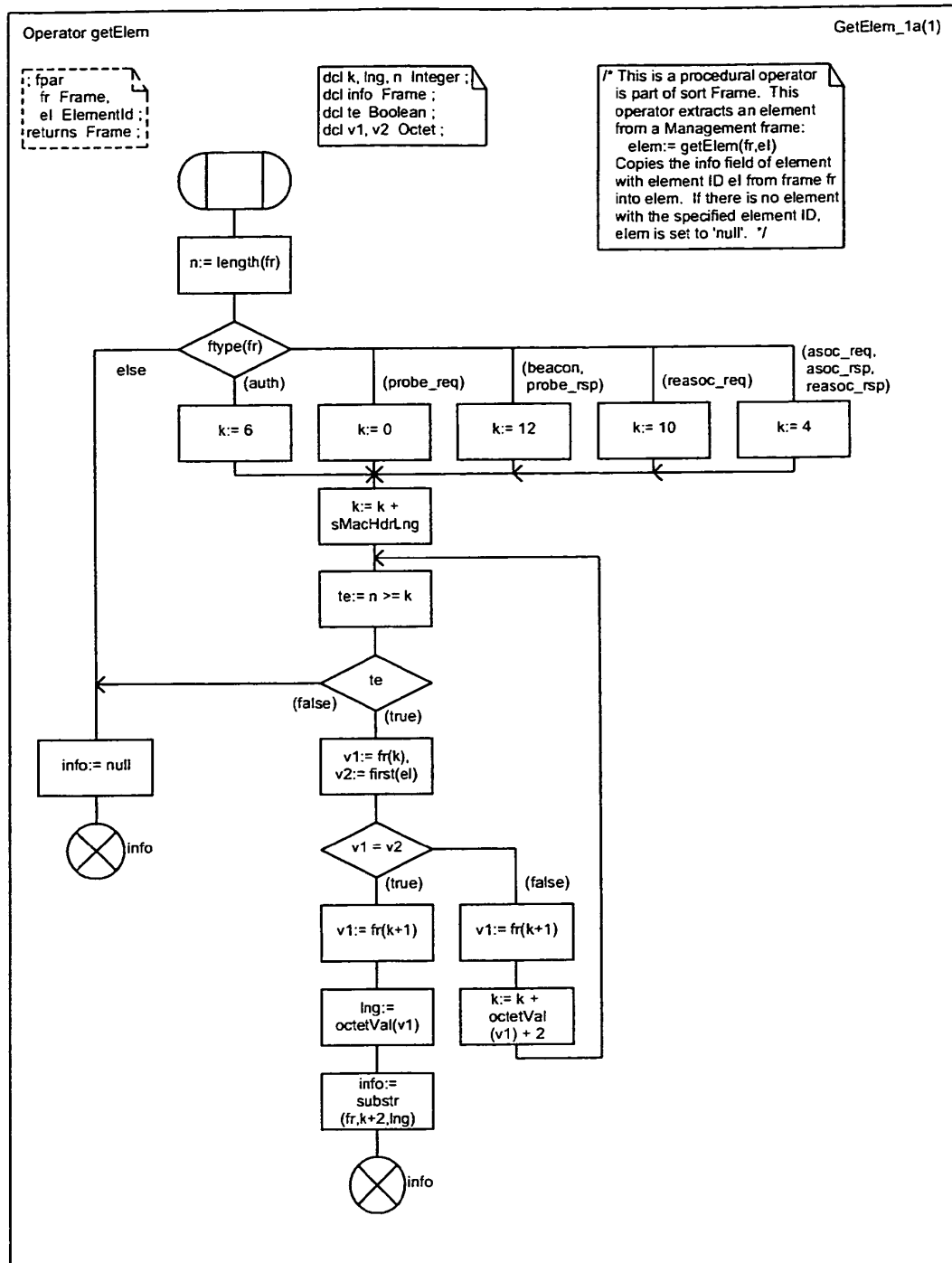
/* ReasonCode sort */
newtype ReasonCode inherits Octetstring operators all;
adding literals unspec_reason, auth_not_valid, deauth_lv_ss,
inactivity, ap_overload, class2_err, class3_err,
disas_lv_ss, asoc_not_auth;
axioms
  unspec_reason == mkOS(1, 2); auth_not_valid == mkOS(2, 2);
  deauth_lv_ss == mkOS(3, 2); inactivity == mkOS(4, 2);
  ap_overload == mkOS(5, 2); class2_err == mkOS(6, 2);
  class3_err == mkOS(7, 2); disas_lv_ss == mkOS(8, 2);
  asoc_not_auth == mkOS(9, 2);
endnewtype ReasonCode;

```

```

/* StatusCode sort */
newtype StatusCode inherits Octetstring operators all;
adding literals successful, unspec_fail, unsup_cap,
reasoc_no_asoc, fail_other, unsupt_alg, auth_seq_fail,
chlng_fail, auth_timeout, ap_full, unsup_rate;
axioms
  successful == mkOS(0, 2); unspec_failure == mkOS(1, 2);
  unsup_cap == mkOS(10, 2); reasoc_no_asoc == mkOS(11, 2);
  fail_other == mkOS(12, 2); unsupt_alg == mkOS(13, 2);
  auth_seq_fail == mkOS(14, 2); chlng_fail == mkOS(15, 2);
  auth_timeout == mkOS(16, 2); ap_full == mkOS(17, 2);
  unsup_rate == mkOS(18, 2);
endnewtype StatusCode;

```





Package macsorts

3121_d\FrameType(31)

```

*
*   Frame Type sorts
*   =====
/* TypeSubtype defines the full, 6-bit frame type identifiers. */
/* These values are useful with ftype operator of Frame sort. */
newtype TypeSubtype inherits Octetstring operators all;
adding literals asoc_req, asoc_rsp, reasoc_req, reasoc_rsp,
probe_req, probe_rsp, beacon, atim, disasoc, auth, deauth,
ps_poll, rts, cts, ack, cfend, cfend_ack, data, data_ack,
data_poll, data_poll_ack, null_frame, cfack, cfpoll, cfpoll_ack;
axioms
asoc_req == MkString(S8(0,0,0,0,0,0,0,0));
asoc_rsp == MkString(S8(0,0,0,0,1,0,0,0));
reasoc_req == MkString(S8(0,0,0,0,0,1,0,0));
reasoc_rsp == MkString(S8(0,0,0,0,1,1,0,0));
probe_req == MkString(S8(0,0,0,0,0,0,1,0));
probe_rsp == MkString(S8(0,0,0,0,1,0,1,0));
beacon == MkString(S8(0,0,0,0,0,0,0,1));
atim == MkString(S8(0,0,0,0,1,0,0,1));
disasoc == MkString(S8(0,0,0,0,0,1,0,1));
auth == MkString(S8(0,0,0,0,1,1,0,1));
deauth == MkString(S8(0,0,0,0,0,0,1,1));
ps_poll == MkString(S8(0,0,1,0,0,1,0,1));
rts == MkString(S8(0,0,1,0,1,1,0,1));
cts == MkString(S8(0,0,1,0,0,0,1,1));
ack == MkString(S8(0,0,1,0,1,0,1,1));
cfend == MkString(S8(0,0,1,0,0,1,1,1));
cfend_ack == MkString(S8(0,0,1,0,1,1,1,1));
data == MkString(S8(0,0,0,1,0,0,0,0));
data_ack == MkString(S8(0,0,0,1,1,0,0,0));
data_poll == MkString(S8(0,0,0,1,0,1,0,0));
data_poll_ack == MkString(S8(0,0,0,1,1,1,0,0));
null_frame == MkString(S8(0,0,0,1,0,0,1,0));
cfack == MkString(S8(0,0,0,1,1,0,1,0));
cfpoll == MkString(S8(0,0,0,1,0,1,1,0));
cfpoll_ack == MkString(S8(0,0,0,1,1,1,1,0));
endnewtype TypeSubtype;
/* BasicTypes defines the 2-bit frame type groups */
newtype BasicType inherits Bitstring operators all;
adding literals control, data, management, reserved;
axioms
control == S8(0,0,1,0,0,0,0,0); data == S8(0,0,0,1,0,0,0,0);
management == S8(0,0,0,0,0,0,0,0); reserved == S8(0,0,1,1,0,0,0,0);
endnewtype BasicType;

```




Package macsorts

3122_dWgmtFields(31)

```

* ElementID sort
-----/
newtype ElementID inherits Octetstring operators all;
adding literals eSsId, eSupRates, eFhParms, eDsParms,
eCfParms, eTim, elbParms, eCtext;
axioms
eSsId == mkOS(0, 1); /* service set identifier (0:32) */
eSupRates == mkOS(1, 1); /* supported rates (1:8) */
eFhParms == mkOS(2, 1); /* FH parameter set (5) */
eDsParms == mkOS(3, 1); /* DS parameter set (1) */
eCfParms == mkOS(4, 1); /* CF parameter set (6) */
eTim == mkOS(5, 1); /* Traffic Information Map (4:254) */
elbParms == mkOS(6, 1); /* IBSS parameter set (2) */
eCtext == mkOS(16, 1); /* challenge text (128, see 8.1.2.2) */
endnewtype ElementID;

```

```

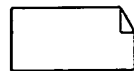
* Capability field bit assignments sort
-----/
newtype Capability inherits Bitstring operators all;
adding literals cEss, clbss, cPollable, cPollReq, cPrivacy;
axioms
cEss == S8(1,0,0,0,0,0,0,0) // 0x00; /* ESS capability */
clbss == S8(0,1,0,0,0,0,0,0) // 0x00; /* IBSS capability */
cPollable == S8(0,0,1,0,0,0,0,0) // 0x00; /* CF-pollable (sta), PC present (ap) */
cPollReq == S8(0,0,0,1,0,0,0,0) // 0x00; /* not CF poll req (sta), PC polls (ap) */
cPrivacy == S8(0,0,0,0,1,0,0,0) // 0x00; /* WEP required */
endnewtype Capability;

```

```

* IBSS parameter set sort
-----/
newtype IbssParms inherits Octetstring operators all;
adding operators
atimWin : IbssParms -> TU;
setAtimWin : IbssParms, TU -> IbssParms;
axioms
for all ib in IbssParms( for all u in TU(
atimWin(ib) == octetVal(ib(0)) + (octetVal(ib(1)) * 256);
setAtimWin(ib, u) == mkOS(u mod 256, 1) // mkOS(u / 256, 1); ));
endnewtype IbssParms;

```



Package macsorts

3123_dICF_And_AsocParams(31)



```

*
* CF parameter set sort
*
newtype CfParms inherits Octetstring operators all;
adding operators
  cfpCount : CfParms -> Integer; /* CfpCount field (1) */
  setCfpCount : CfParms, Integer -> CfParms;
  cfpPeriod : CfParms -> Integer; /* CfpPeriod field (1) */
  setCfpPeriod : CfParms, Integer -> CfParms;
  cfpMaxDur : CfParms -> TU; /* CfpMaxDuration field (2) */
  setCfpMaxDur : CfParms, TU -> CfParms;
  cfpDurRem : CfParms -> TU; /* CfpDurRemaining field (2) */
  setCfpDurRem : CfParms, TU -> CfParms;
  axioms for all cf in CfParms( for all i in Integer( for all u in TU(
    cfpCount(cf) == octetVal(cf(0));
    setCfpCount(cf, i) == mkOS(i, 1) // Tail(cf);
    cfpPeriod(cf) == octetVal(cf(1));
    setCfpPeriod(cf, i) == cf(0) // mkOS(i, 1) // SubStr(cf,2,4);
    cfpMaxDur(cf) == octetVal(cf(2)) + (octetVal(cf(3)) * 256);
    setCfpMaxDur(cf, u) == SubStr(cf, 0, 2) // mkOS(u mod 256, 1)
    // mkOS(u / 256, 1) // SubStr(cf, 4, 2);
    cfpDurRem(cf) == octetVal(cf(4)) + (octetVal(cf(5)) * 256);
    setCfpDurRem(cf, u) == SubStr(cf, 0, 4) // mkOS(u mod 256, 1)
    // mkOS(u / 256, 1); ));
endnewtype CfParms;

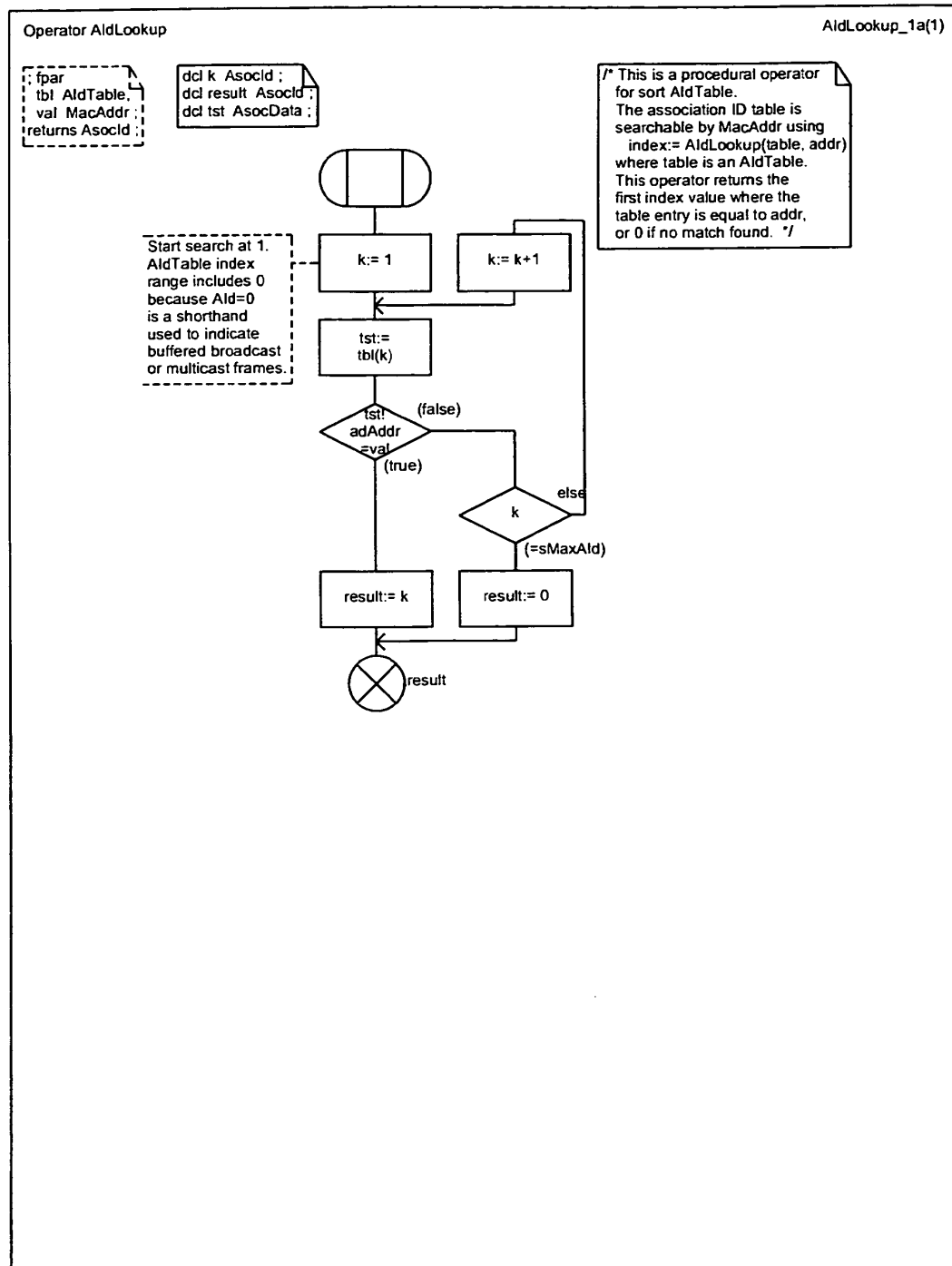
```

operator
AldLookup

```

*
* Sorts for association management at AP
*
synonym sMaxAld Integer = 2007; /* 2007 is largest allowable value */
/* implementation limit may be lower */
syntype AsocId = Integer constants 0:sMaxAld endsyntype AsocId;
/* Station Association Record -- only used at APs */
newtype AsocData struct
  adAddr MacAddr; /* address of associated station */
  adPsm PwrSave; /* power save mode of the station */
  adCfPoll Boolean; /* true if station is CfPollable */
  adPollRq Boolean; /* true if station requested polling */
  adNoPoll Boolean; /* true if station requested no polling */
  adMsduIP Boolean; /* true if partial Msdu outstanding to sta */
  adAuth AuthType; /* authentication type used by station */
  adRates RateSet; /* supported rates from association request */
  adAge Time; /* time of association */
endnewtype AsocData;
/* Association table -- array of AsocData, only used at APs */
/* index:= AldLookup(table, addr) */
/* returns the index of location where table(x).adAddr=addr */
/* or 0 if no such location found. */
newtype AldTable Array(AsocId, AsocData);
adding operators
  AldLookup : AldTable, MacAddr -> AsocId;
operator AldLookup;
fpar tbl AldTable, val MacAddr; returns AsocId; referenced;
endnewtype AldTable;

```





Package macsorts

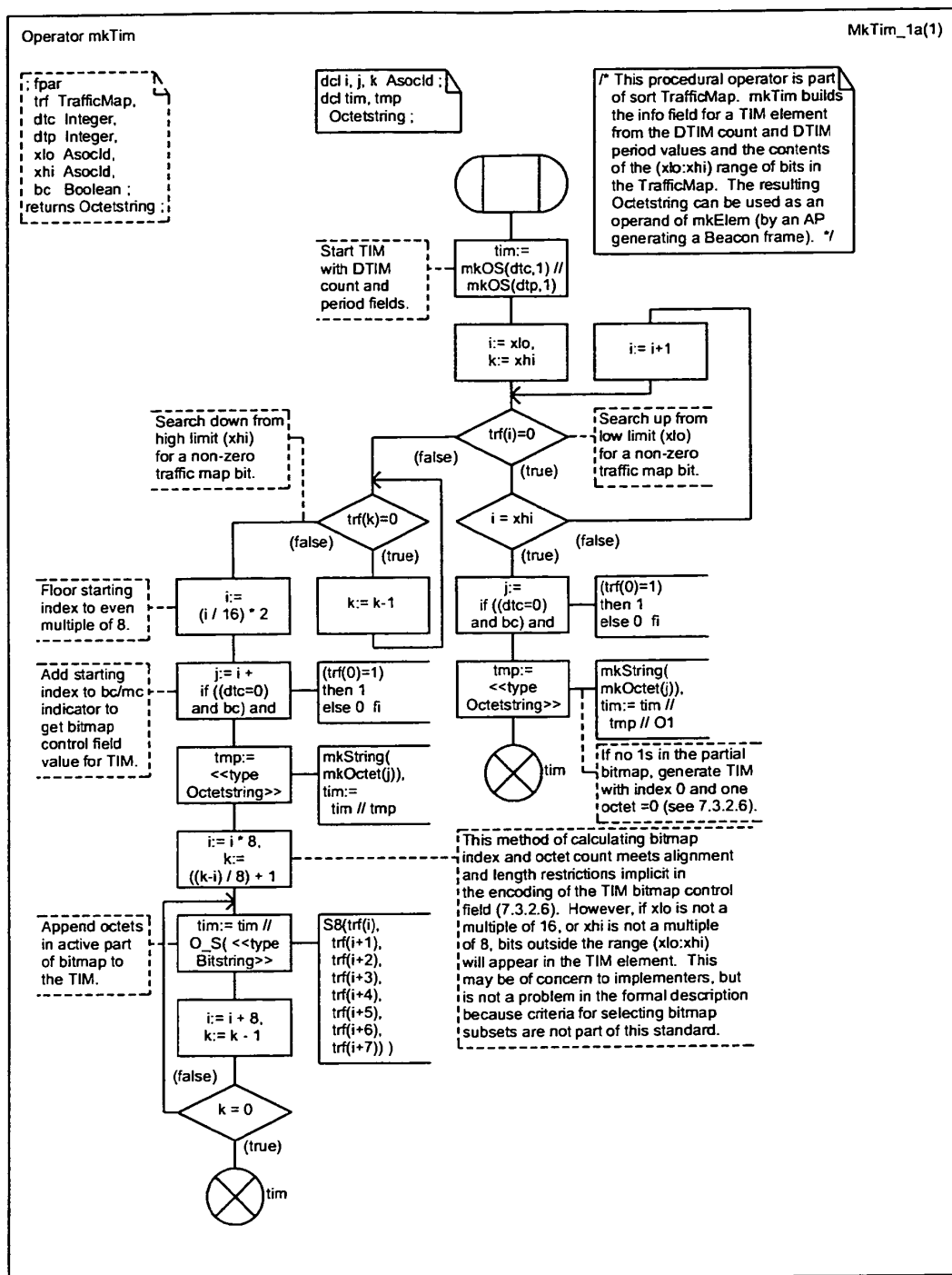
3124_dTIM(31)

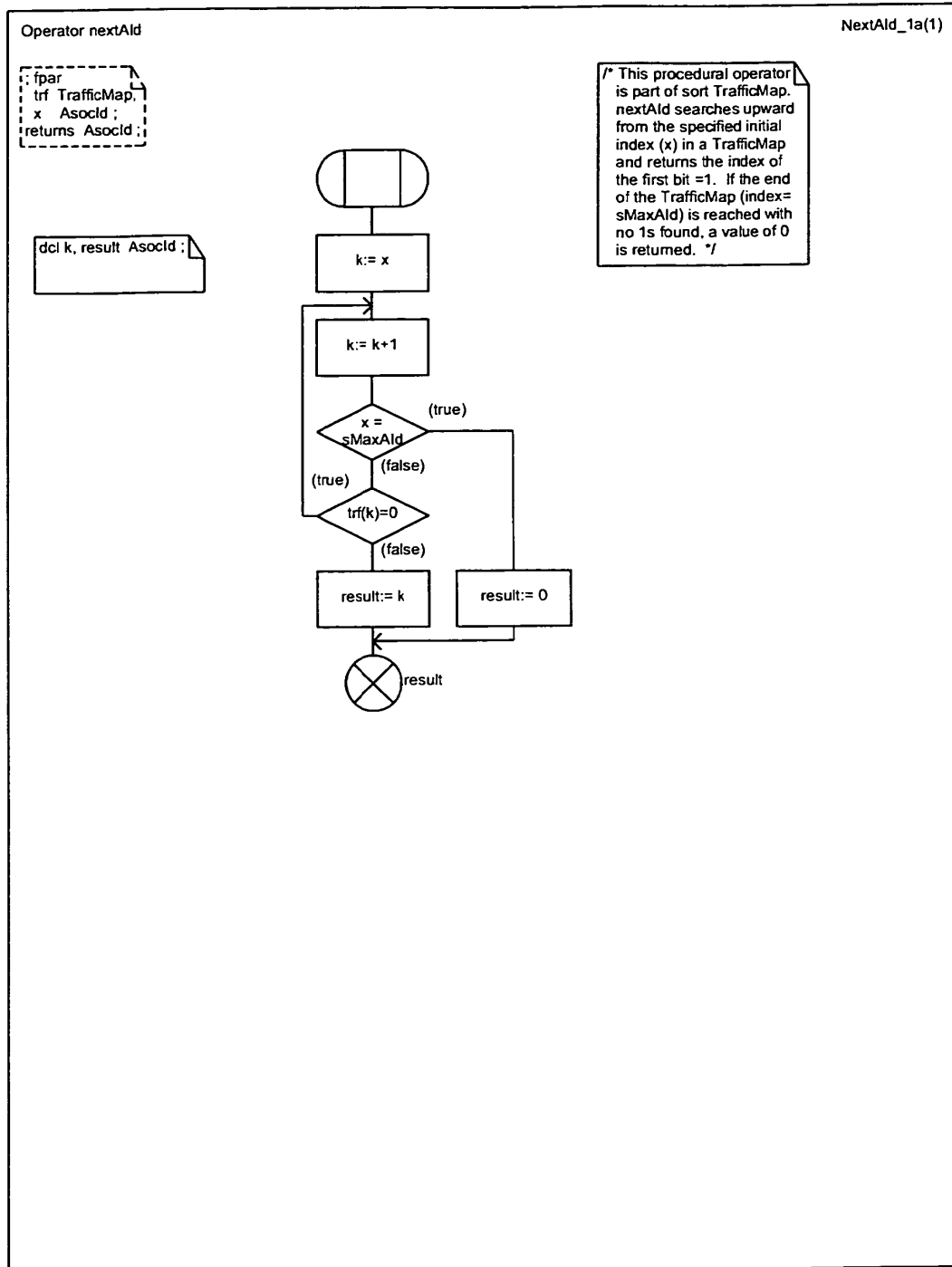
operator
mkTimoperator
nextAld

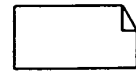
```

-----
* Traffic Information Map (TIM) support sorts
-----
/* TrafficMap is an Array of Bit indexed by Ald. */
/* Bits =1 in TrafficMap denote the presence of buffered frame(s) */
/* for the station assigned that Ald. TrafficMap operators are: */
/* mkTim(TrafficMap, dtimCnt, dtimPer, lowAld, highAld, bcst) */
/* returns Octetstring to use as the info field of a TIM element */
/* The TIM will contain bits =1 for TrafficMap locations in the */
/* range (lowAld):(highAld). Buffered broadcasts and multicasts */
/* (Ald 0) are indicated if dtimCnt=0 and if bcst=true. */
/* nextAld(TrafficMap, currentAld) */
/* returns index greater than currentAld at which TrafficMap=1. */
/* If no locations before sMaxAld are =1, returns 0. */
newtype TrafficMap Array( AsocId, Bit);
adding operators
mkTim : TrafficMap, Integer, Integer, AsocId, AsocId, Boolean -> Octetstring;
nextAld : TrafficMap, AsocId -> AsocId;
operator mkTim;
fpar trf TrafficMap, dtc Integer, dtp Integer, xlo AsocId,
xhi AsocId, bc Boolean; returns Octetstring; referenced;
operator nextAld;
fpar trf TrafficMap, x AsocId; returns AsocId; referenced;
endnewtype TrafficMap;
/* TIM is a subtype of Octetstring with operators: */
/* bufFrame(tim,Ald) returns true if the TIM info field */
/* (obtained using getElem) is =1 at tim(Ald). */
/* bufBcst(tim) returns true if the TIM info field */
/* indicates buffered broadcast/multicast traffic */
/* dtCount(tim) returns DTIM count value from TIM */
/* dtPeriod(tim) returns DTIM period value from TIM */
newtype TIM inherits Octetstring operators all;
adding operators
bufFrame : TIM, AsocId -> Boolean;
bufBcst : TIM -> Boolean;
dtCount : TIM -> Integer;
dtPeriod : TIM -> Integer;
axioms
for all el in TIM( for all a in AsocId(
bufFrame(el, a) ==
if a < (octetVal(el(2) and 0xFE) * 8) then false
else
if a >= ((octetVal(el(2) and 0xFE)*8) + ((Length(el)-3)*8))
then false
else
Extract!(B_S(el), (a-(octetVal(el(2) and 0xFE)*8)+24)) = 1
fi fi;
bufBcst(el) == (el(2) and 0x01) = 0x01;
dtCount(el) == octetVal(el(0));
dtPeriod(el) == octetVal(el(1)); );
endnewtype TIM;

```







Package macsorts

3125_dRateAndDurationSorts(31)

```

-----
* Multi-rate support sorts
-----
newtype Rate inherits Octet operators all;
adding operators
  calcDur : Rate, Integer -> Integer; /* converts (rate,bitCount) to integer usec */
  rateVal : Rate -> Rate; /* clears high-order bit */
  basicRate : Rate -> Rate; /* sets high-order bit */
  isBasic : Rate -> Boolean; /* true if high-order bit set */
axioms
  for all r in Rate( for all i in Integer( for all b in Boolean(
    calcDur(r, i) == (((10000000 + (octetVal(r and 0x7F) - 1)) /
      (500 * octetVal(r and 0x7F))) * i) + 9999) / 10000;
    rateVal(r) == r and 0x7F; basicRate(r) == r or 0x80;
    isBasic(r) == (r and 0x80) = 0x80; ));
endnewtype Rate;
syntype RateString = Octetstring endsyntype RateString;

```

```

-----
* MPDU duration factor support sort
-----
/* These operators support the encoding used to allow */
/* an Integer to represent the value of aMpduDurationFactor. */
/* calcDF(PlcpBits, MpduBits) returns an Integer which is */
/* the fractional part of ((PlcpBits/MpduBits)-1)*(1e9). */
/* stuff(durFactor, MpduBits) returns the number of PlcpBits */
/* which result from MpduBits at the specified durFactor. */
newtype DurFactor inherits Integer operators all;
adding operators
  calcDF : Integer, Integer -> DurFactor;
  stuff : DurFactor, Integer -> Integer;
axioms
  for all df in DurFactor( for all mb, pb in Integer(
    calcDF(pb, mb) == ((pb * 1000000000) / mb) - 1000000000;
    stuff(df, mb) == ((mb * df) + (mb - 1)) / 1000000000; ));
endnewtype DurFactor;

```



Package macsorts

3126_dVH_DS_Params(31)

```

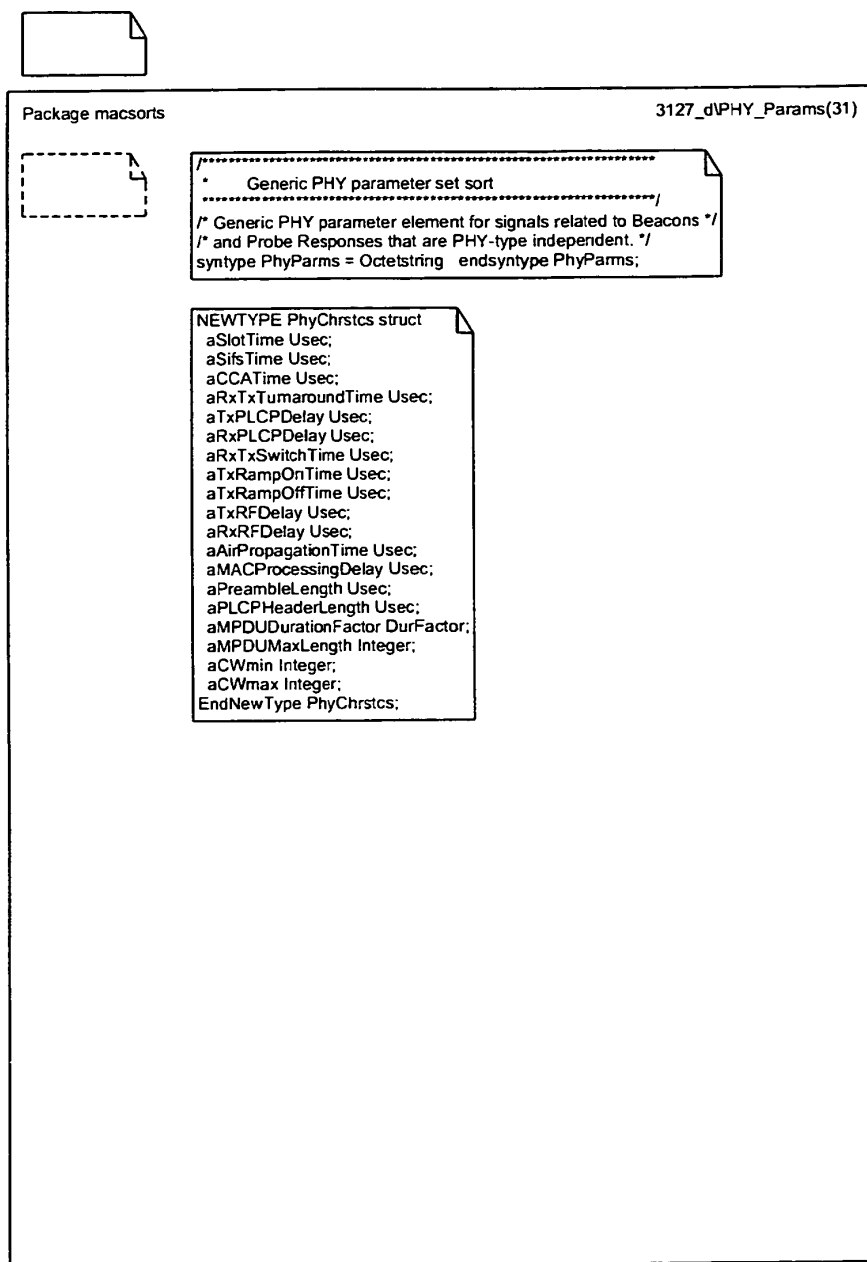
-----
*      FH parameter set sort
-----
newtype FhParms inherits Octetstring operators all;
adding operators
  dwellTime : FhParms -> TU; /* Dwell Time field (2) */
  setDwellTime : FhParms, TU -> FhParms;
  hopSet : FhParms -> Integer; /* Hop Set field (1) */
  setHopSet : FhParms, Integer -> FhParms;
  hopPattern : FhParms -> Integer; /* Hop Pattern field (1) */
  setHopPattern : FhParms, Integer -> FhParms;
  hopIndex : FhParms -> Integer; /* Hop Index field (1) */
  setHopIndex : FhParms, Integer -> FhParms;
axioms
  for all fh in FhParms( for all i in Integer( for all u in TU(
    dwellTime(fh) == octetVal(fh(0)) + (octetVal(fh(1)) * 256);
    setDwellTime(fh, u) == mkOS(u mod 256, 1) // mkOS(u / 256, 1) // SubStr(fh, 2, 3);
    hopSet(fh) == octetVal(fh(2));
    setHopSet(fh, i) == SubStr(fh, 0, 2) // mkOS(i, 1) // SubStr(fh, 3, 2);
    hopPattern(fh) == octetVal(fh(3));
    setHopPattern(fh, i) == SubStr(fh, 0, 3) // mkOS(i, 1) // Last(fh);
    hopIndex(fh) == octetVal(fh(4));
    setHopIndex(fh, i) == SubStr(fh, 0, 4) // mkOS(i, 1);));
endnewtype FhParms;

```

```

-----
*      DS parameter set sort
-----
newtype DsParms inherits Octetstring operators all;
adding operators
  curChannel : DsParms -> Integer; /* Current Channel (1) */
  setCurChannel : DsParms, Integer -> DsParms;
axioms
  for all ds in DsParms( for all i in Integer(
    curChannel(ds) == octetVal(ds(0));
    setCurChannel(ds, i) == mkOS(i);));
endnewtype DsParms;

```

use macsorts ;

Package macmib

3201_dStationConfig(5)

/* This Package contains definitions of the MAC MIB attributes and the subset of the PHY MIB attributes used by the MAC state machines. These are needed under Z.100 to permit analysis of the state machine definitions. In future revisions these may be replaced with the ASN.1 MIB definition which appears as Annex D, for use with a Z.105-compliant SDL tool is available. */

```

/*=====
 *      StationConfig Table
 *=====*/
remote dot11MediumOccupancyLimit TU nodeLAY;
synonym dot11CfPollable Boolean = <<package macsorts>> sCfPollable;
remote dot11CfPeriod Integer nodeLAY;
remote dot11CfMaxDuration TU nodeLAY;
remote dot11AuthenticationResponseTimeout TU nodeLAY;
synonym dot11PrivacyOptionImplemented Boolean=true;
remote dot11PowerMangementMode PwrSave nodeLAY;
remote dot11DesiredSsid OctetString nodeLAY;
remote dot11DesiredBssType BssType nodeLAY;
remote dot11OperationalRateSet RateString nodeLAY;
remote dot11BeaconPeriod TU nodeLAY;
remote dot11DtimPeriod Integer nodeLAY;
remote dot11AssociationResponseTimeout TU nodeLAY;

remote dot11WepUndecryptableCount Counter32 nodeLAY;
remote dot11ReceiveDTIMs Boolean nodeLAY;
remote dot11AuthenticationType AuthTypeSet nodeLAY;

```

```

/*=====
 *      AuthenticationAlgorithms Table
 *=====*/
synonym dot11AuthenticationAlgorithms AuthTypeSet =
incl(open_system, incl(shared_key));
/* NOTE: The members of this set are the
dot11AuthenticationAlgorithm values of all
dot11 AuthenticationAlgorithmsEntry instances
for which dot11AuthenticationAlgorithmsEnable=True.
Do not include shared_key in this set
unless dot11PrivacyOptionImplemented=true. */

```

```

/*=====
 *      WepDefaultKeys Table
 *      (if dot11PrivacyOptionImplemented=true)
 *=====*/
remote dot11WepDefaultKeys KeyVector nodeLAY;

```

```

/*=====
 *      WepKeyMappings Table
 *      (if dot11PrivacyOptionImplemented=true)
 *=====*/
remote dot11WepKeyMappings KeyMapArray nodeLAY;

```

use macsorts ;

Package macmib

3202_dPrivOperation(5)

* Privacy Table
* (only if dot11PrivacyOptionImplemented=true)

remote dot11PrivacyInvoked Boolean nodelay;
remote dot11WepDefaultKeyId KeyIndex nodelay;
synonym dot11WepKeyMappingLength Integer =
 <<package macsorts>> sWepKeyMappingLength;
remote dot11ExcludeUnencrypted Boolean nodelay;
remote dot11WepPcvErrorCount Counter32 nodelay;
remote dot11WepExcludedCount Counter32 nodelay;

* Operation Table

synonym dot11MacAddress MacAddr =
 <<type MacAddr>> S6(0x00, 0x11, 0x22, 0x33, 0x44, 0x55);
 /* each station has a unique globally administered address */
 /* Value may be overwritten with locally administered address at */
 /* MlmeReset, but is always a static value during MAC operation */
remote dot11RtsThreshold Integer nodelay;
remote dot11ShortRetryLimit Integer nodelay;
remote dot11LongRetryLimit Integer nodelay;
remote dot11FragmentationThreshold Integer nodelay;
remote dot11MaxTransmitMsduLifetime TU nodelay;
remote dot11MaxReceiveLifetime TU nodelay;
synonym dot11ManufacturerId Charstring = 'name of manufacturer';
synonym dot11ProductId Charstring = 'identifier unique to manufacturer';

* GroupAddresses Table

remote dot11GroupAddresses MacAddrSet nodelay;

use macsorts ;

Package macmib

3203_dCounters(5)



Counters Table		
remote dot11TransmittedFragmentCount	Counter32	nodelay;
remote dot11MulticastTransmittedFrameCount	Counter32	nodelay;
remote dot11FailedCount	Counter32	nodelay;
remote dot11RetryCount	Counter32	nodelay;
remote dot11MultipleRetryCount	Counter32	nodelay;
remote dot11RtsSuccessCount	Counter32	nodelay;
remote dot11RtsFailureCount	Counter32	nodelay;
remote dot11AckFailureCount	Counter32	nodelay;
remote dot11ReceivedFragmentCount	Counter32	nodelay;
remote dot11MulticastReceivedFrameCount	Counter32	nodelay;
remote dot11FcsErrorCount	Counter32	nodelay;
remote dot11FrameDuplicateCount	Counter32	nodelay;

use macsorts;

Package macmib

3204_dVPhyOperation(5)

```

.....
*   PhyOperation Table
*   (values shown are mostly for FH PHY)
...../
synonym FHphy Integer = 01; /* enumerated dot11PHYType value */
synonym DSphy Integer = 02; /* enumerated dot11PHYType value */
synonym IRPhy Integer = 03; /* enumerated dot11PHYType value */
synonym dot11PHYType Integer = FHphy;
remote dot11CurrentRegDomain Integer nodelay;
synonym dot11TempType Integer = 01;

...../
*   PhyCharacteristic Parameters (values shown are mostly for FH PHY )
...../
/* NOTE: The PhyCharacteristics are defined as synonyms because
their values are static during MAC operation. It is assumed
that, during each initialization of MAC operation, current
values for each of these parameters are obtained from the
PHY using the PlmeCharacteristics primitive. */
synonym aSlotTime Usec = (aCcaTime + aRxTxTurnaroundTime +
aAirPropagationTime + aMacProcessingTime);
synonym aCcaTime Usec = 27;
synonym aRxTxTurnaroundTime Usec = (aTxPlcpDelay + aRxTxSwitchTime +
aTxRampOnTime + aTxRfDelay);
synonym aTxPlcpDelay Usec = 1;
synonym aRxTxSwitchTime Usec = 10;
synonym aTxRampOnTime Usec = 8;
synonym aTxRfDelay Usec = 1;
synonym aSifsTime Usec = (aRxRfDelay + aRxPlcpDelay +
aMacProcessingTime + aRxTxTurnaroundTime);
synonym aRxRfDelay Usec = 4;
synonym aRxPlcpDelay Usec = 2;
synonym aMacProcessingTime Usec = 2;
synonym aTxRampOffTime Usec = 8;
synonym aPreambleLength Usec = 96;
synonym aPlcpHeaderLength Usec = 32;
synonym aMpduDurationFactor <<package macsorts>> DurFactor = 31250000;
synonym aMpduMaxLength Integer = 4095;
synonym aAirPropagationTime Usec = 1;
synonym aCWmax Integer = 1023;
synonym aCWmin Integer = 15;

```

use macsorts :

Package macmib

3205_dPhyRateFhss(5)

```

/*
 * SupportedDataRatesTx Table (values shown are for FH PHY)
 */
synonym aSupportedRatesTx Octetstring = S8(0x82, 0x04, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00);

/*
 * SupportedDataRatesRx Table (values shown are for FH PHY)
 */
synonym aSupportedRatesRx Octetstring = S8(0x82, 0x04, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00);

synonym aPrefMaxMpduFragmentLength Integer = aMpduMaxLength;

```

```

/*
 * PhyFHSS Table
 * (only used with FH PHY)
 */
synonym dot11HopTime Usec = 224;
remote dot11CurrentChannelNumber Integer nodelay;
synonym dot11MaxDwellTime TU = 390;
remote dot11CurrentSet Integer nodelay;
remote dot11CurrentPattern Integer nodelay;
remote dot11CurrentIndex Integer nodelay;

```

```

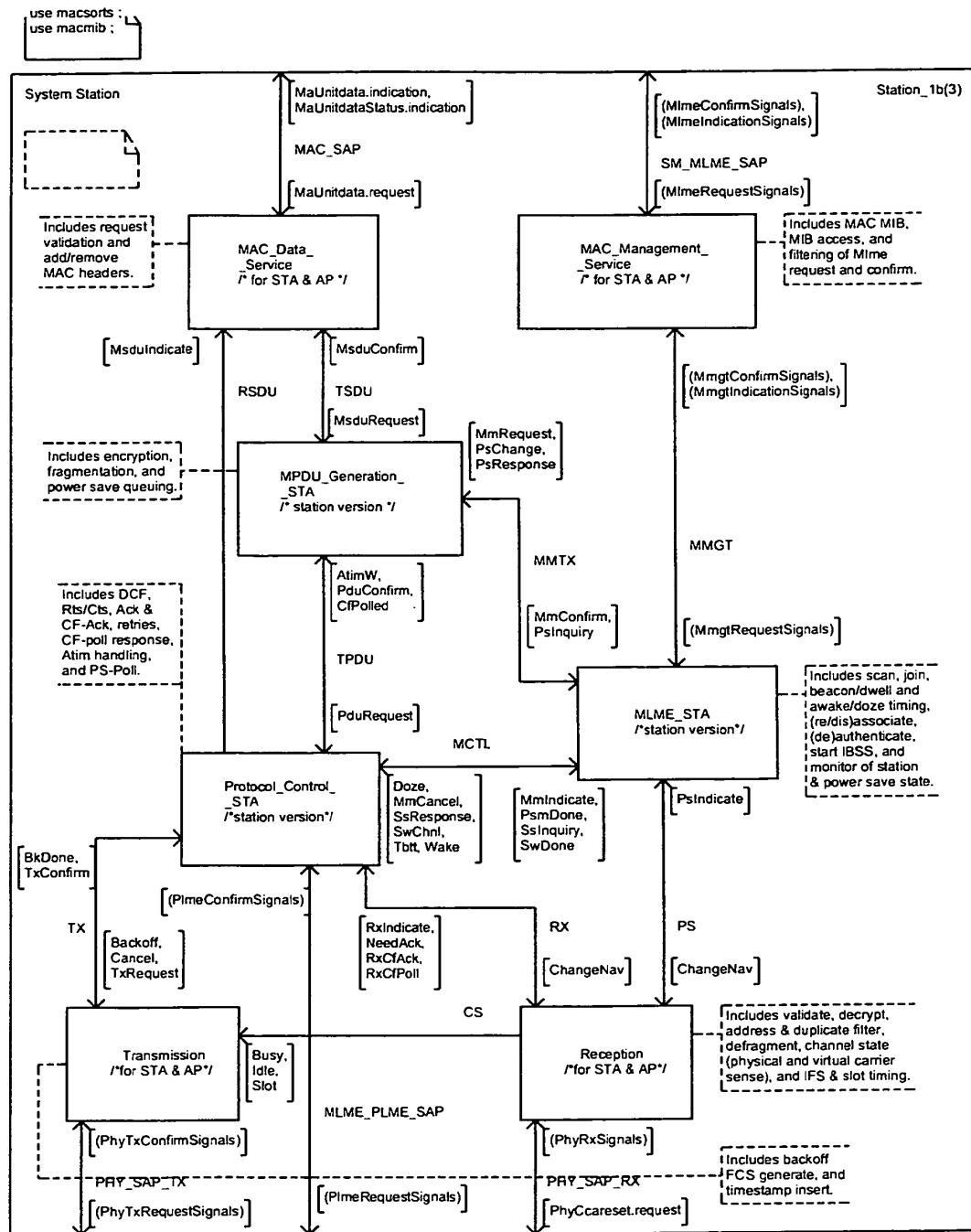
/* The MAC state machines currently do not reference any attributes in:
   PhyAntenna Table, PhyTxPower Table, PhyDsss Table, PhyIrr Table,
   RegDomainsSupported Table, AntennasList Table. */
/endpackage;

```

C.3 State machines for MAC stations

The following SDL-92 system specification defines operation of the MAC protocol at an IEEE 802.11 STA. Many aspects of STA operation also apply to AP operation. These are defined in blocks and processes referenced from both the STA and AP system specifications. Blocks and processes used in both STA and AP are identifiable by the SDL comment `/* for STA & AP */` below the block or process name. Blocks and processes specific to STA operation are identifiable by the SDL comment `/* station version */` below the block or process name. The definitions of all blocks and processes referenced in the station system specification appear in Clause C.3.

The remainder of Clause C.3 is the formal description, in SDL/GR, of an IEEE 802.11 STA.



use macsorts ;
use macmib ;

System Station

Sta_signals_2d(3)

```

signal
  AtimW,
  Backoff(Integer,Integer),
  BkDone(Integer),
  Busy,
  Cancel,
  CfPolled,
  ChangeNav(Time,Duration,NavSrc),
  Doze,
  Idle,
  MaUnitdata.indication(MacAddr,MacAddr,
    Routing,Octetstring,RxStatus,
    CIPriority,ServiceClass),
  MaUnitdata.request(MacAddr,MacAddr,
    Routing,Octetstring,CIPriority,ServiceClass),
  MaUnitdataStatus.indication(MacAddr,
    MacAddr,TxStatus,CIPriority,ServiceClass),
  MimeAssociate.confirm(MlmeStatus),
  MimeAssociate.indication(MacAddr),
  MimeAssociate.request(MacAddr,Kusec,Capability,Integer),
  MimeAuthenticate.confirm
    (MacAddr,AuthType,MlmeStatus),
  MimeAuthenticate.indication(MacAddr,AuthType),
  MimeAuthenticate.request(MacAddr,AuthType,Kusec),
  MimeDeauthenticate.confirm(MacAddr,MlmeStatus),
  MimeDeauthenticate.indication(MacAddr,ReasonCode),
  MimeDeauthenticate.request(MacAddr,ReasonCode),
  MimeDisassociate.confirm(MlmeStatus),
  MimeDisassociate.indication(MacAddr,ReasonCode),
  MimeDisassociate.request(MacAddr,ReasonCode),
  MimeGet.confirm(MibStatus,MibAtrib,MibValue),
  MimeGet.request(MibAtrib),
  MimeJoin.confirm(MlmeStatus),
  MimeJoin.request(BssDscr,Integer,Usec,Ratestring),
  MimePowermgt.confirm(MlmeStatus),
  MimePowermgt.request(PwrSave,Boolean,Boolean),
  MimeReassociate.confirm(MlmeStatus),
  MimeReassociate.indication(MacAddr),
  MimeReassociate.request(MacAddr,Kusec,Capability,Integer),
  MimeReset.confirm(MlmeStatus),
  MimeReset.request(MacAddr,Boolean),
  MimeScan.confirm(BssDscrSet,MlmeStatus),
  MimeScan.request(BssTypeSet,MacAddr,Octetstring,
    ScanType,Usec,Intstring,Kusec,Kusec),
  MimeSet.confirm(MibStatus,MibAtrib),
  MimeSet.request(MibAtrib,MibValue),
  MimeStart.confirm(MlmeStatus),
  MimeStart.request(Octetstring,BssType,Kusec,
    Integer,CIParms,PhyParms,IbssParms,Usec,
    Capability,Ratestring,Ratestring) ;

```

```

signal
  MmCancel,
  MmConfirm(Frame,TxStatus),
  MmIndicate(Frame,Time,Time,StateErr),
  MmRequest(Frame,Imed,Rate),
  MsduConfirm(Frame,CIPriority,TxStatus),
  MsduIndicate(Frame,CIPriority),
  MsduRequest(Frame,CIPriority),
  NeedAck(MacAddr,Time,Duration,Rate),
  PduConfirm(FragSdu,TxResult),
  PduRequest(FragSdu),
  PhyCca.indication(Ccstatus),
  PhyCcarst.confirm,
  PhyCcarst.request,
  PhyData.confirm,
  PhyData.indication(Octet),
  PhyData.request(Octet),
  PhyRxEnd.indication(PhyRxStat),
  PhyRxStart.indication(Integer,Rate),
  PhyTxEnd.confirm,
  PhyTxEnd.request,
  PhyTxStart.confirm,
  PhyTxStart.request(Integer,Rate),
  PimeCharacteristics.confirm(PhyChrctcs),
  PimeCharacteristics.request,
  PimeGet.confirm(MibStatus,
    MibAtrib,MibValue),
  PimeGet.request(MibAtrib),
  PimeReset.confirm(Boolean),
  PimeReset.request,
  PimeSet.confirm(MibStatus,MibAtrib),
  PimeSet.request(MibAtrib,MibValue),
  PsmDone,
  PsChange(MacAddr,PsMode),
  PsIndicate(MacAddr,PsMode),
  PsInquiry(MacAddr),
  PsResponse(MacAddr,PsMode),
  ResetMAC,
  RxClAck(MacAddr),
  RxIndicate(Frame,Time,Time,Rate),
  Slot,
  Ssinquiry(MacAddr),
  SsResponse(MacAddr,
    StationState,StationState),
  SwChnl(Integer,Boolean),
  SwDone,
  TBTT,
  TxConfirm,
  TxRequest(Frame,Rate),
  Wake ;

```

use macsorts ;
use macmb ;

System Station

Sta_signallists_3c(3)



signallist
MimeRequestSignals=
MimeAssociate.request,
MimeAuthenticate.request,
MimeDeauthenticate.request,
MimeDisassociate.request,
MimeGet.request,
MimeJoin.request,
MimePowermgt.request,
MimeReassociate.request,
MimeReset.request,
MimeScan.request,
MimeSet.request,
MimeStart.request ;

signallist
MimeConfirmSignals=
MimeAssociate.confirm,
MimeAuthenticate.confirm,
MimeDeauthenticate.confirm,
MimeDisassociate.confirm,
MimeGet.confirm,
MimeJoin.confirm,
MimePowermgt.confirm,
MimeReassociate.confirm,
MimeReset.confirm,
MimeScan.confirm,
MimeSet.confirm,
MimeStart.confirm ;

signallist
MimeIndicationSignals=
MimeAuthenticate.indication,
MimeDeauthenticate.indication,
MimeDisassociate.indication,
MimeAssociate.indication,
MimeReassociate.indication ;

signallist
MmgmtRequestSignals=
MimeAssociate.request,
MimeAuthenticate.request,
MimeDeauthenticate.request,
MimeDisassociate.request,
MimeJoin.request,
MimePowermgt.request,
MimeReassociate.request,
MimeReset.request,
MimeScan.request,
MimeStart.request ;

signallist
MmgmtConfirmSignals=
MimeAssociate.confirm,
MimeAuthenticate.confirm,
MimeDeauthenticate.confirm,
MimeDisassociate.confirm,
MimeJoin.confirm,
MimePowermgt.confirm,
MimeReassociate.confirm,
MimeReset.confirm,
MimeScan.confirm,
MimeStart.confirm ;

signallist
MmgmtIndicationSignals=
MimeAuthenticate.indication,
MimeDeauthenticate.indication,
MimeDisassociate.indication,
MimeAssociate.indication,
MimeReassociate.indication ;

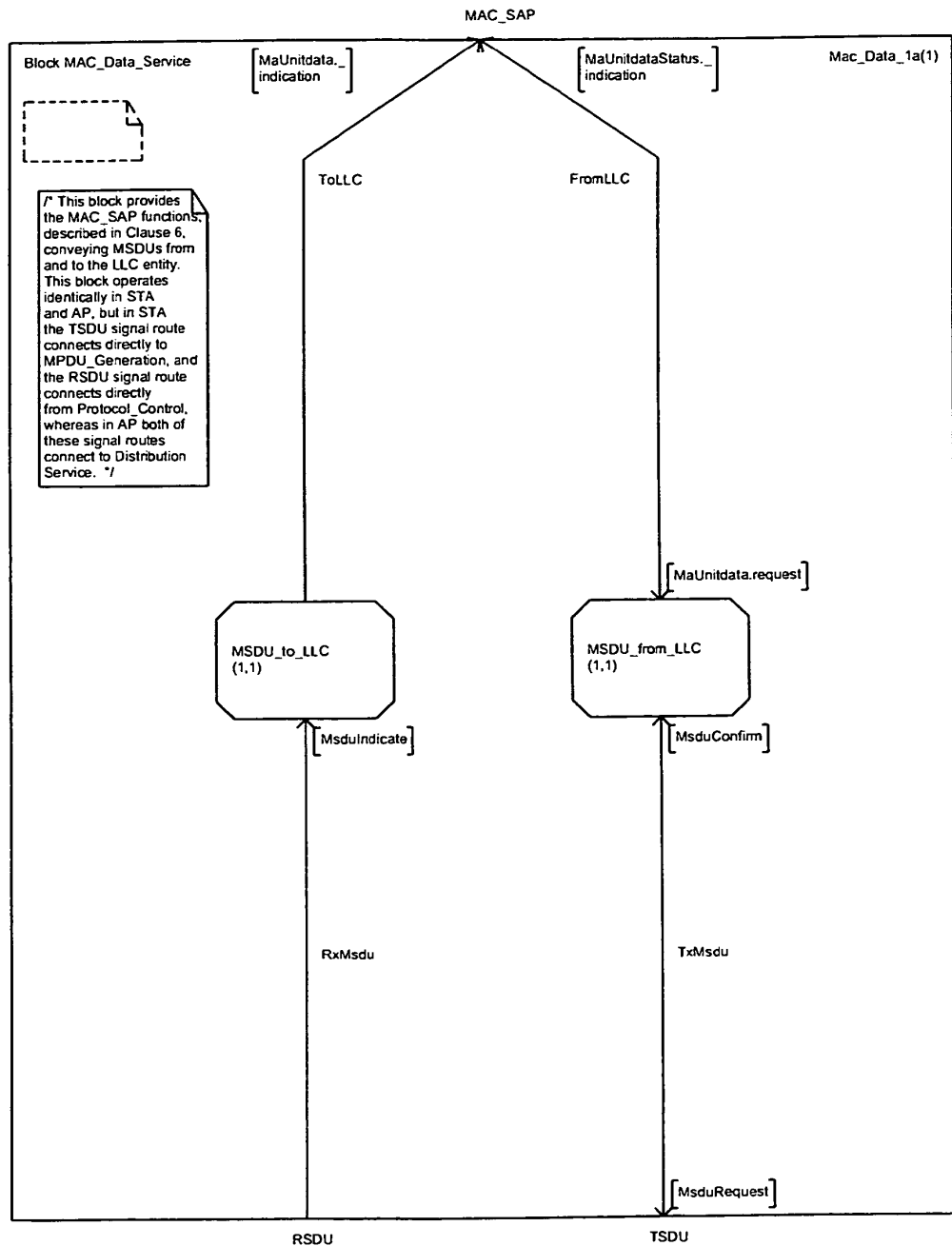
signallist
PhyTxRequestSignals=
PhyTxStart.request,
PhyTxEnd.request,
PhyData.request ;

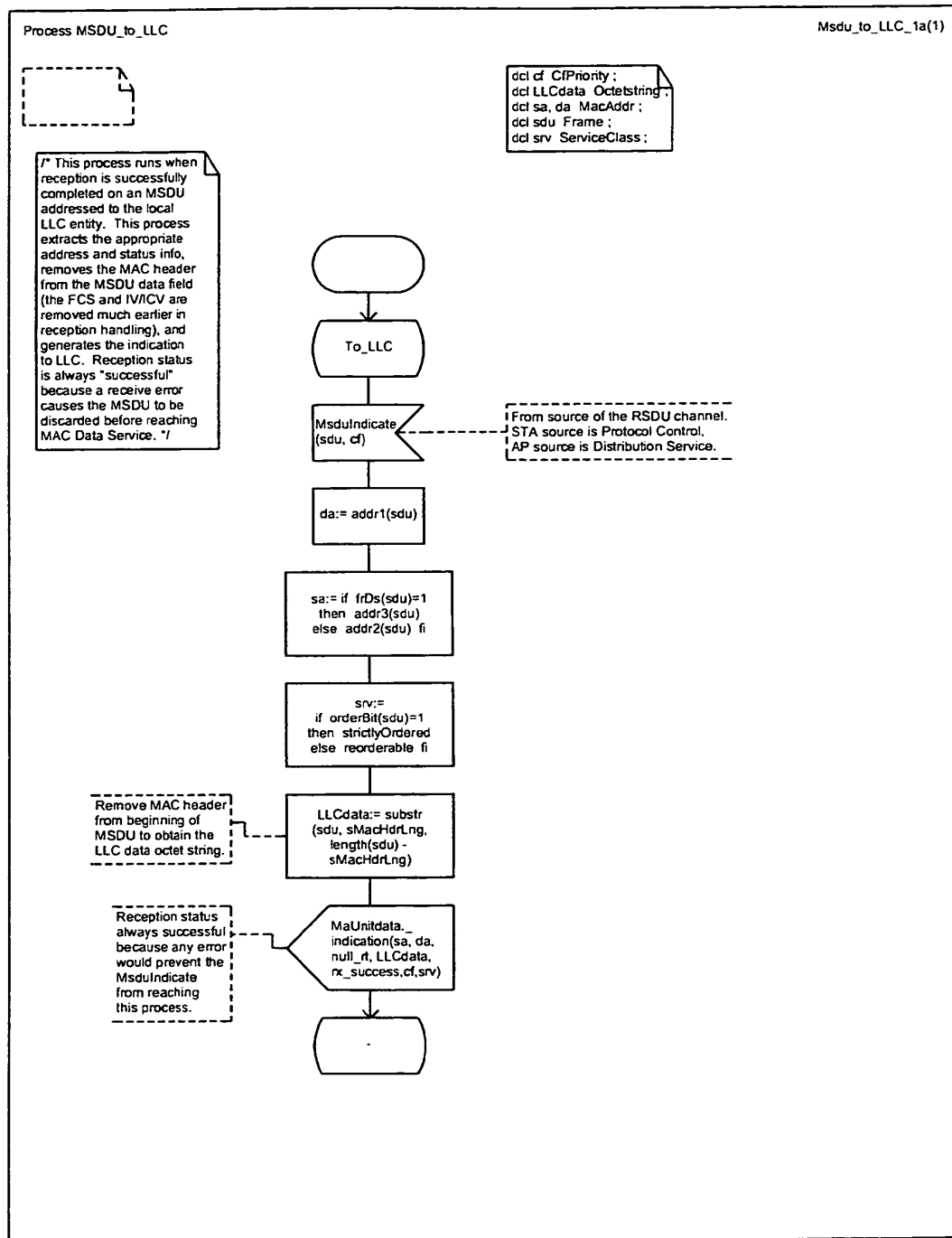
signallist
PhyTxConfirmSignals=
PhyTxStart.confirm,
PhyTxEnd.confirm,
PhyData.confirm ;

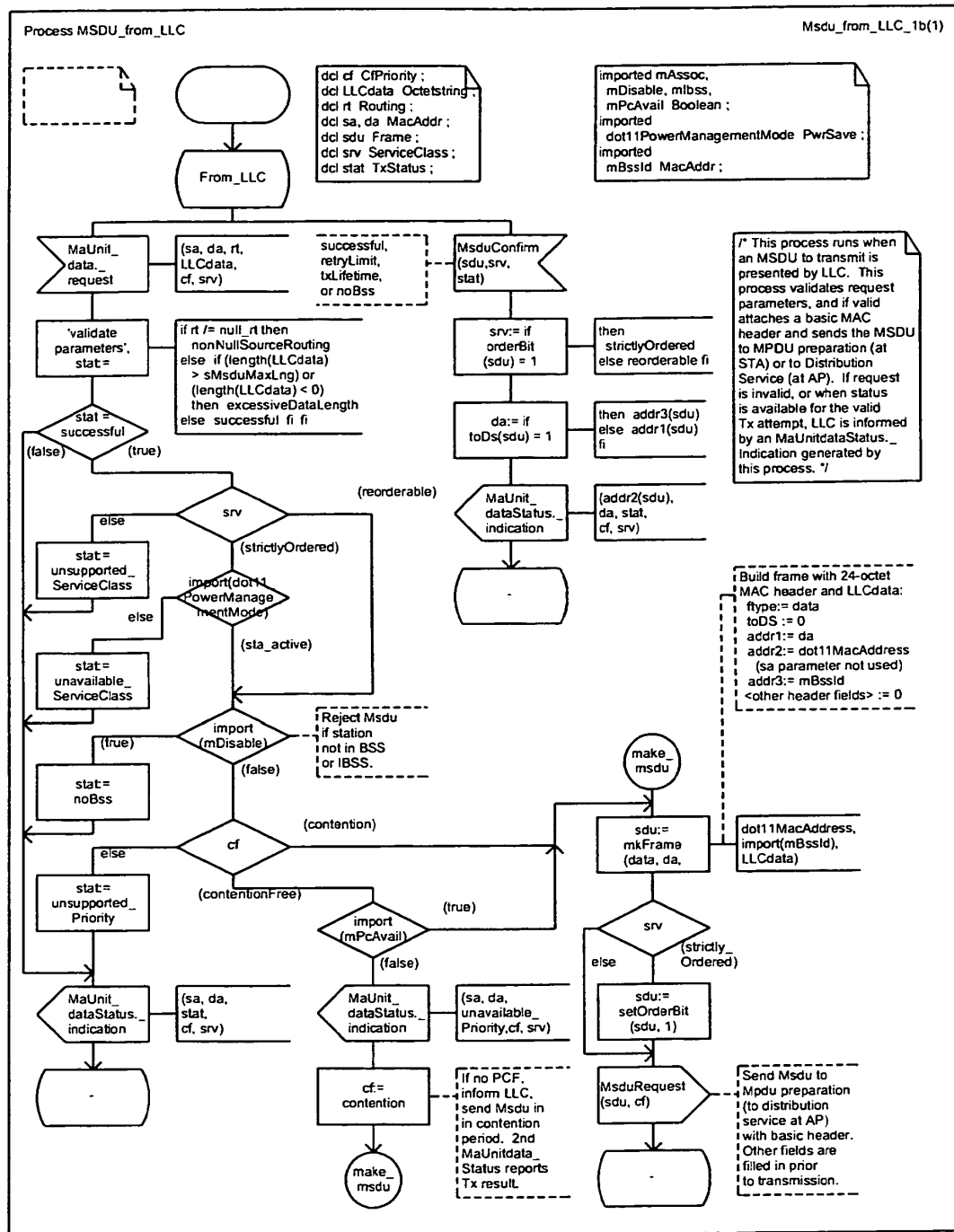
signallist
PhyRxSignals=
PhyRxStart.indication,
PhyRxEnd.indication,
PhyData.indication,
PhyCca.indication,
PhyCcareset.confirm ;

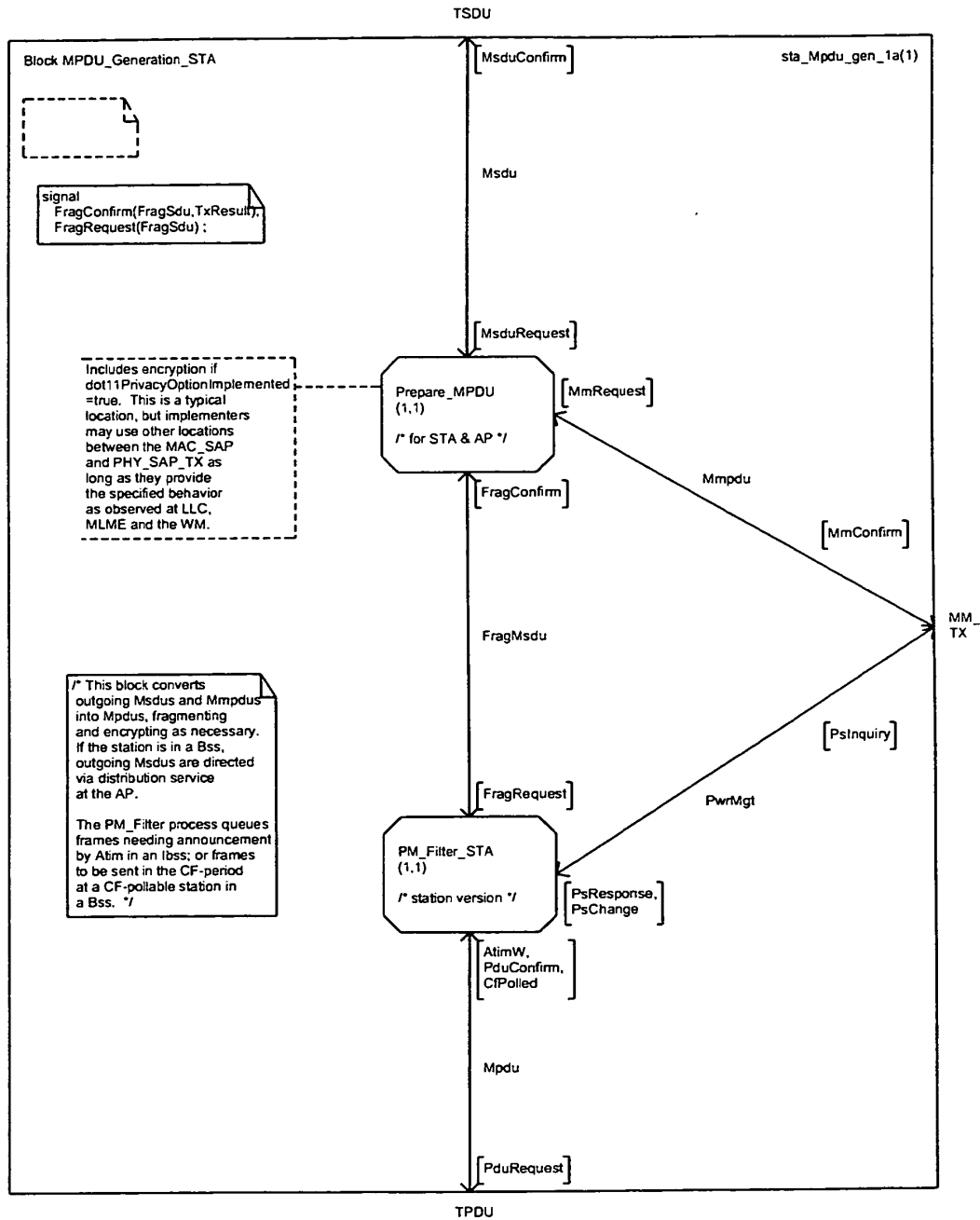
signallist
PimeRequestSignals=
PimeCharacteristics.request,
PimeGet.request,
PimeSet.request,
PimeReset.request

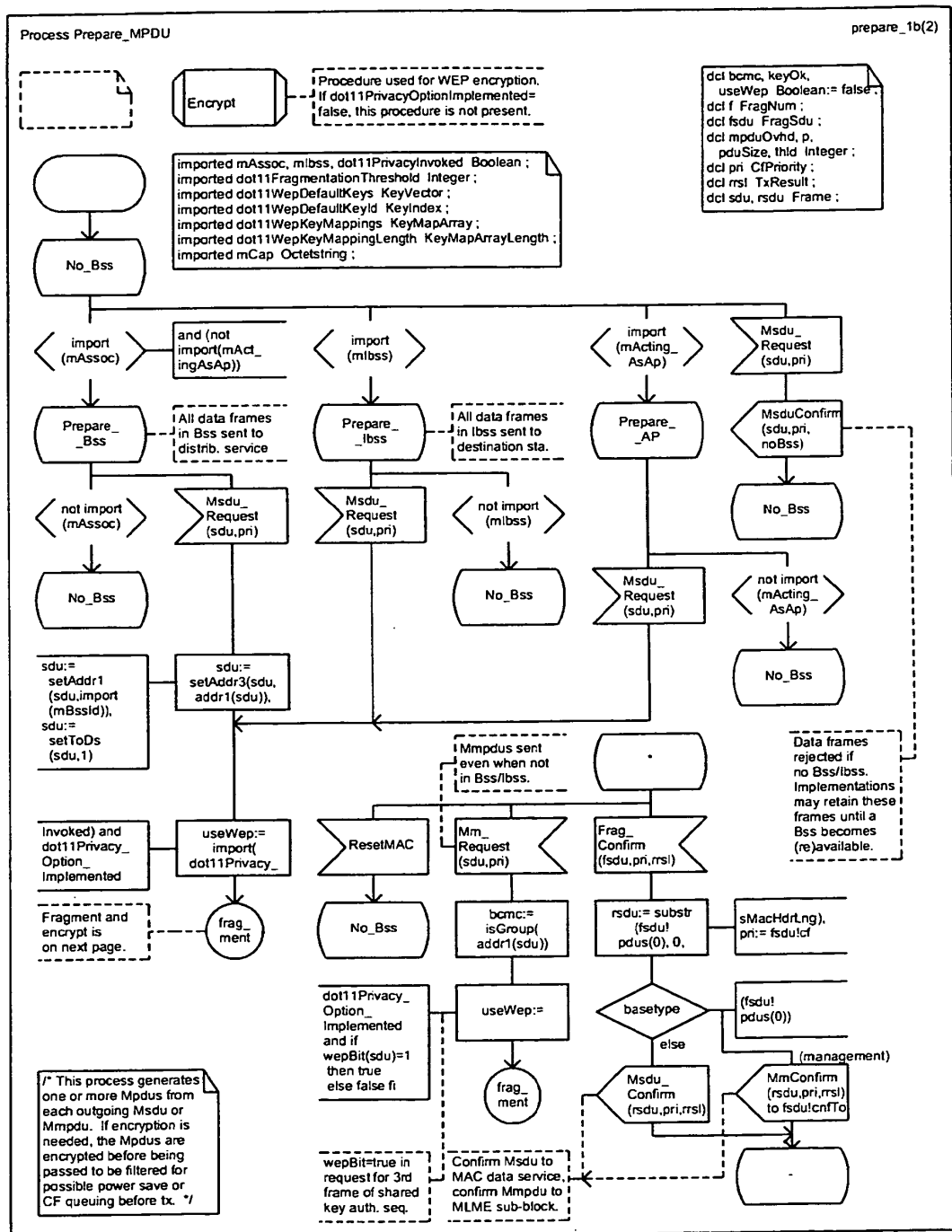
signallist
PimeConfirmSignals=
PimeCharacteristics.confirm,
PimeGet.confirm,
PimeReset.confirm,
PimeSet.confirm ;





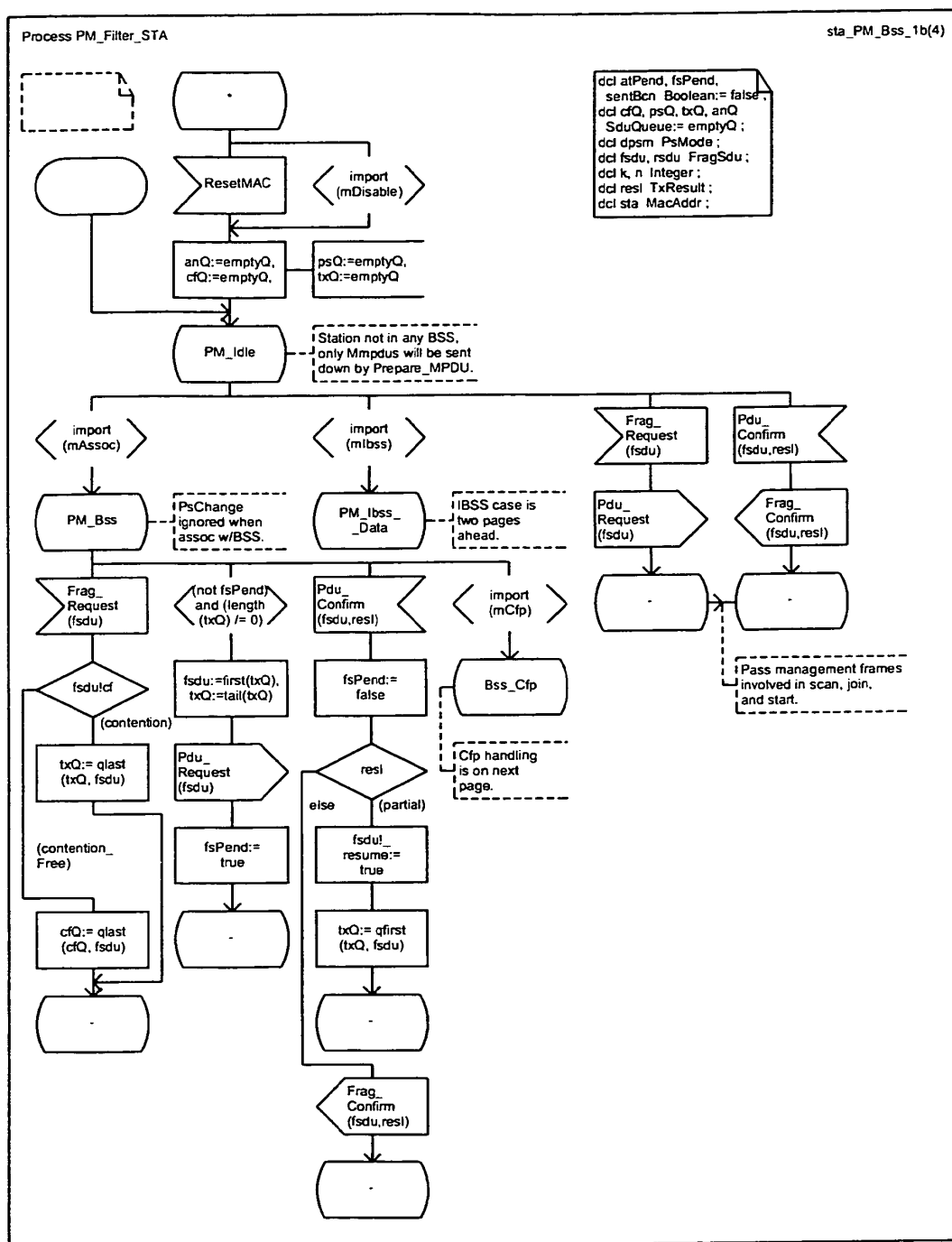


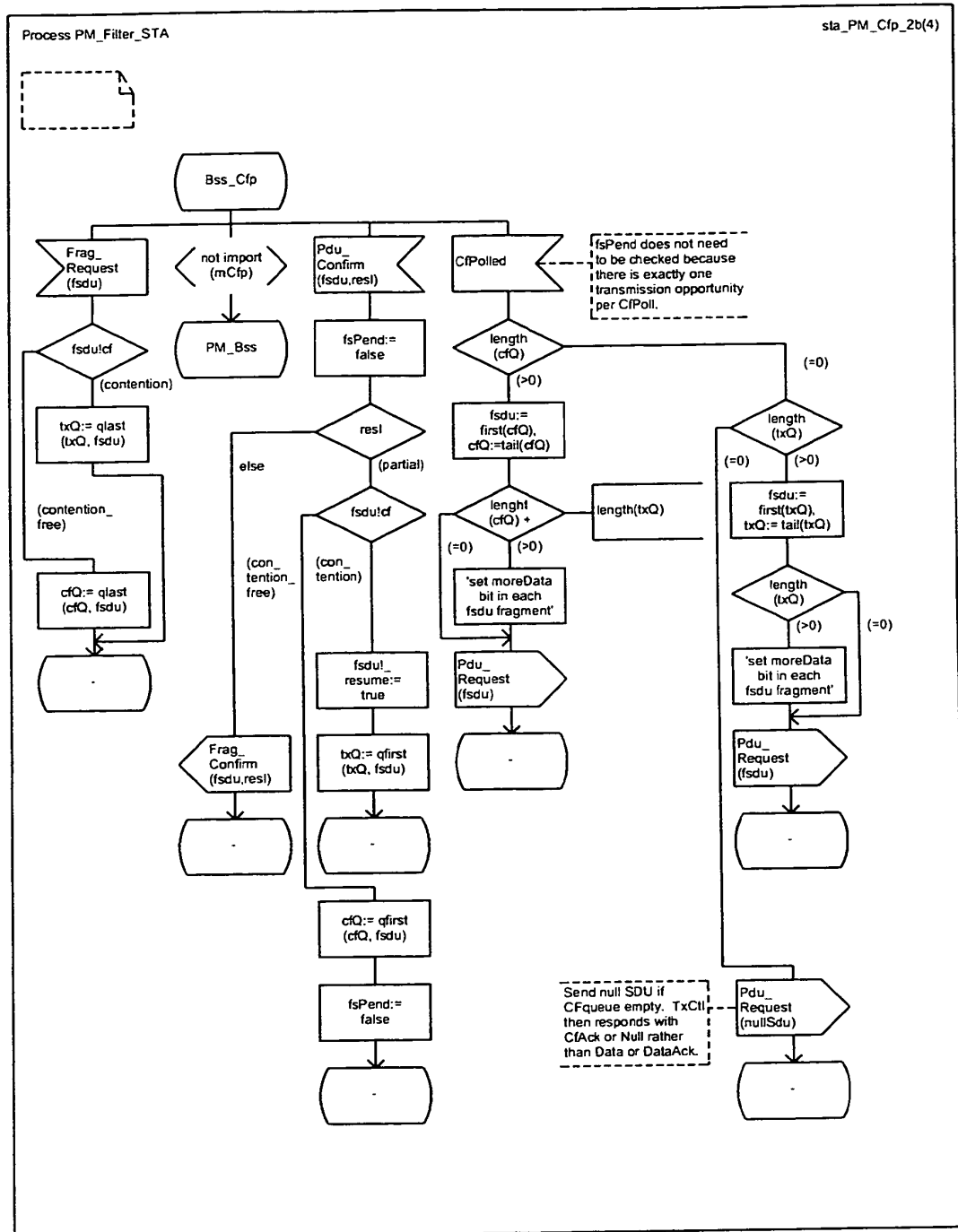


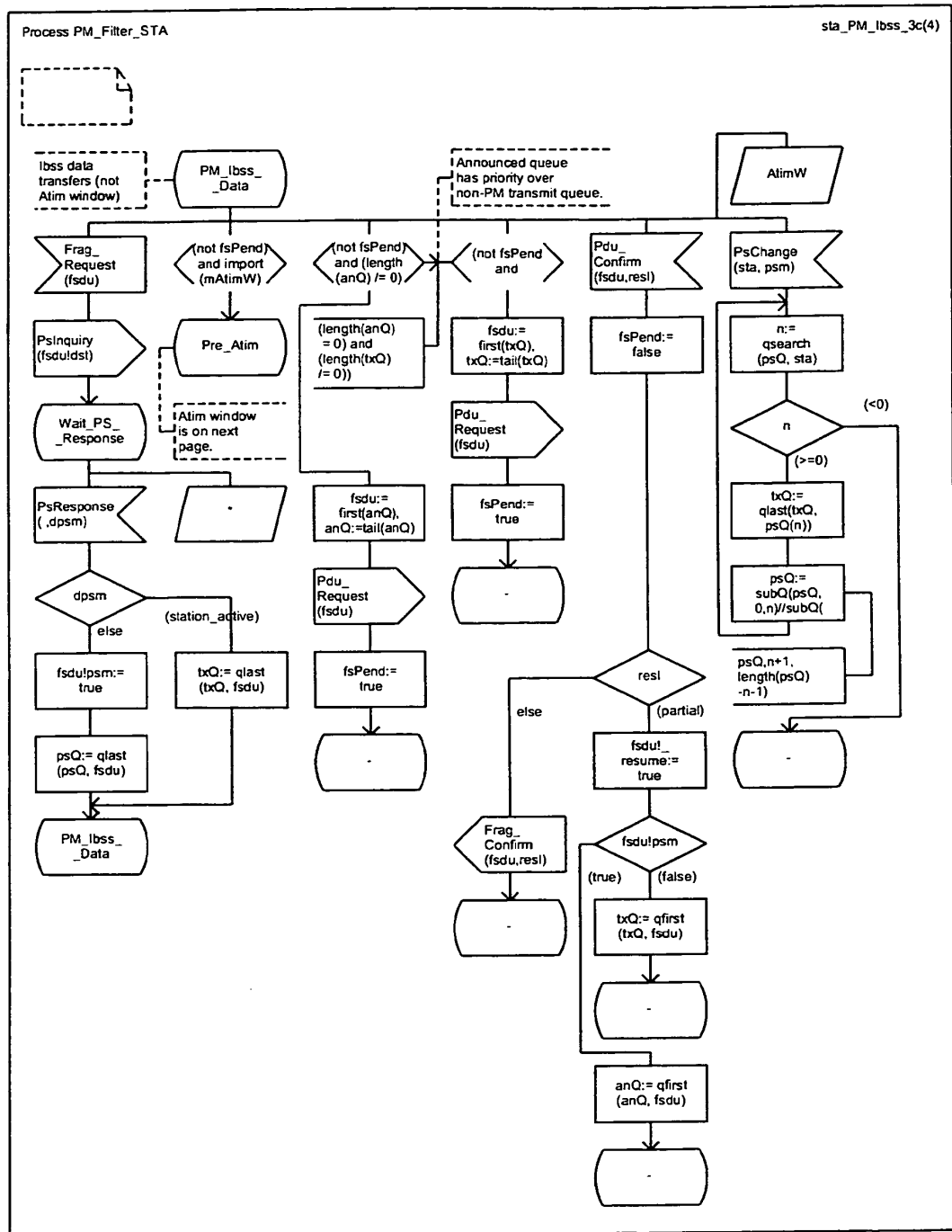


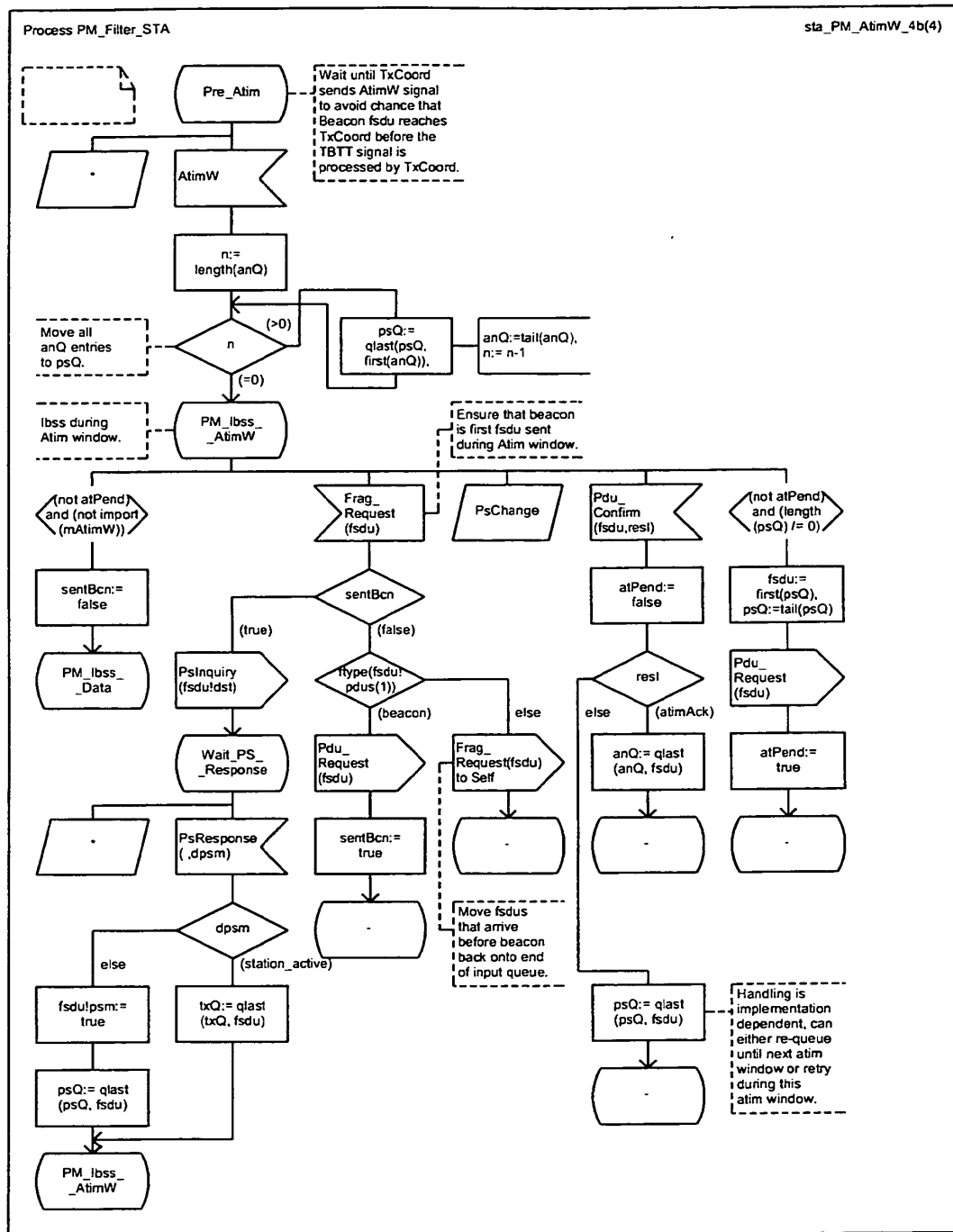




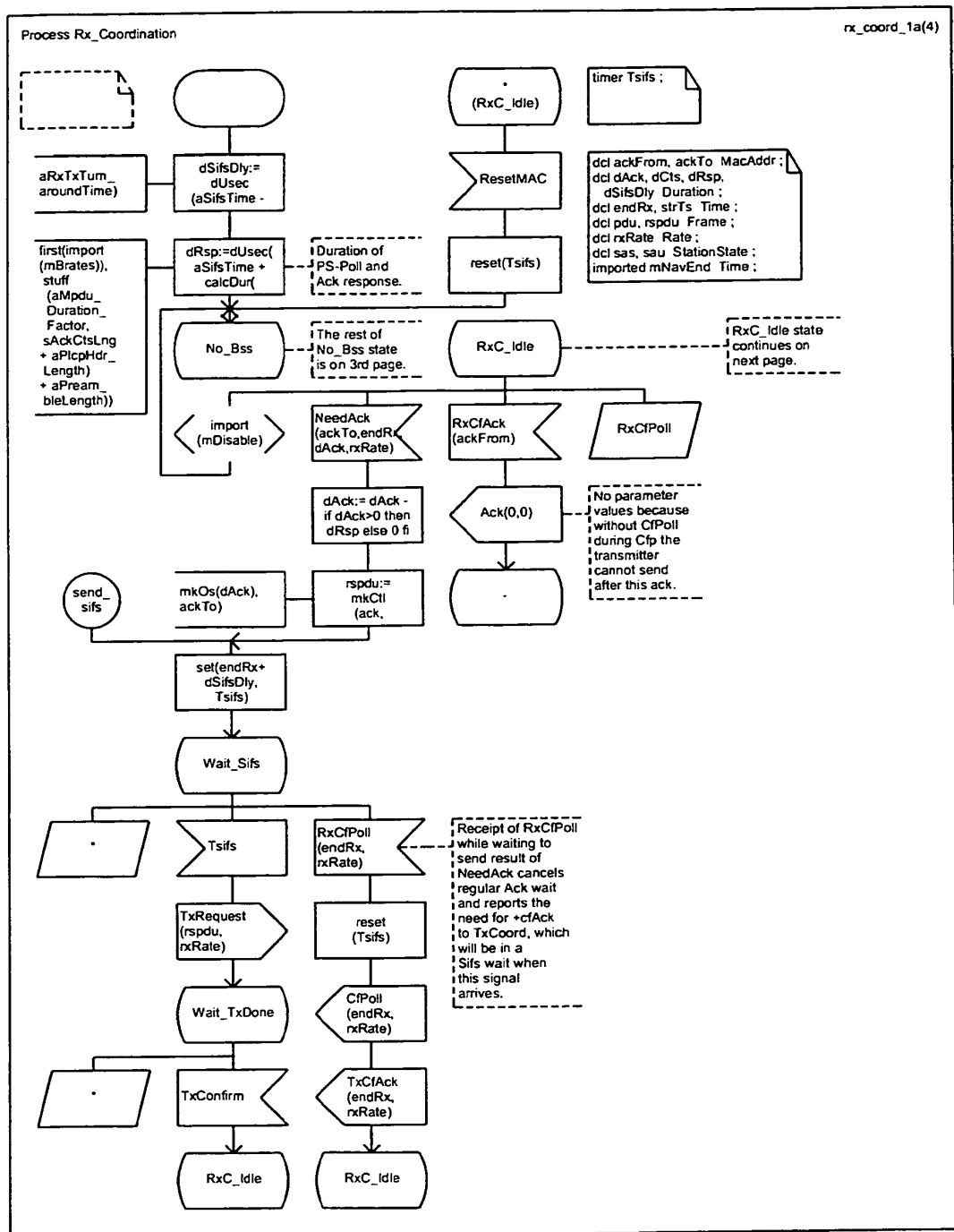


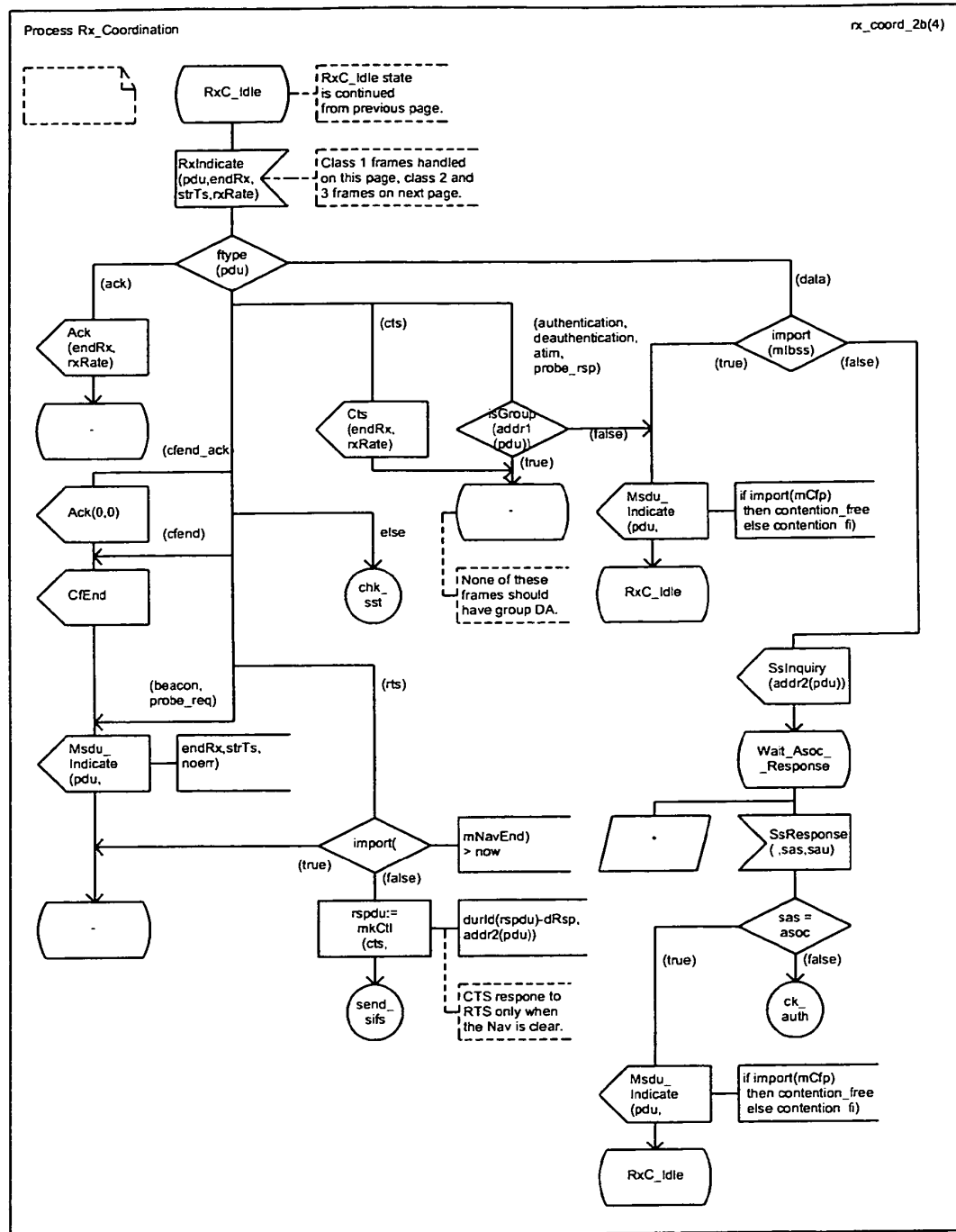


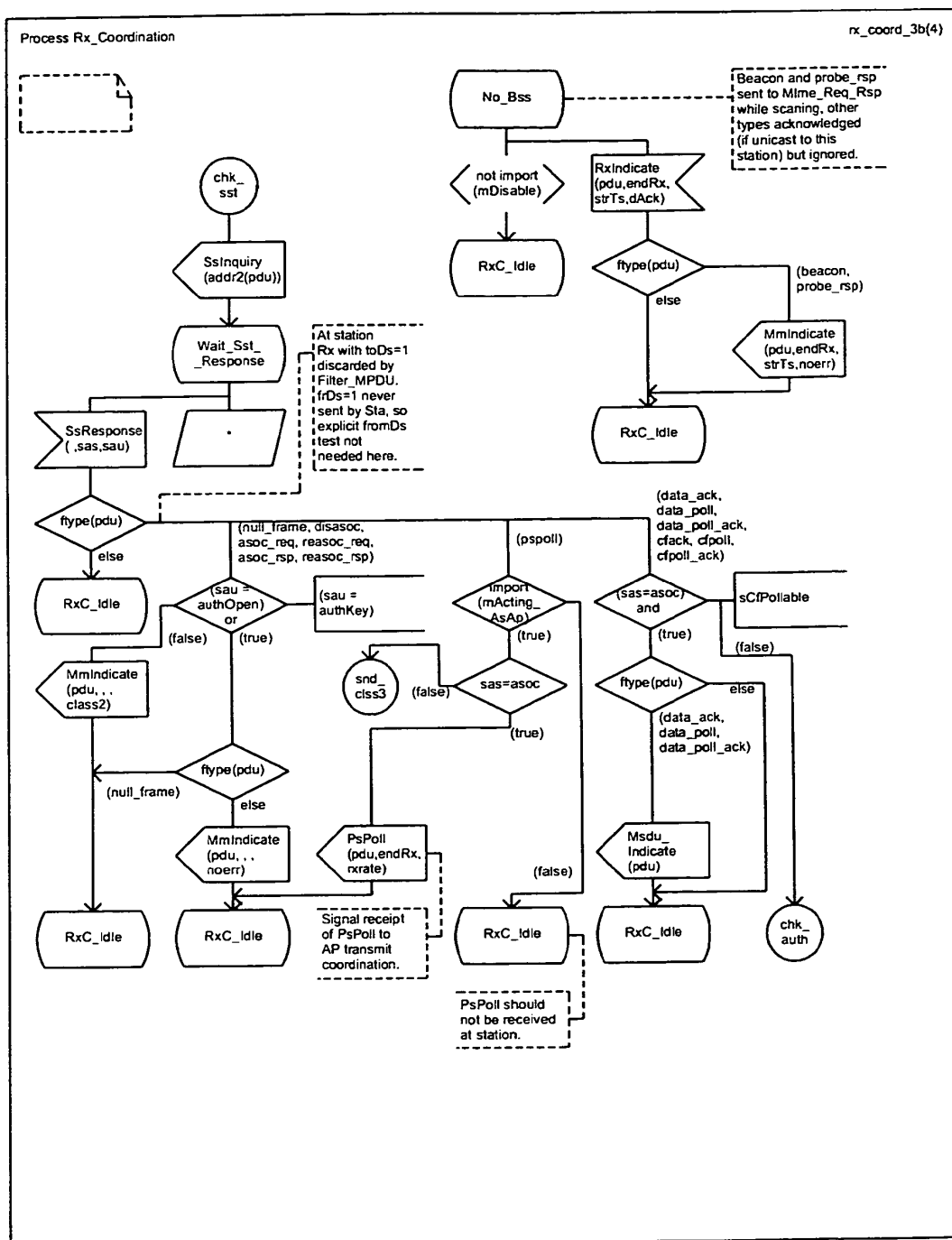






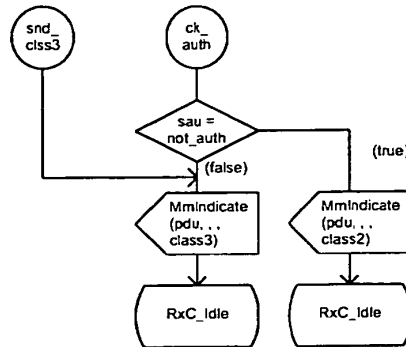


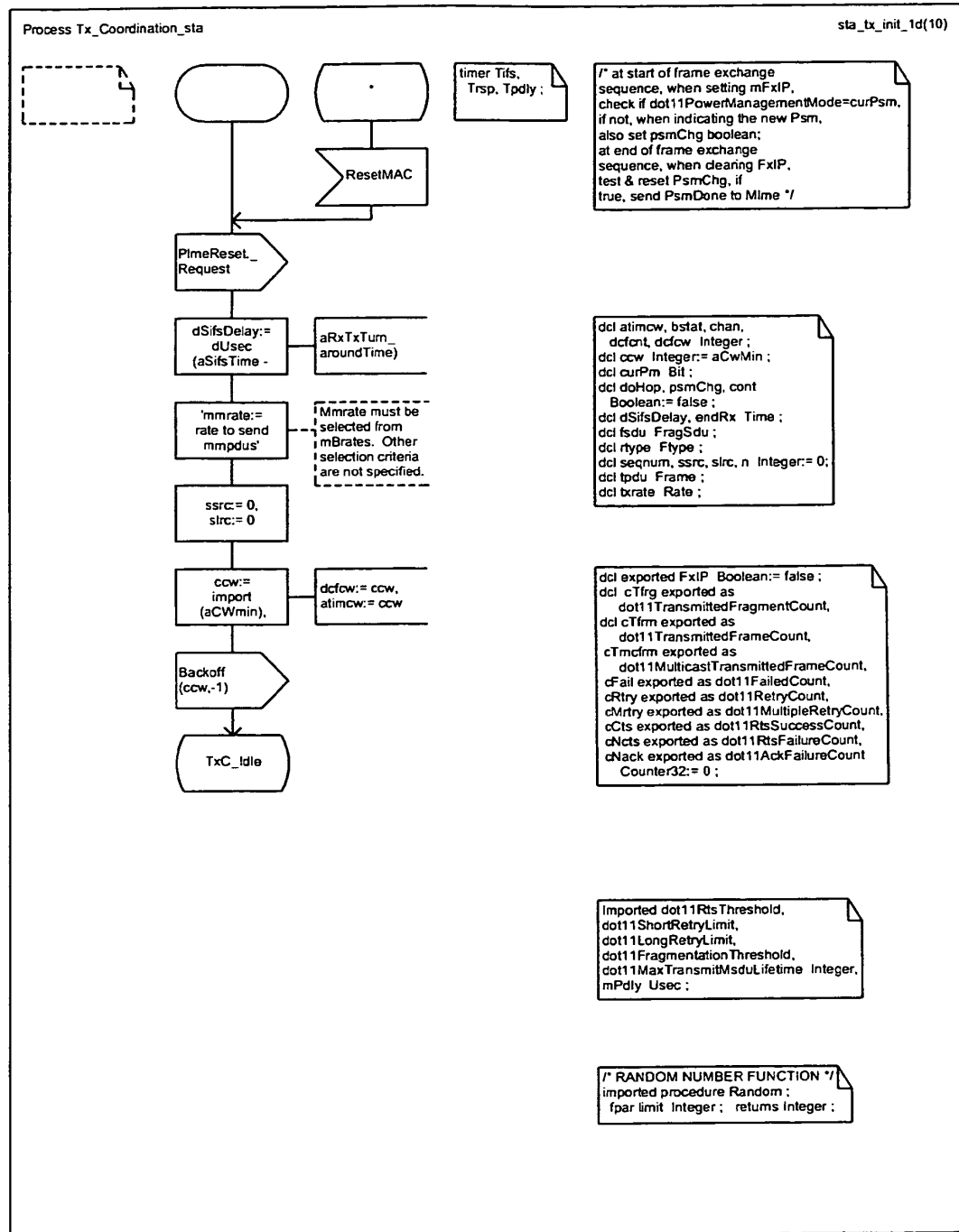


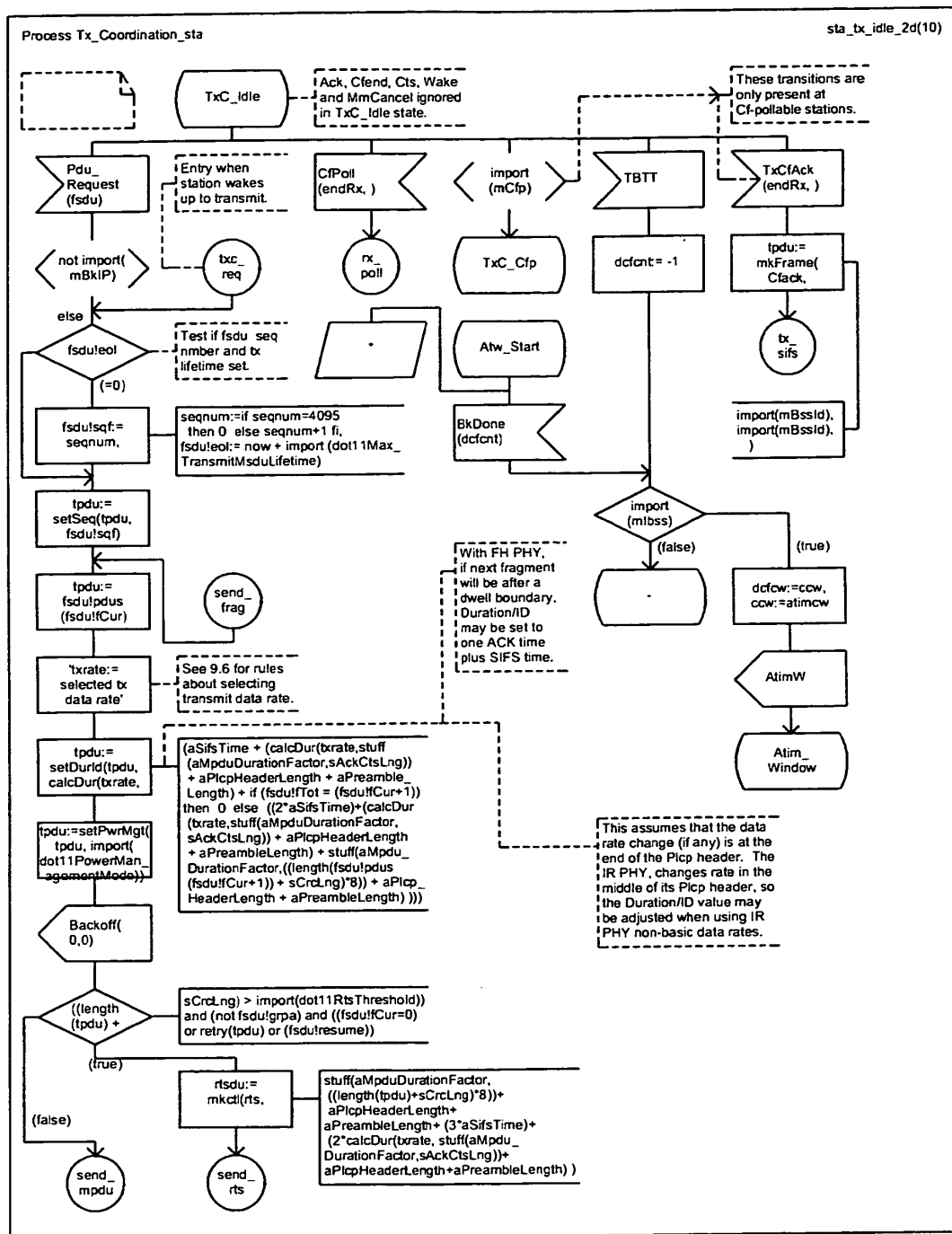


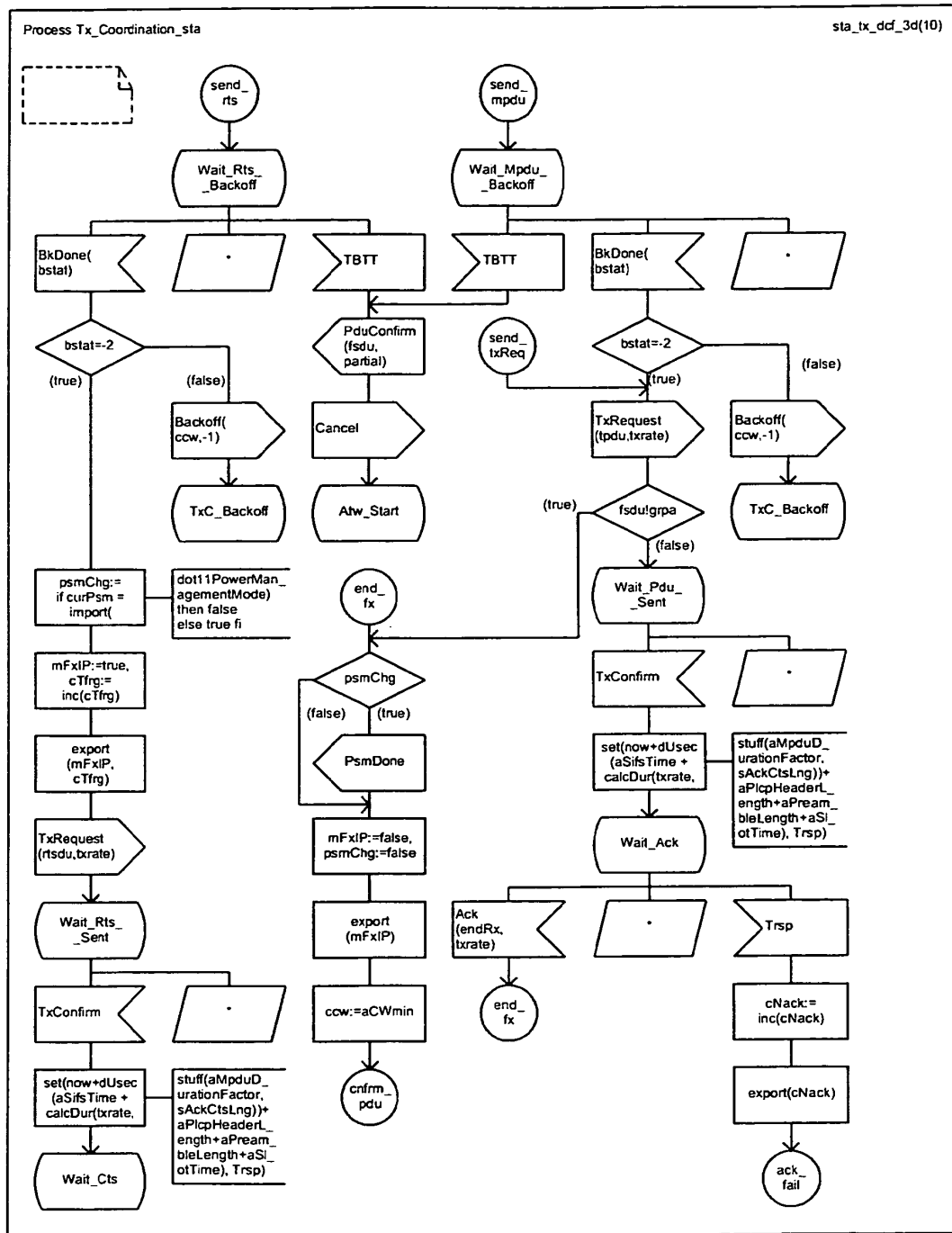
Process Rx_Coordination

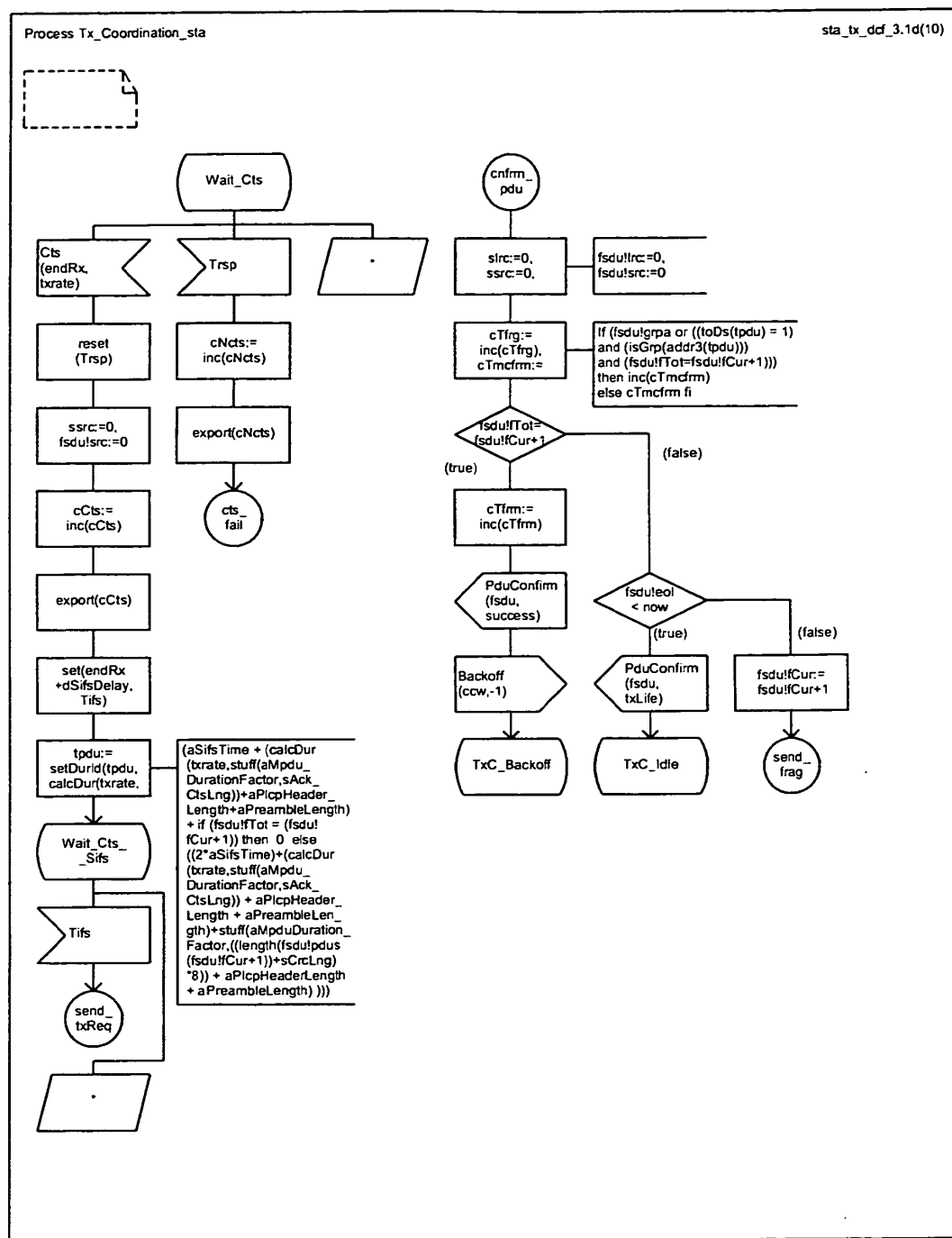
rx_coord_3.1a(4)

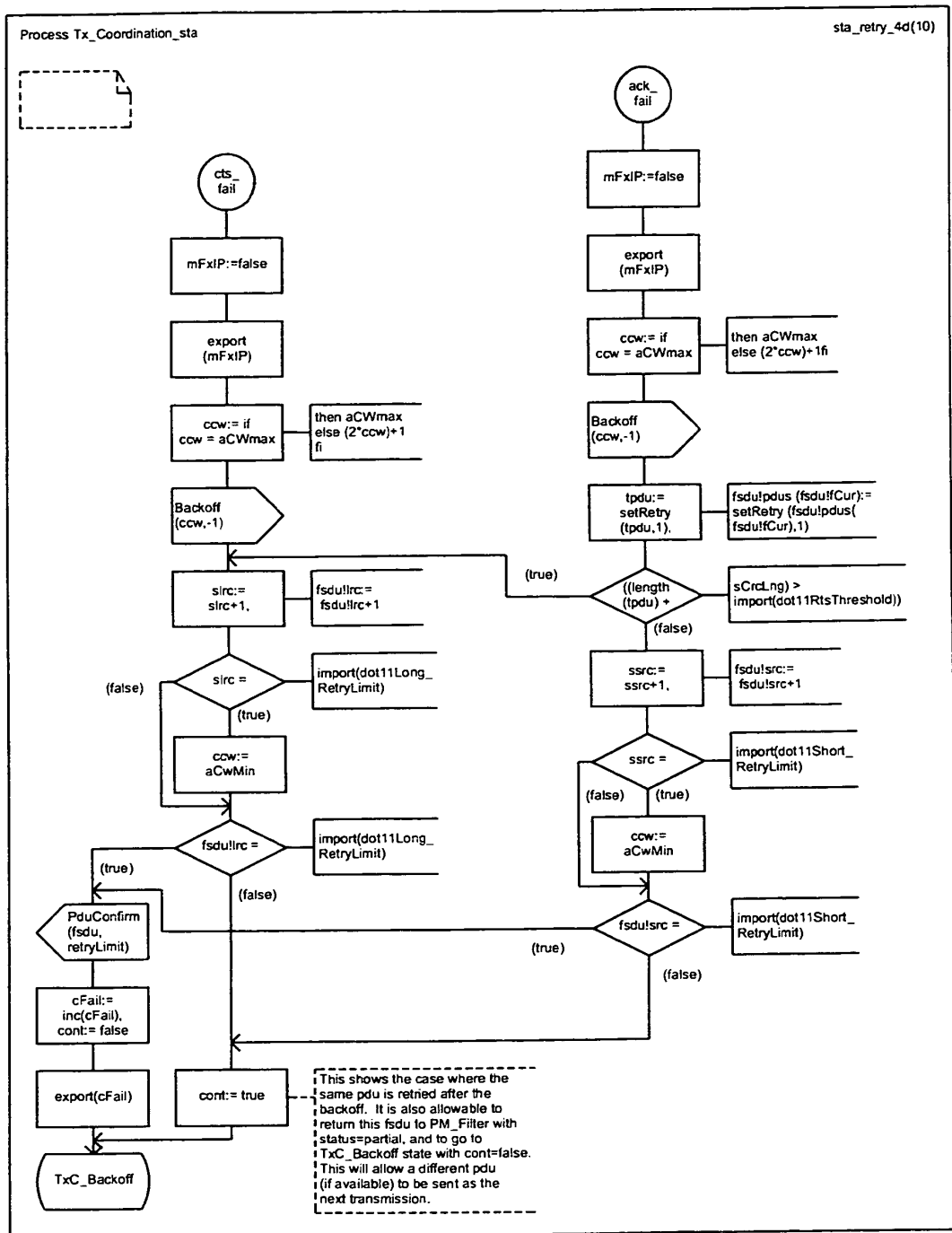




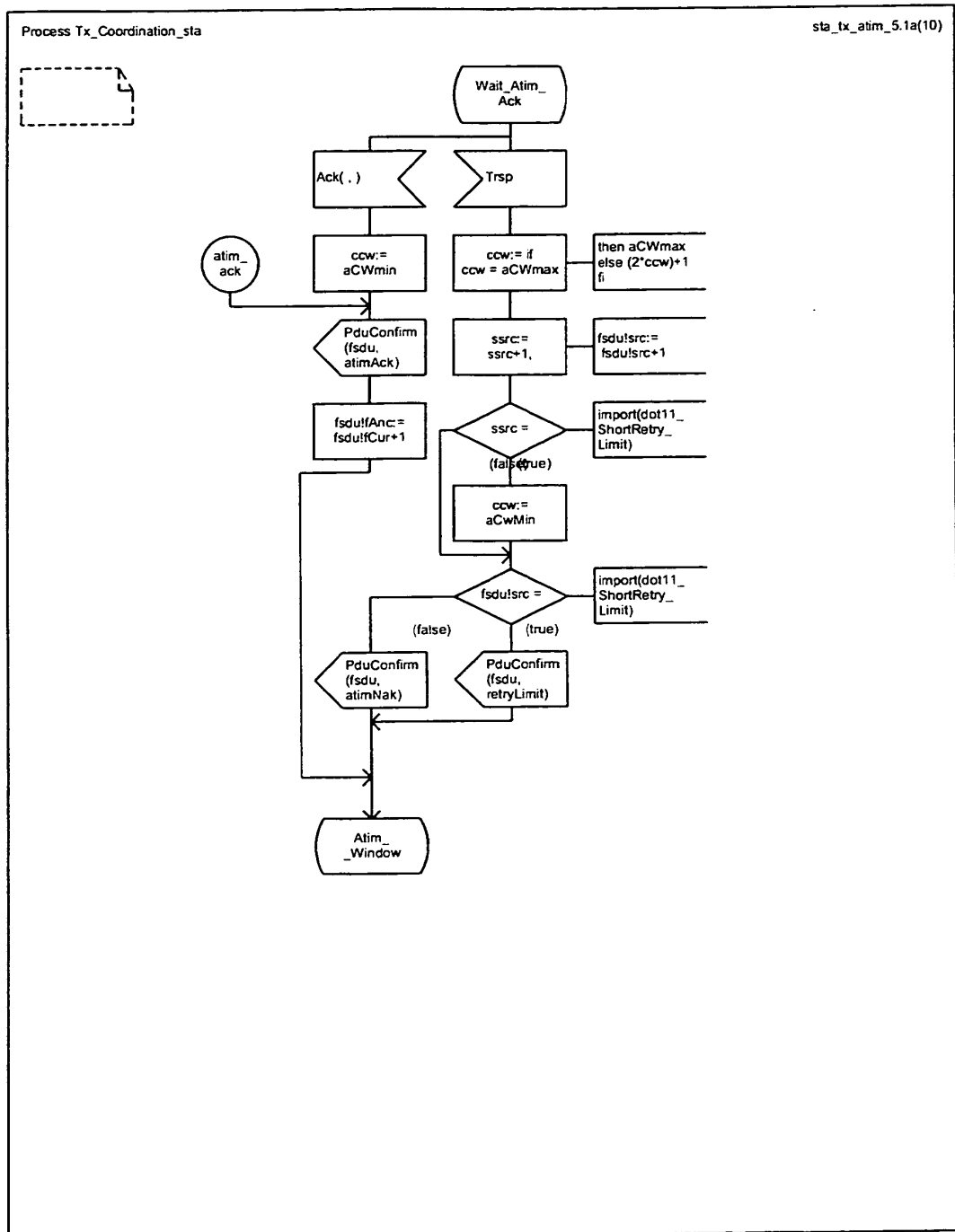


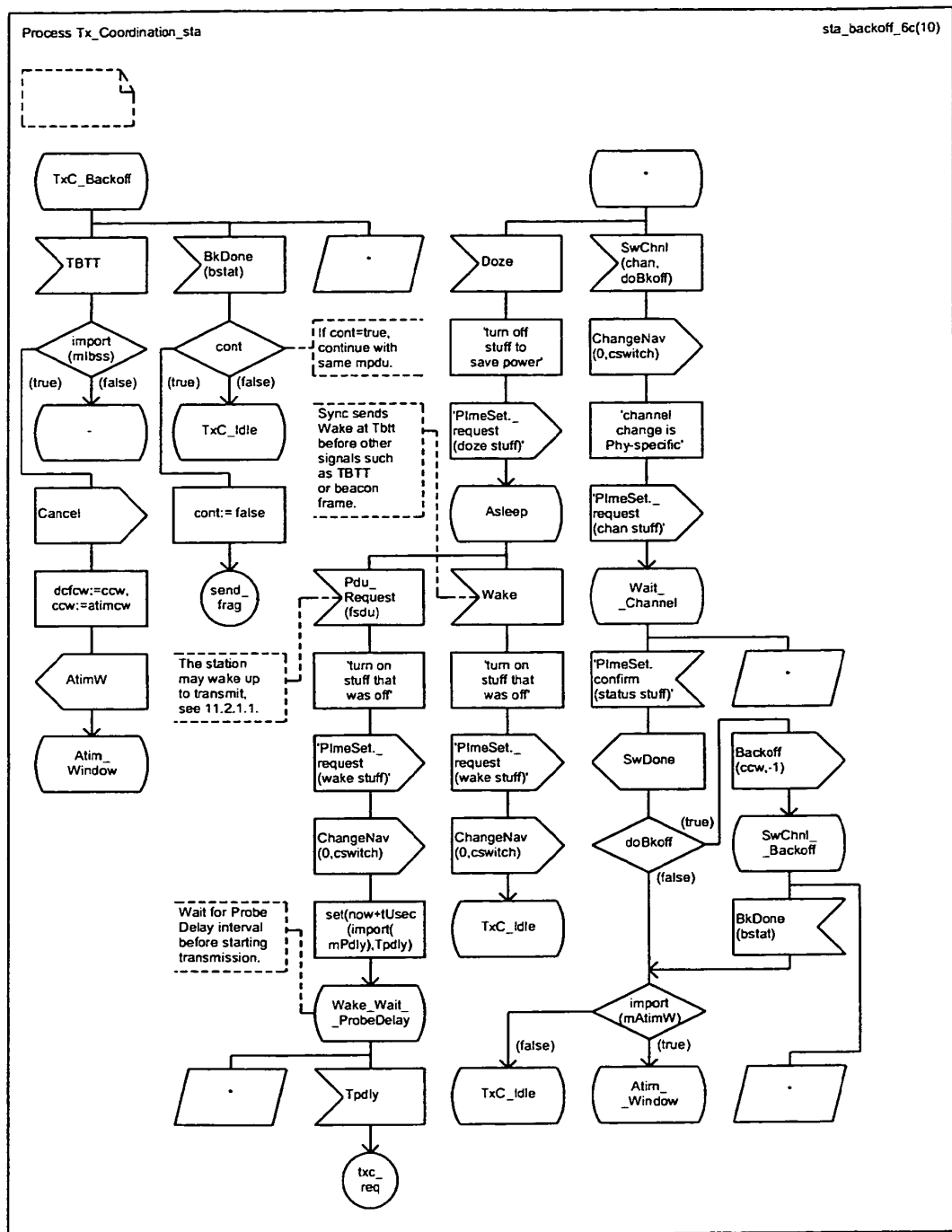




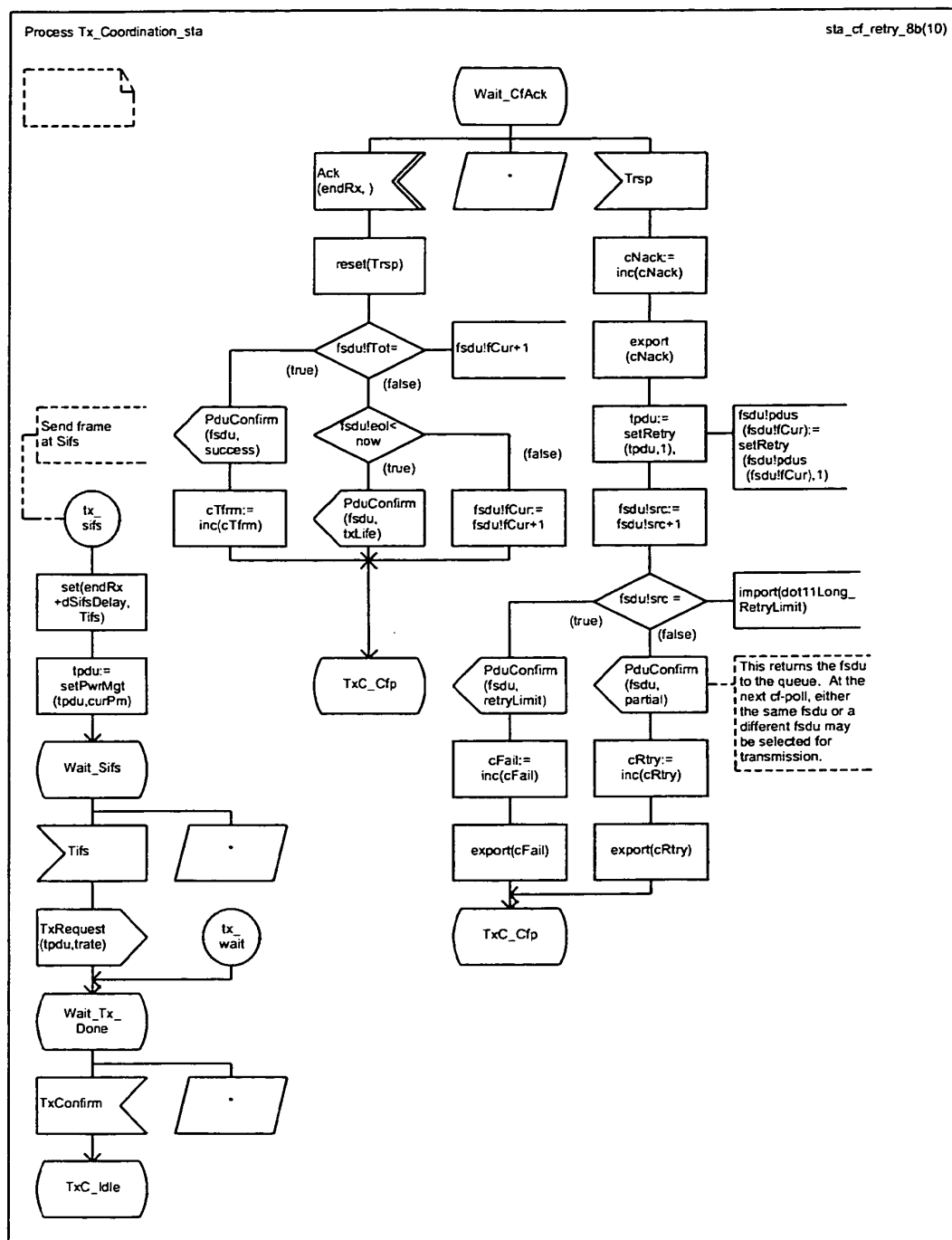


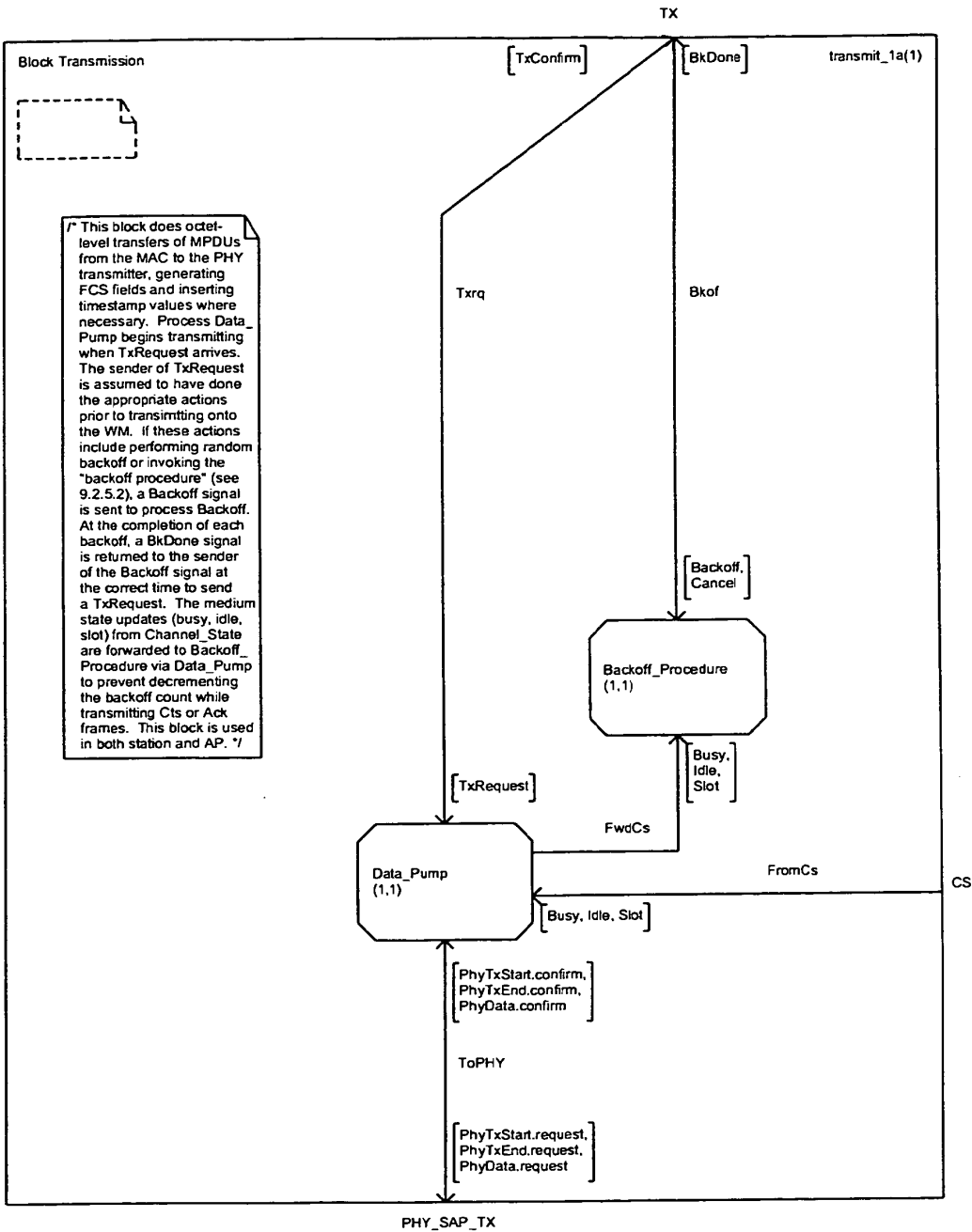


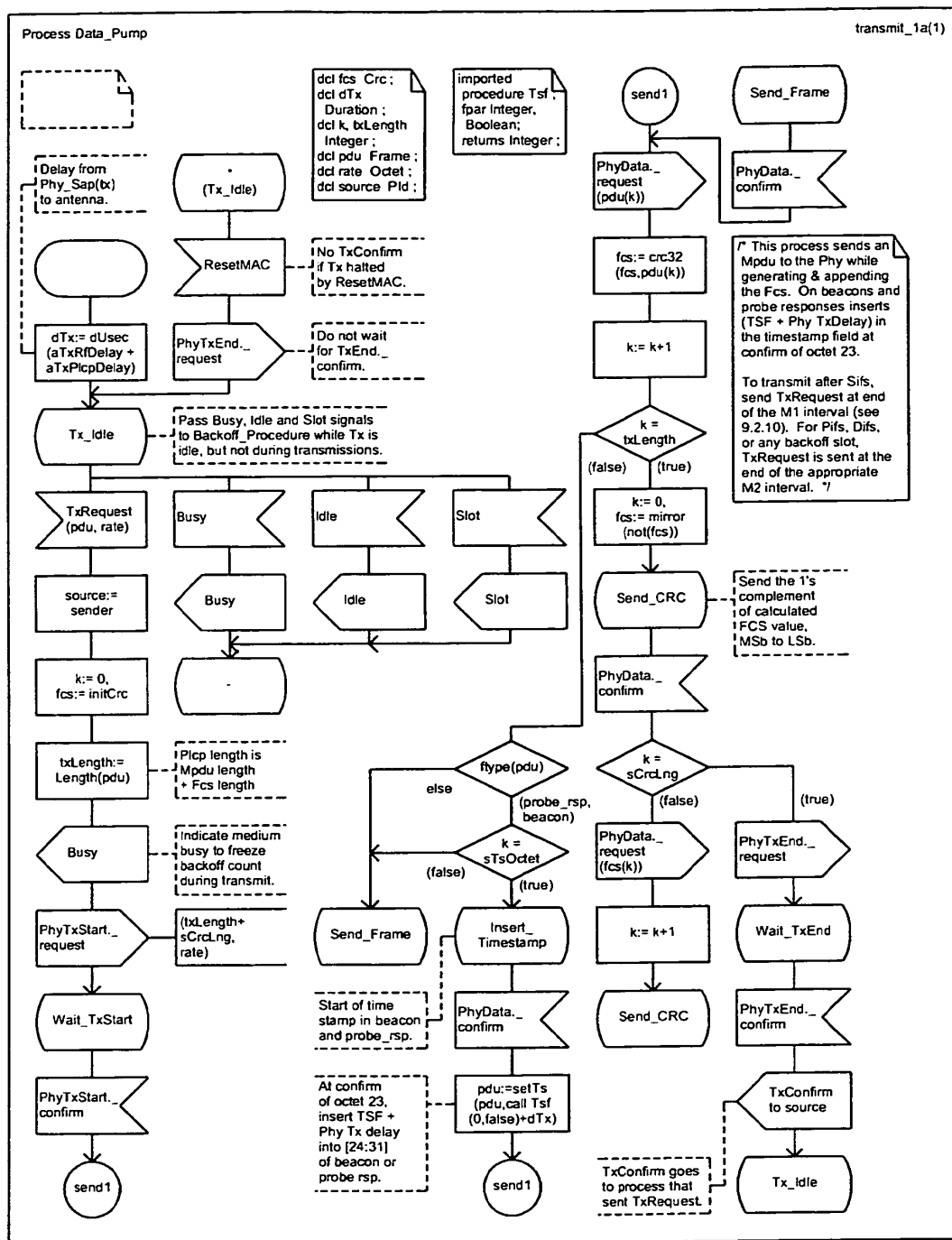


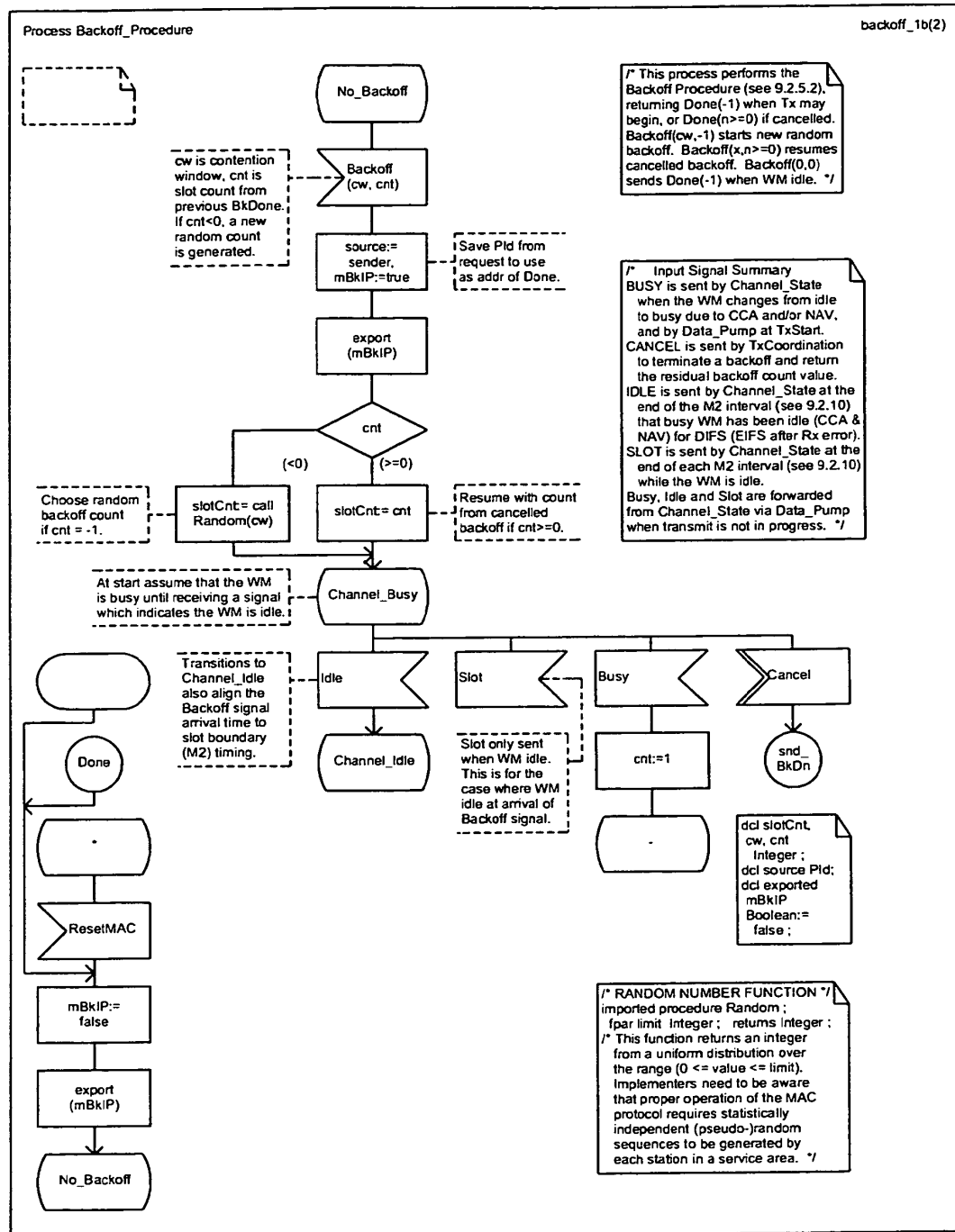


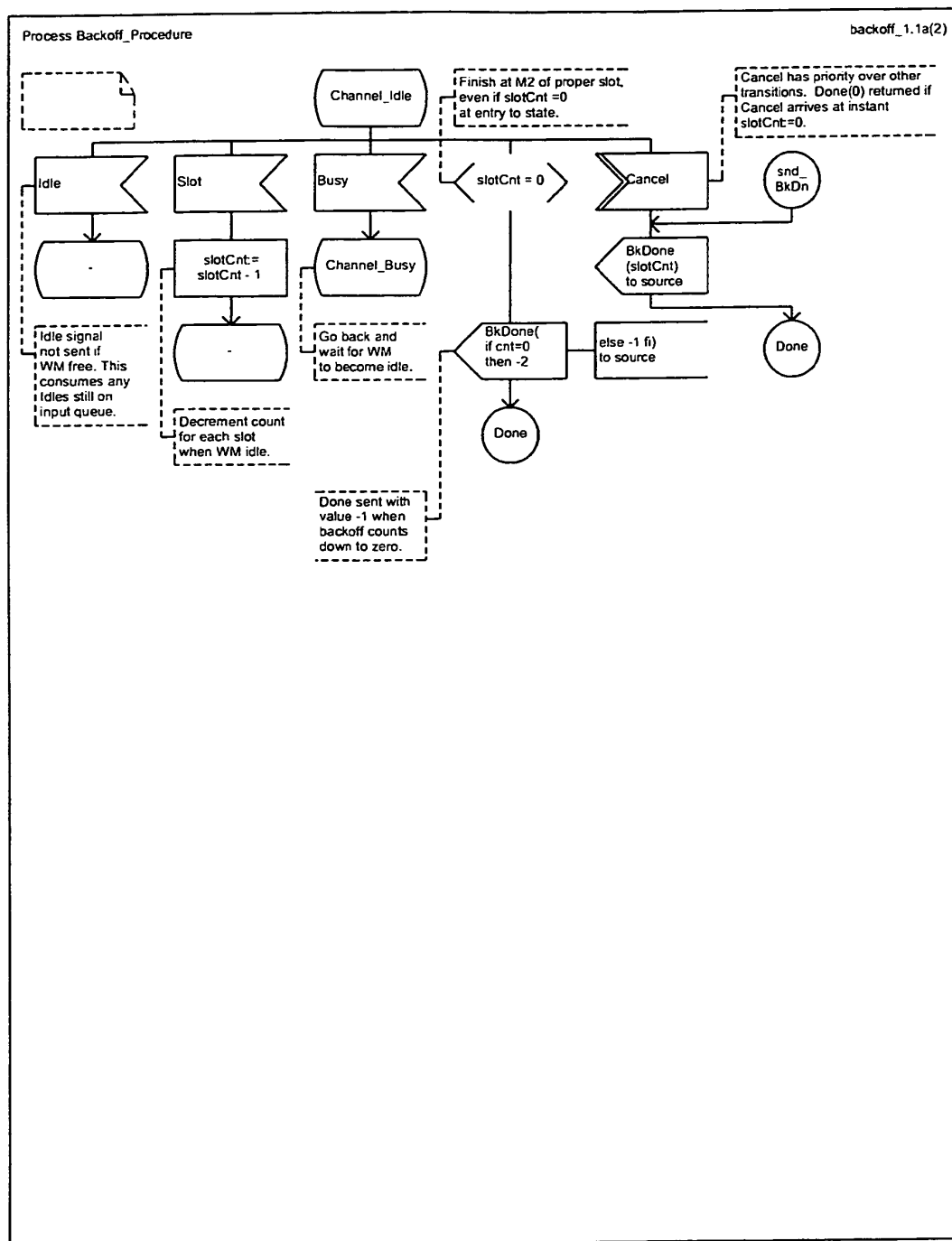


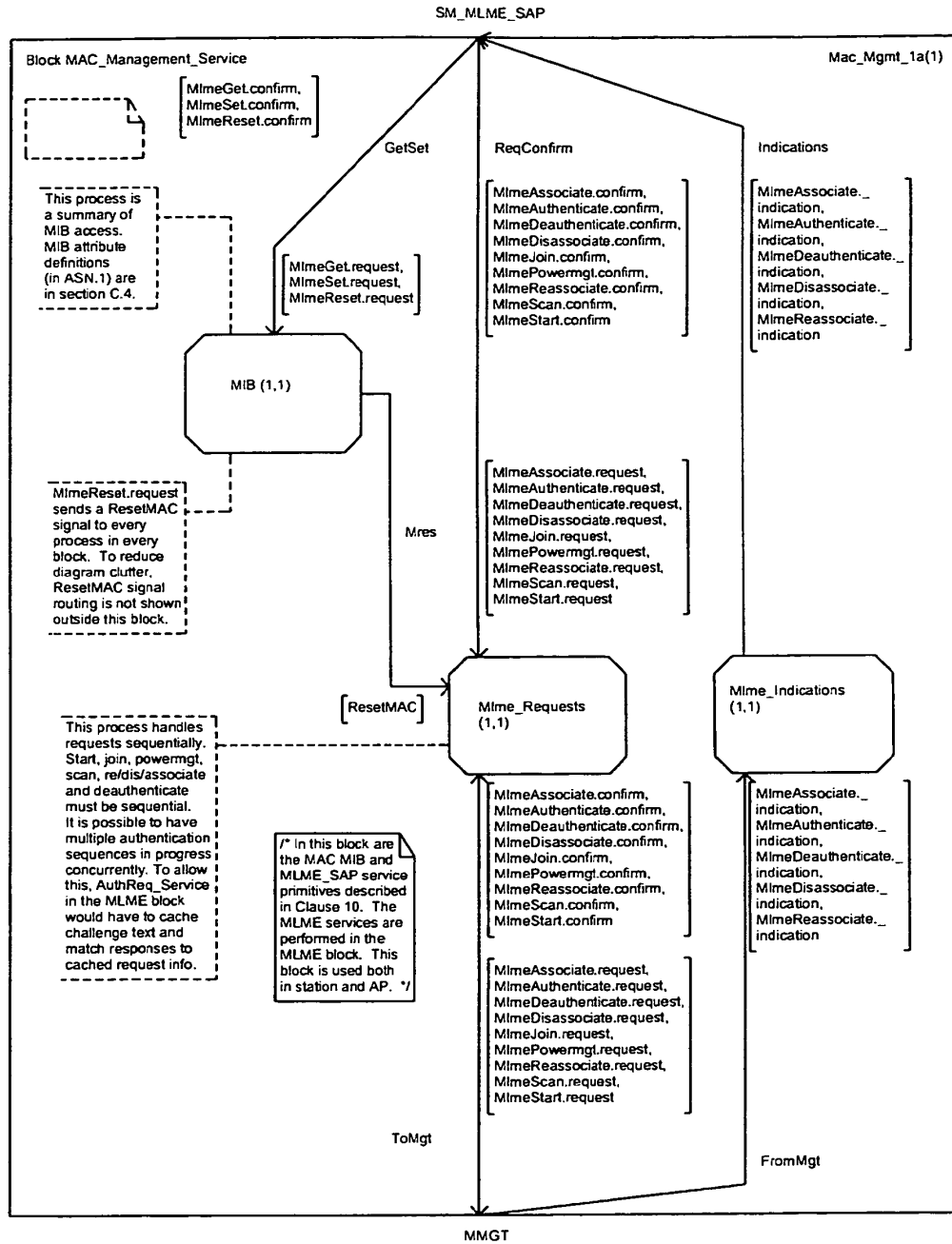


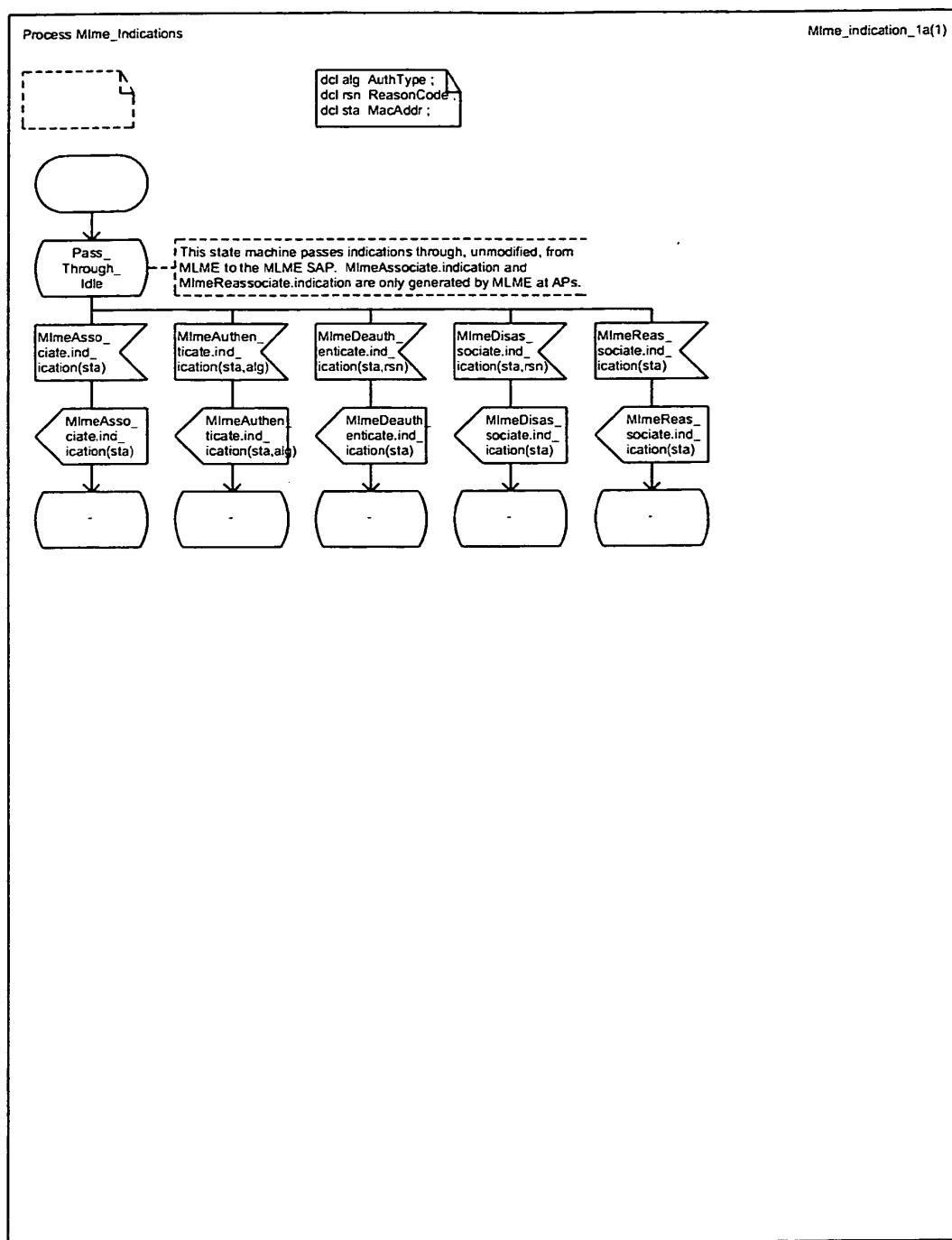


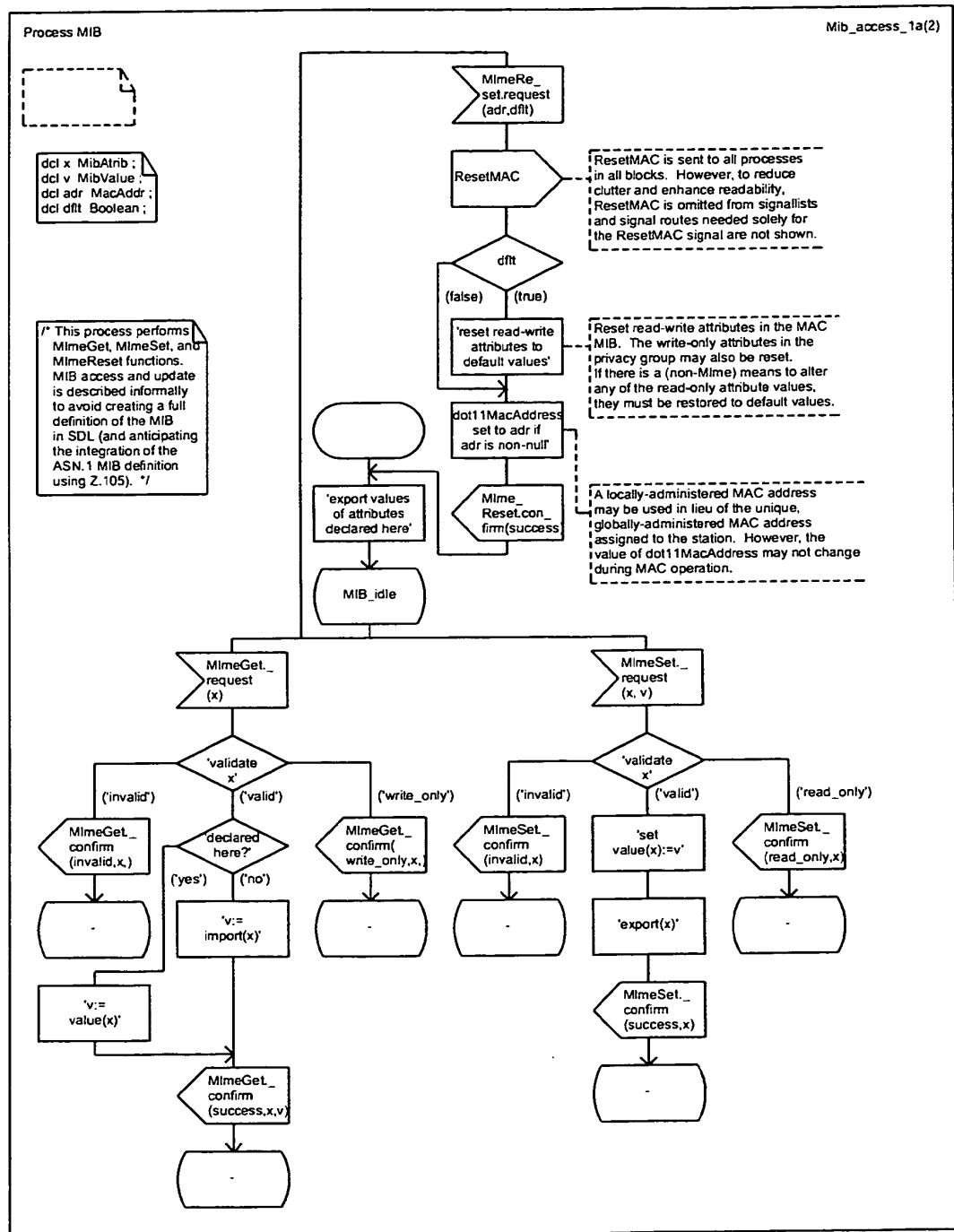












Process MIB

Mib_import_export_2b(2)

```

/* Import of (Read-Only) MIB counter
values exported from other processes */
imported
dot11AckFailureCount,
dot11FailedCount,
dot11FcsErrorCount,
dot11FrameDuplicateCount,
dot11MulticastReceivedFrameCount,
dot11MulticastTransmittedFrameCount,
dot11MultipleRetryCount,
dot11ReceivedFragmentCount,
dot11RetryCount,
dot11RtsFailureCount,
dot11RtsSuccessCount,
dot11TransmittedFragmentCount,
dot11WepExcludedCount,
dot11WepIcvErrorCount,
dot11WepUndecryptableCount Counter32 ;

```

```

/* The following Read-Only attributes in the
MAC MIB are defined as synonyms (named
constants) rather than remote variables
because they describe properties of the
station which are static, at least during
any single instance of MAC operation:
dot11AuthenticationAlgorithms AuthTypeSet,
dot11CfPollable Boolean,
dot11MacAddress MacAddr,
dot11ManufacturerID Octetstring,
dot11PrivacyOptionImplemented Boolean,
dot11ProductID Octetstring,
aStationID MacAddr,
dot11WepKeyMappingLength Integer ;

```

In addition, all Read-Only attributes in the PHY MIB which are accessed by the MAC are defined as synonyms.

*/

```

/* Declarations of MIB attributes exported from
this process */

```

```

/* Read-Write attributes */
dcl exported
dot11AuthenticationAlgorithms AuthTypeSet=
ind(open_system, shared_key),
dot11ExcludeUnencrypted Boolean:= false,
dot11FragmentationThreshold Integer:= 2346,
dot11GroupAddresses MacAddrSet:= empty,
dot11LongRetryLimit Integer:= 4,
dot11MaxReceiveLifetime Kusec:= 512,
dot11MaxTransmitMsduLifetime Kusec:= 512,
dot11MediumOccupancyLimit Kusec:= 100,
dot11PrivacyInvoked Boolean:= false,
mReceivedTIMs Boolean:= true,
dot11CfpPeriod Integer:= 1,
dot11CfpMaxDuration Kusec:= 200,
dot11AuthenticationResponseTimeout Kusec:= 512,
dot11RtsThreshold Integer:= 3000,
dot11ShortRetryLimit Integer:= 7,
dot11WepDefaultKeyId KeyIndex:= 0,
dot11CurrentChannelNumber Integer:= 0,
dot11CurrentSet Integer:= 0,
dot11CurrentPattern Integer:= 0,
dot11CurrentIndex Integer:= 0 ;

```

```

/* Write-Only attributes */
dcl exported
dot11WepDefaultKeys KeyVector:= nullKey,
dot11WepKeyMappings
KeyMapArray:= (. nullAddr, false, nullKey .) ;

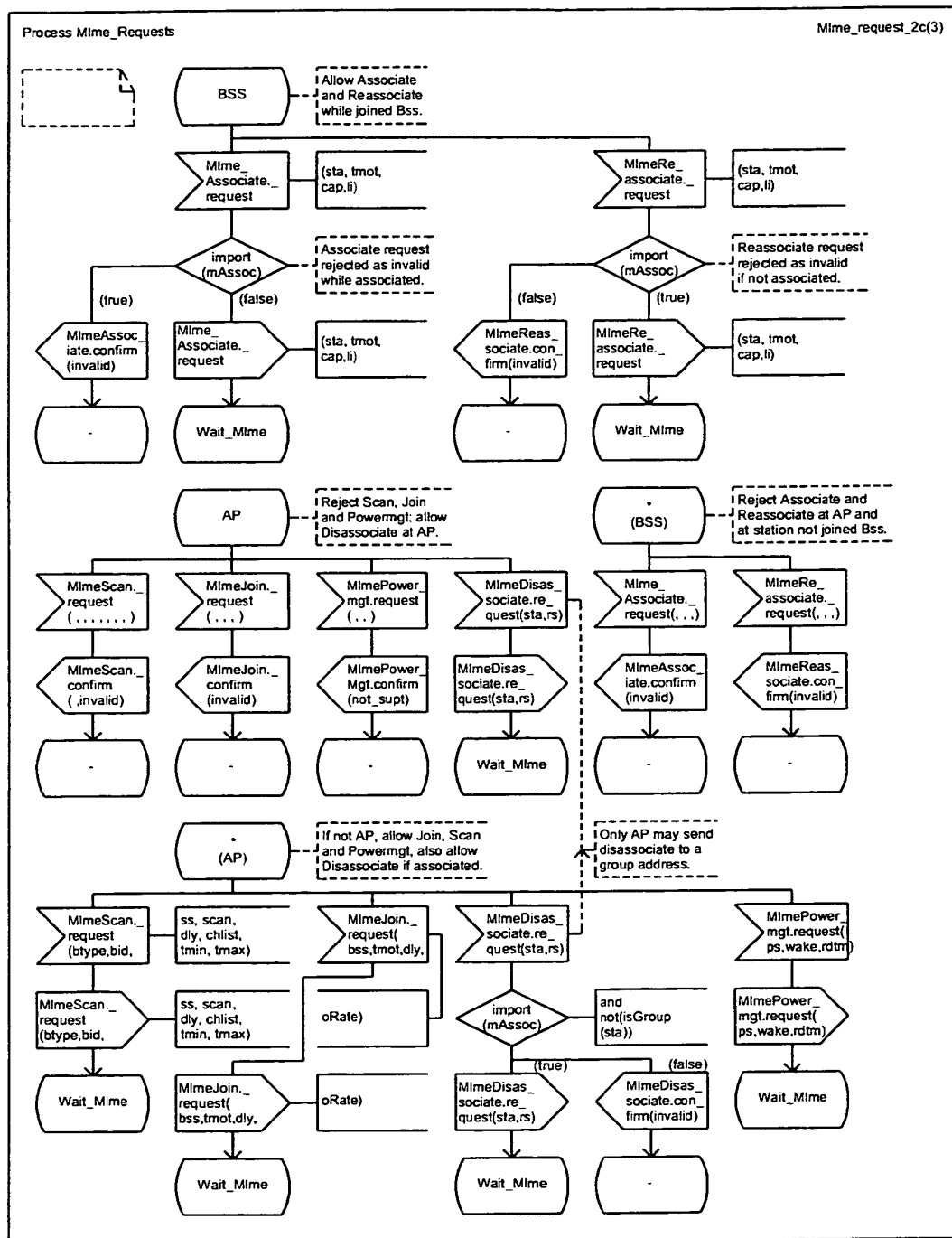
```

```

/* NOTE:
The values listed for MAC MIB attributes are the
specified default values for those attributes.
The values listed for PHY MIB attributes are either
the default values for the FH PHY, or arbitrary
values within the specified range. The specific
values for PHY attributes in this SDL description
of the MAC do not have normative significance.
*/

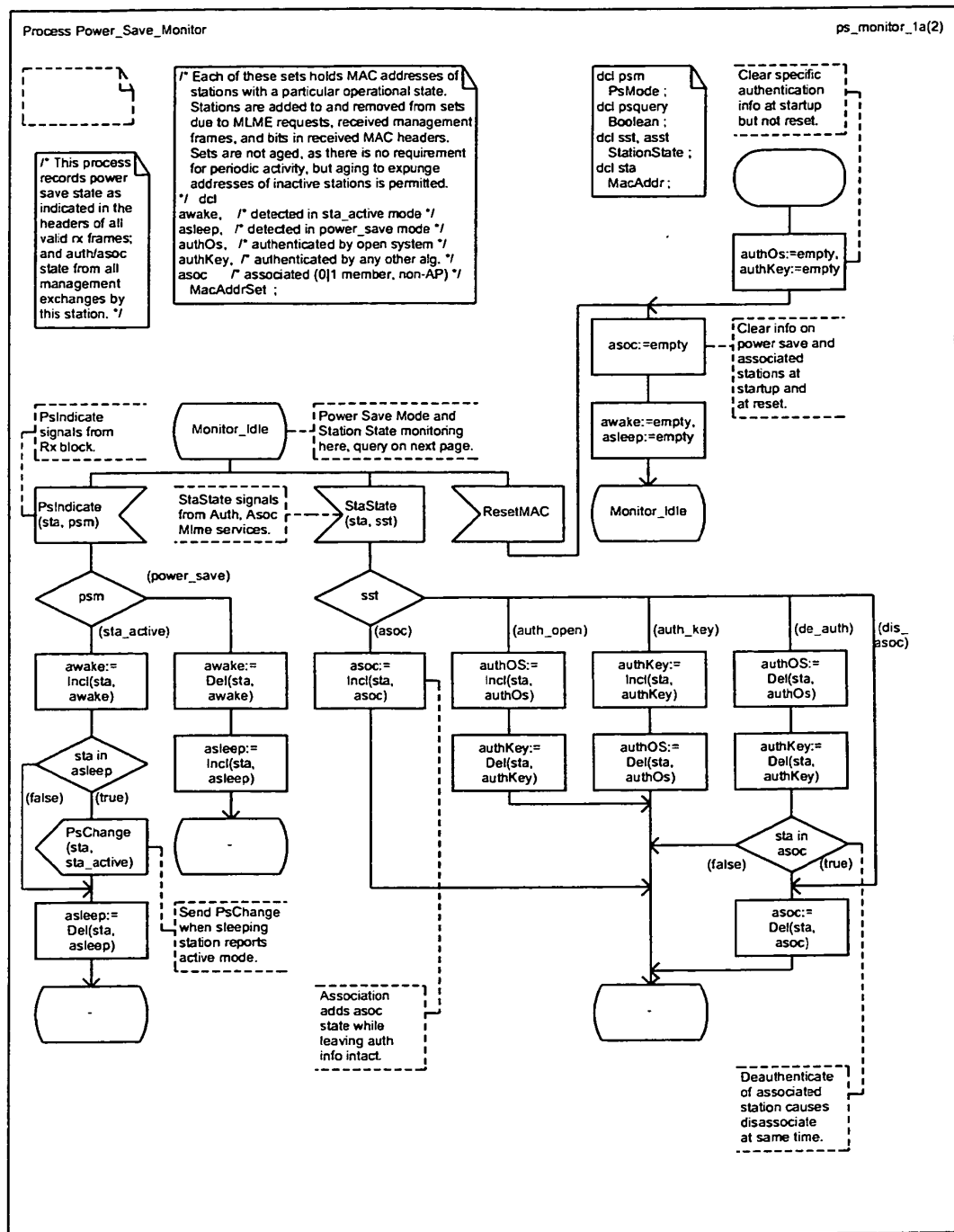
```

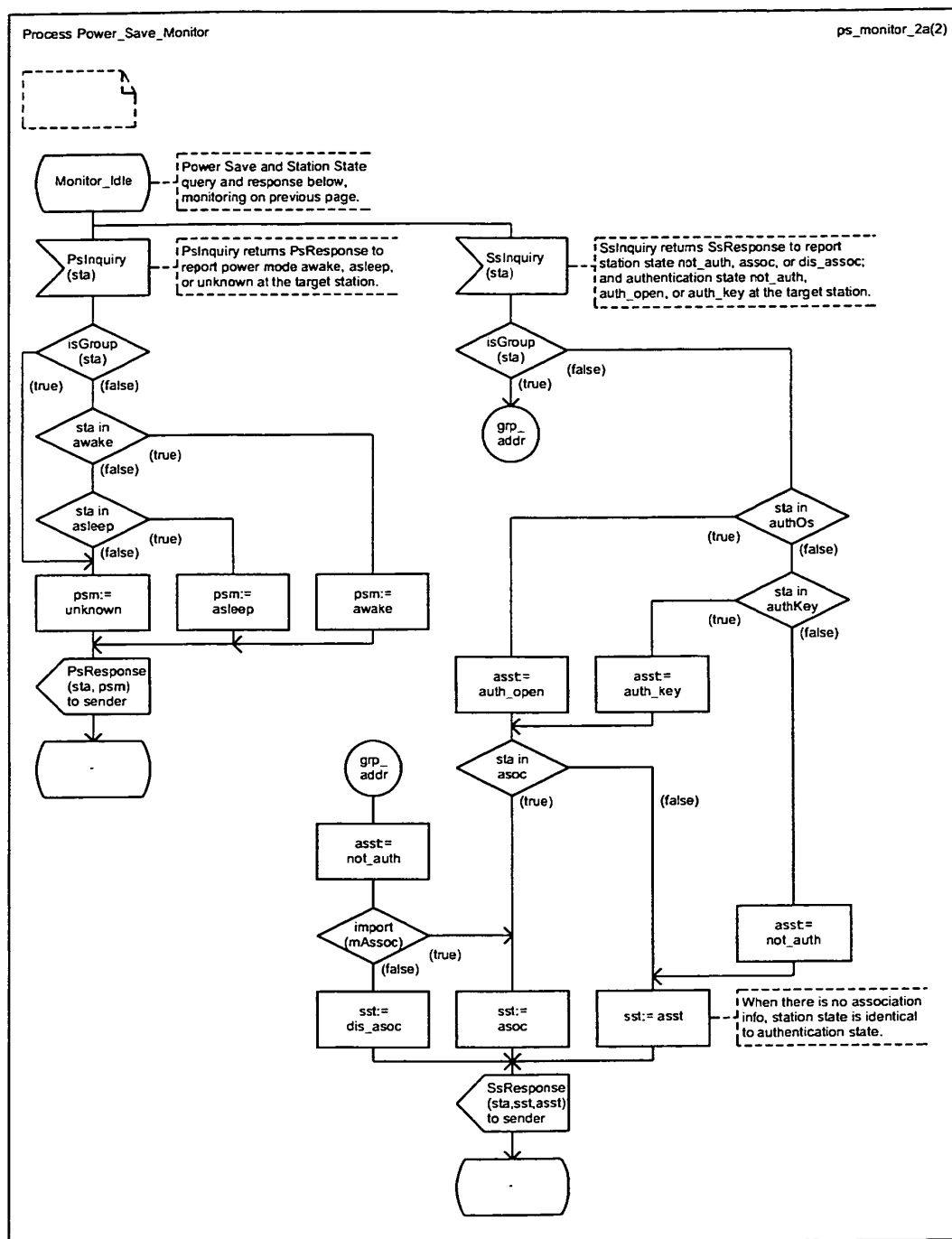


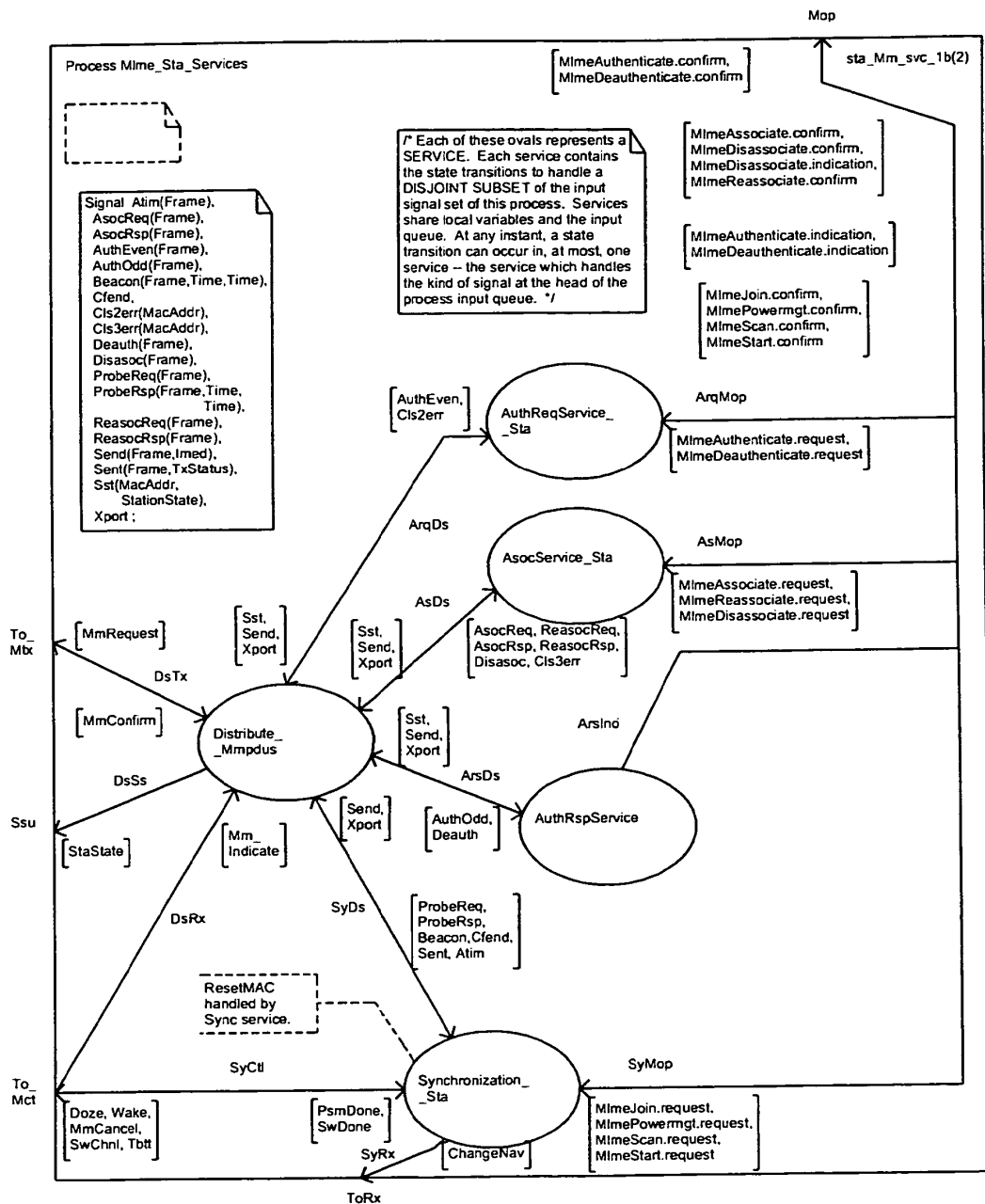


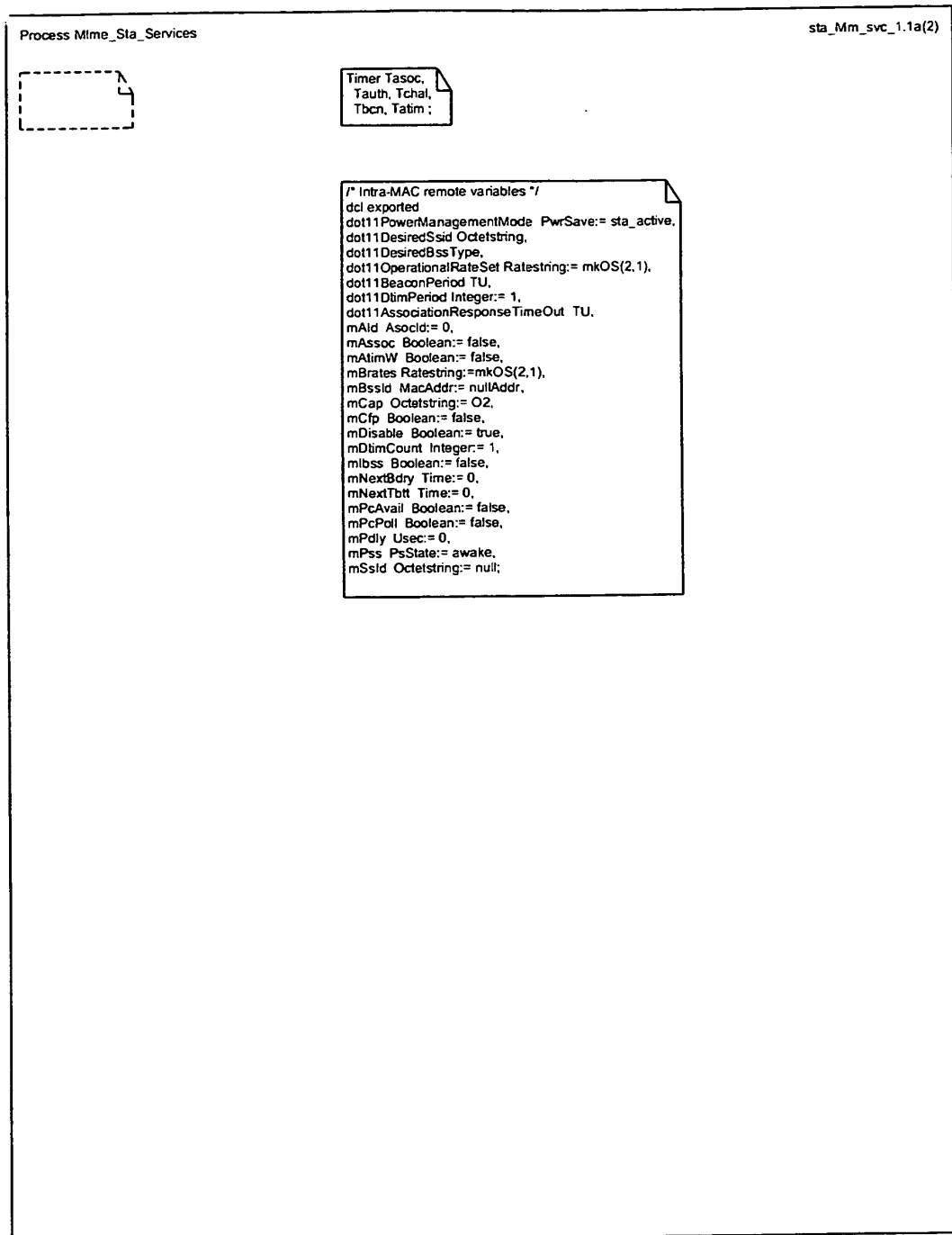


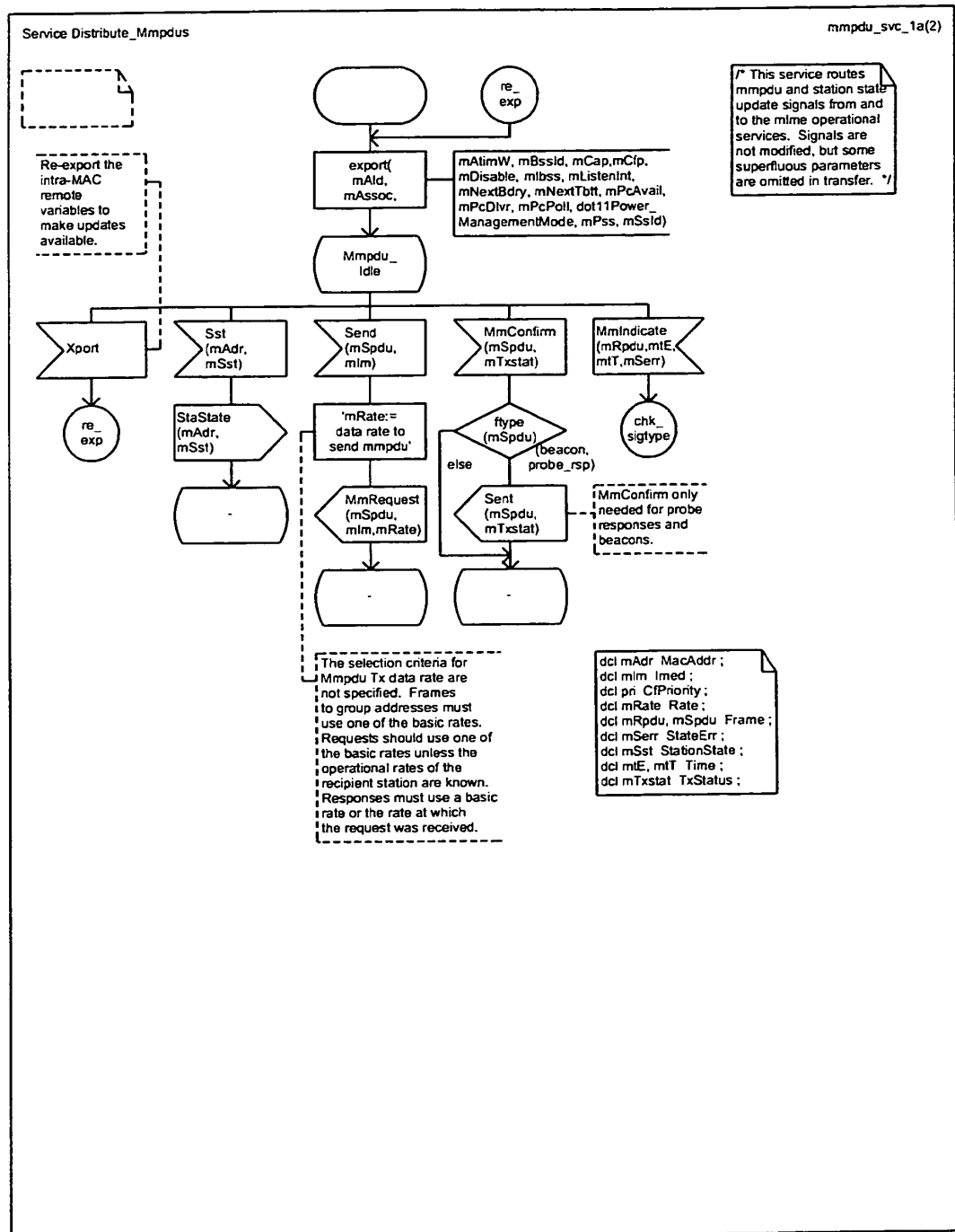


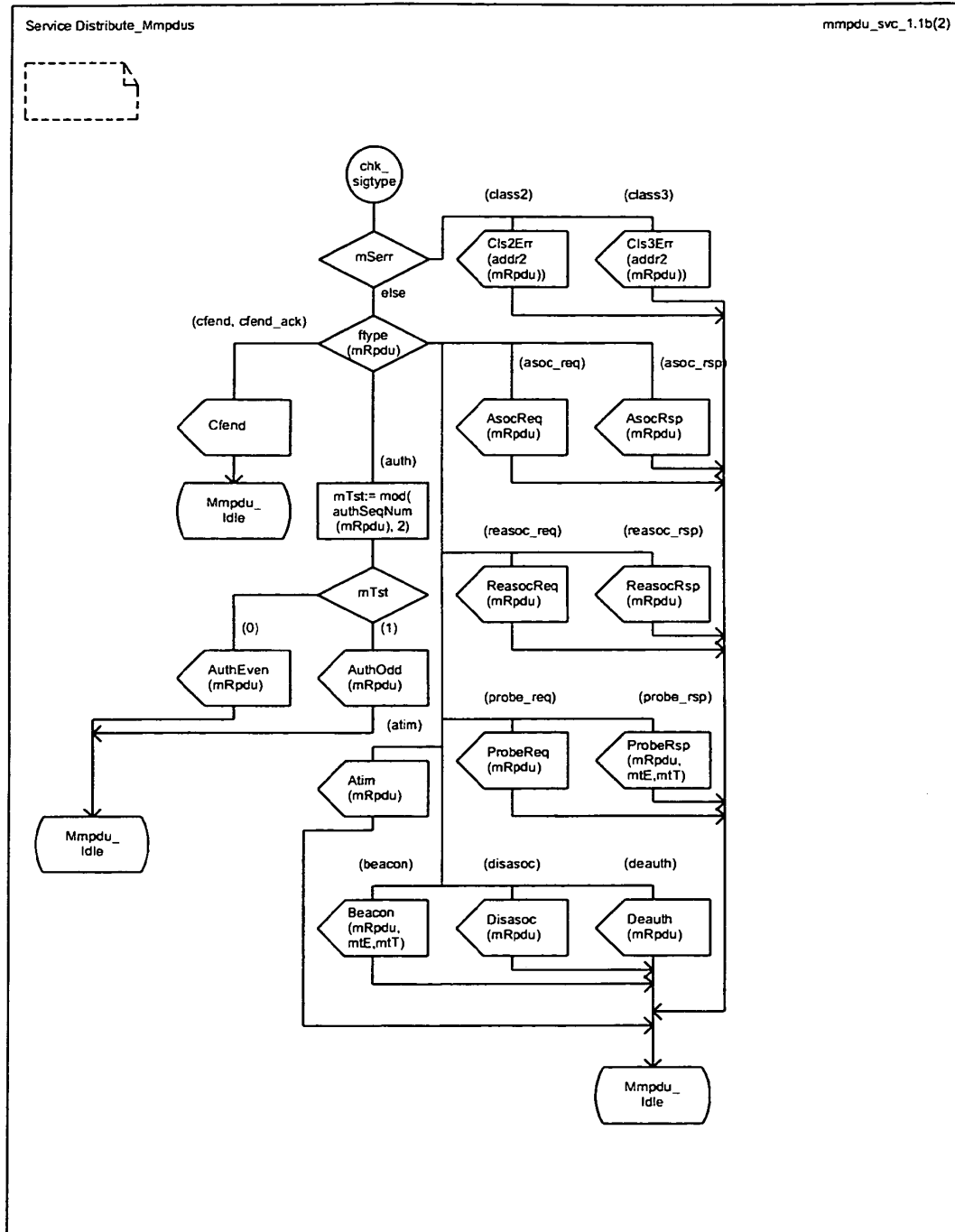




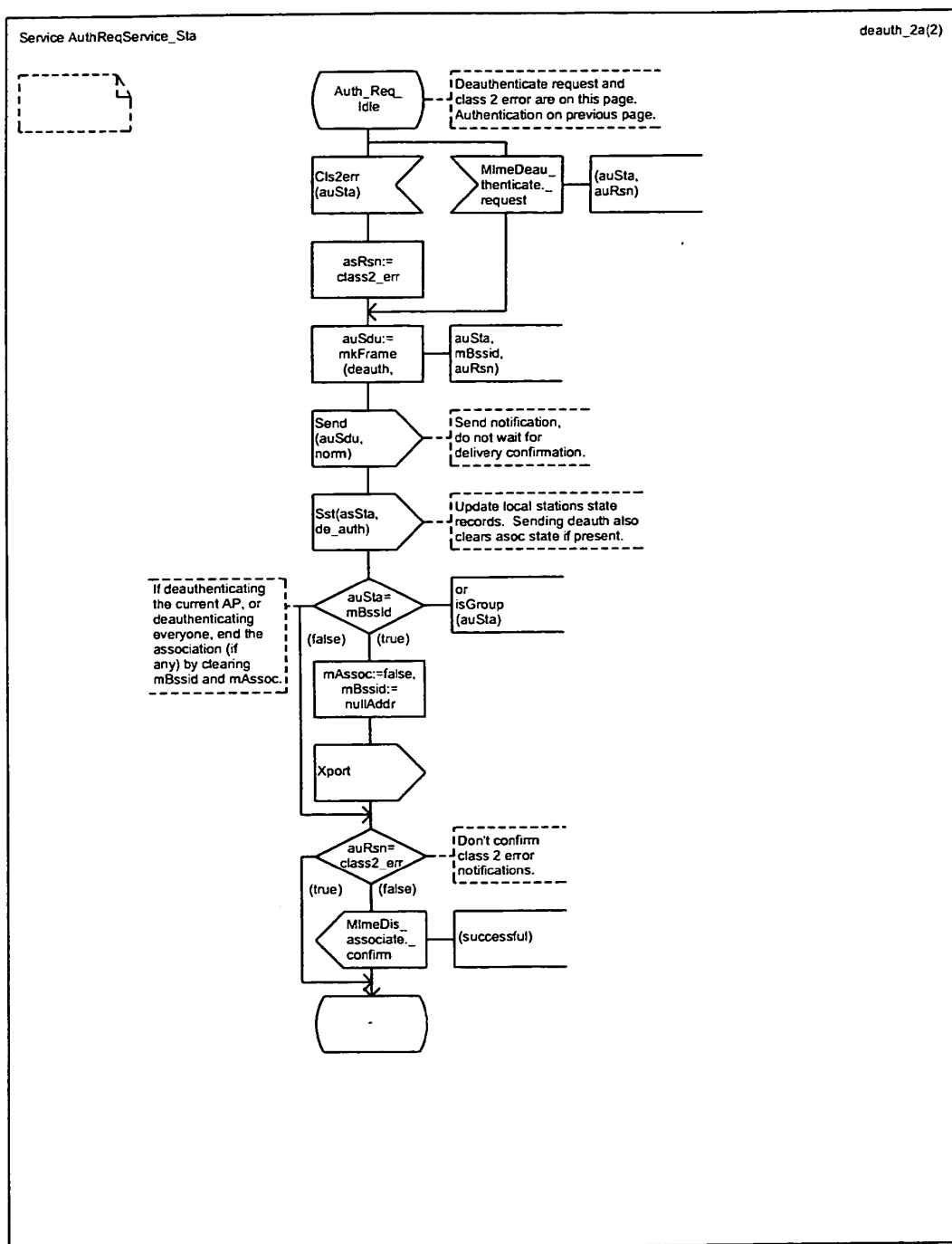


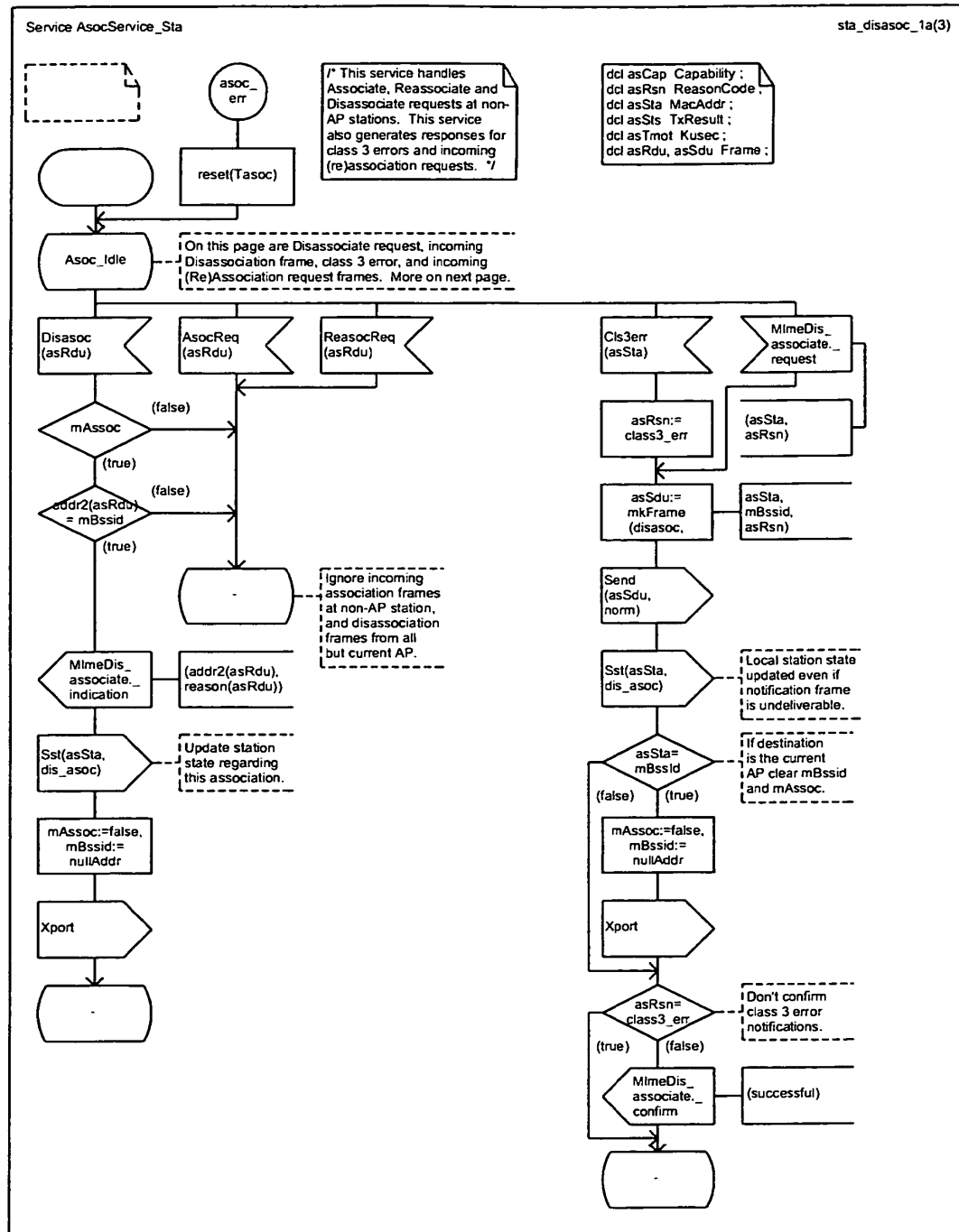


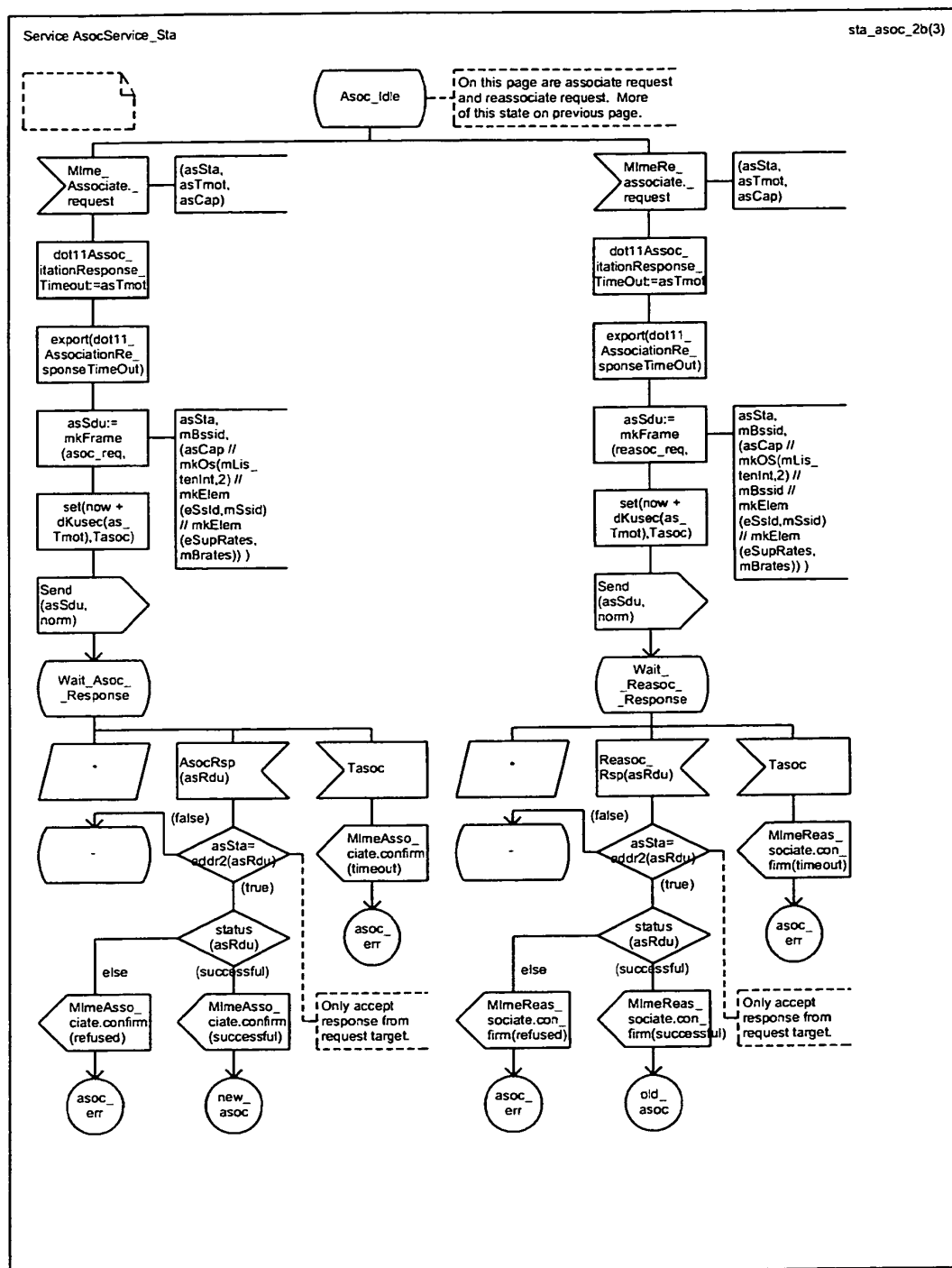


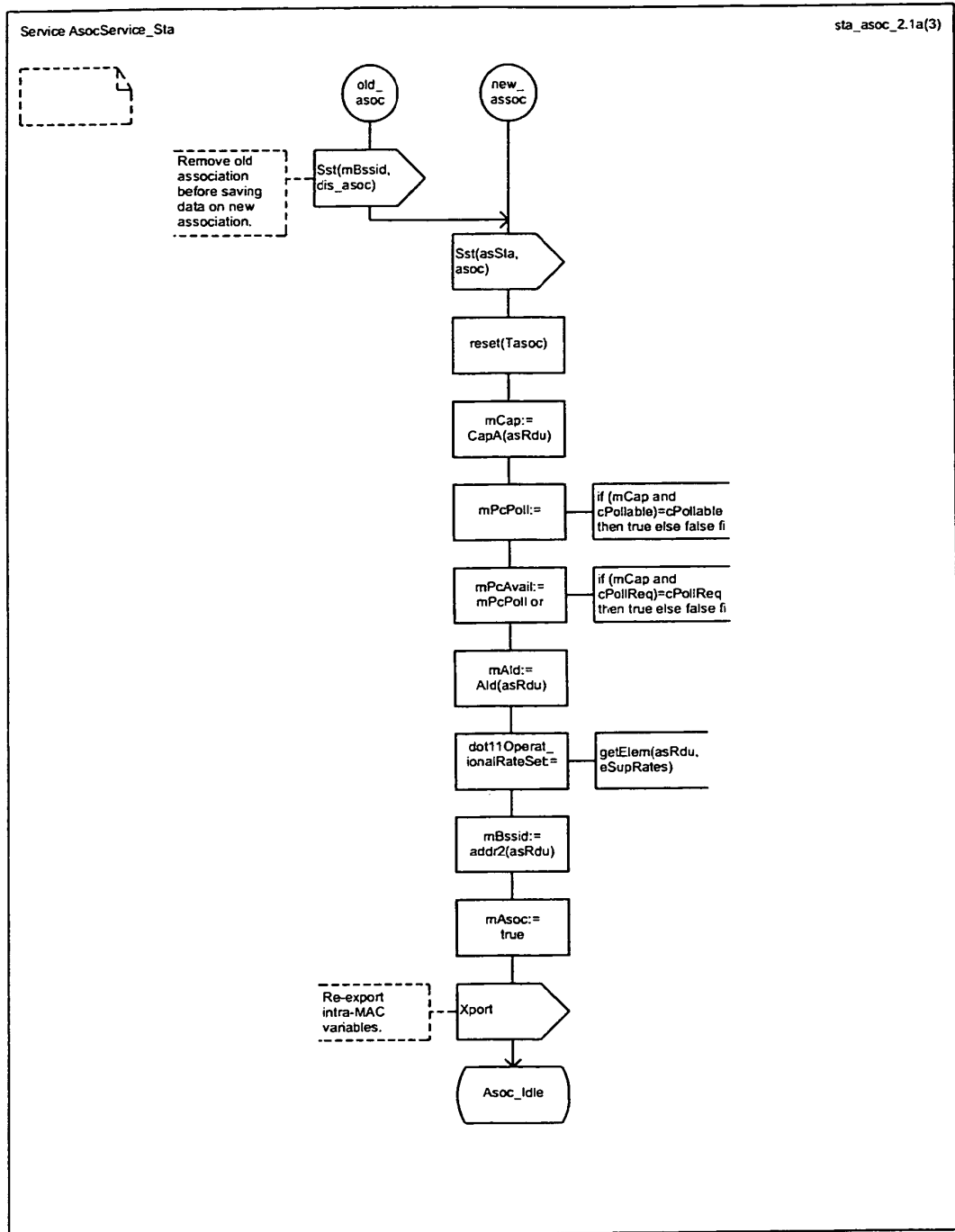


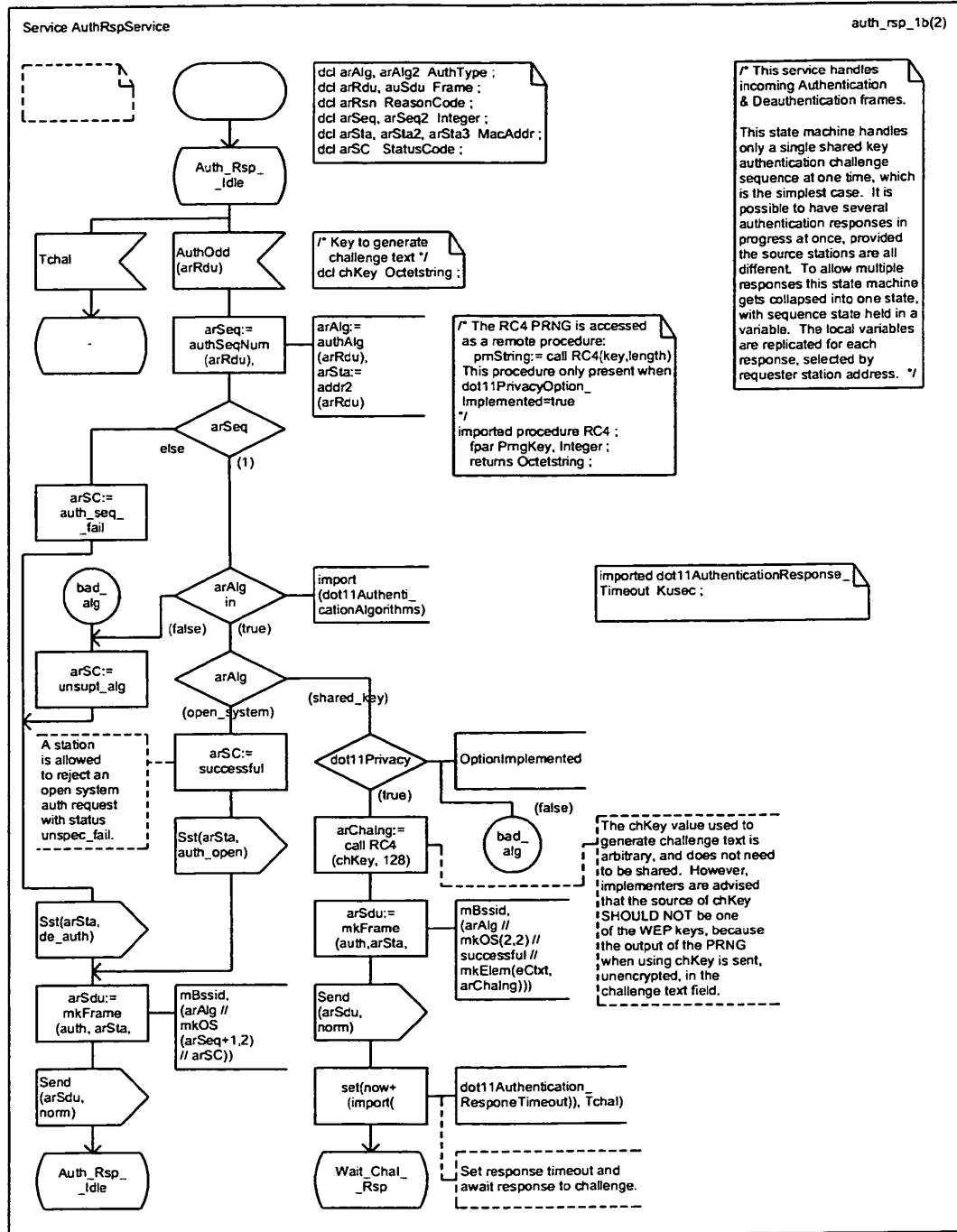


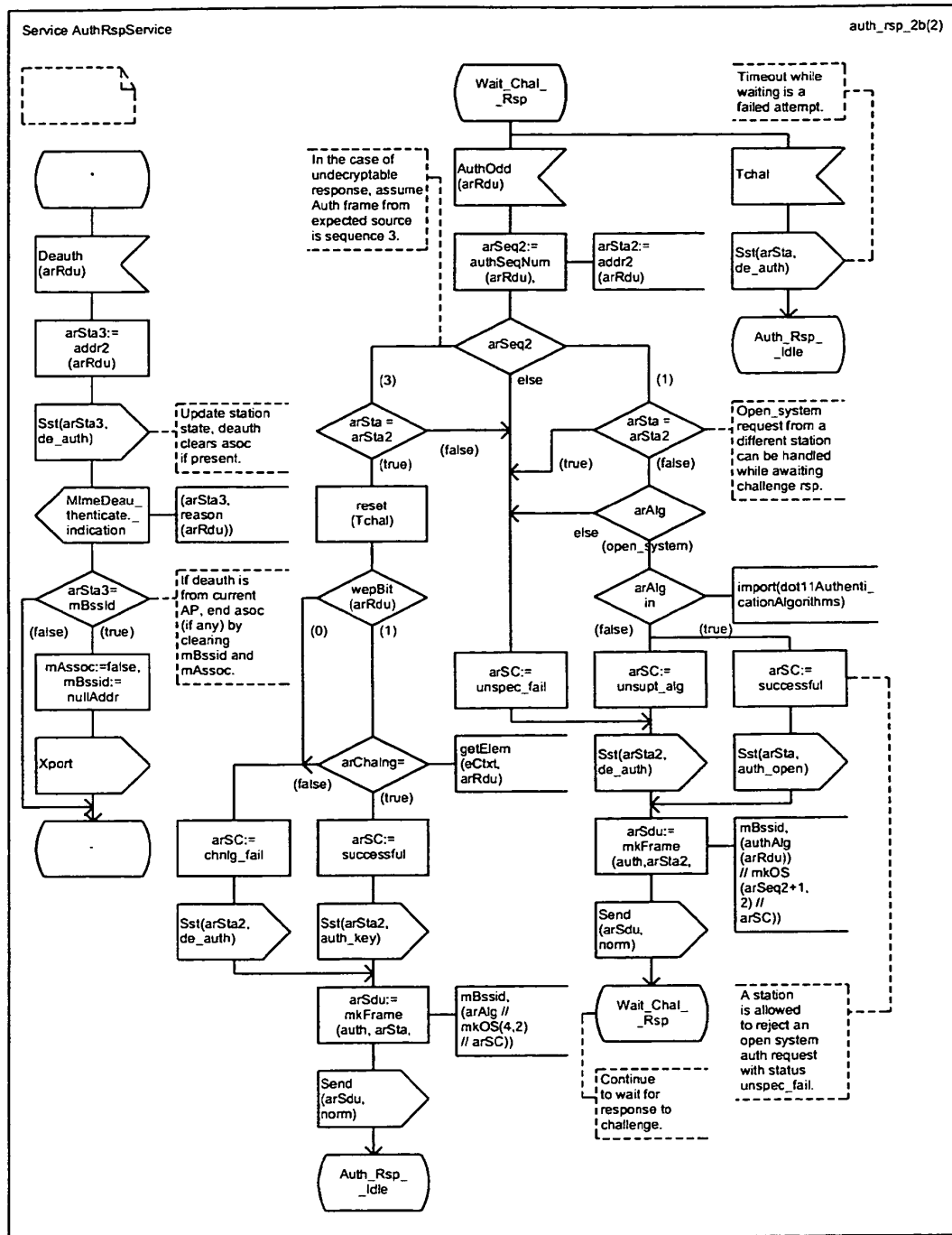


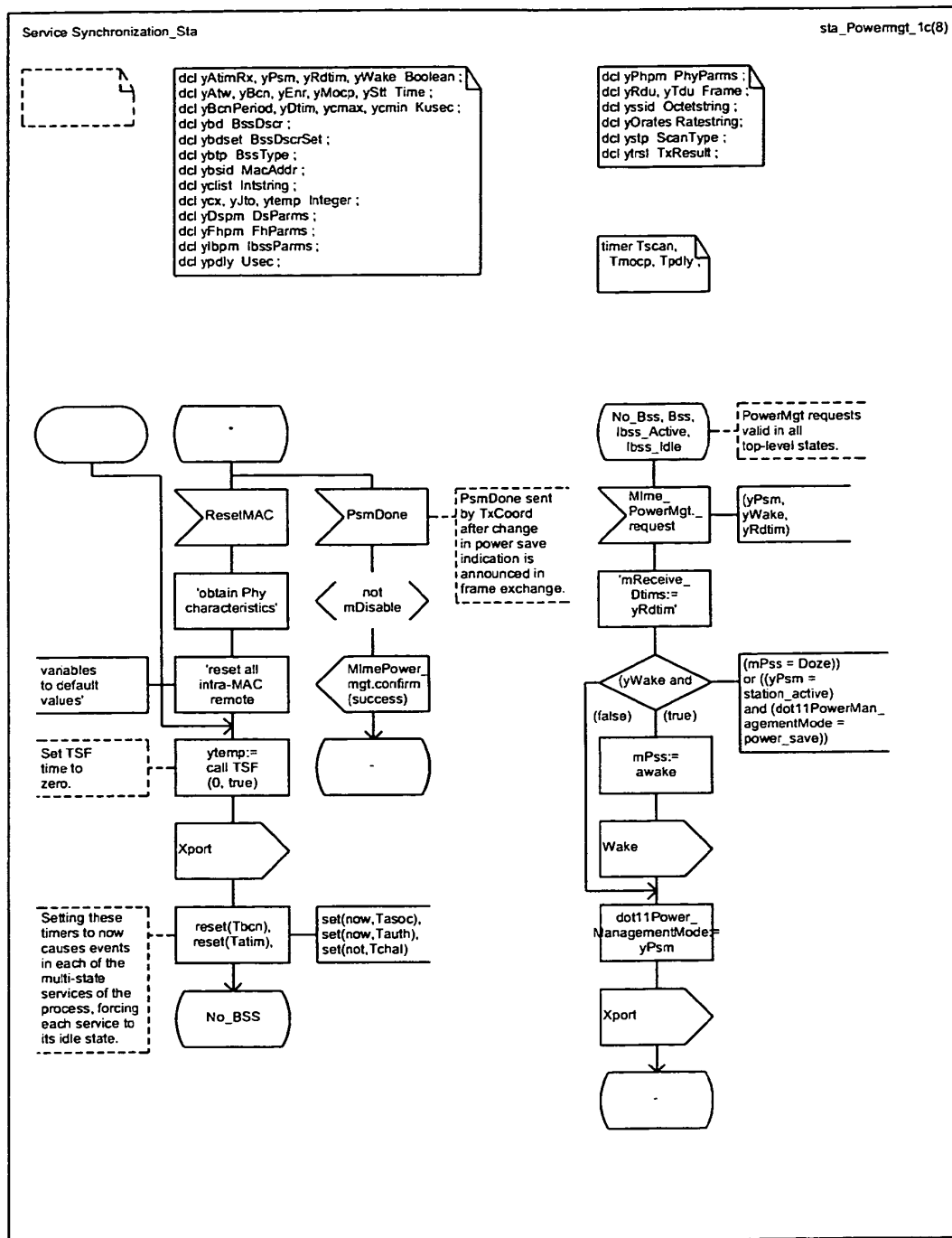


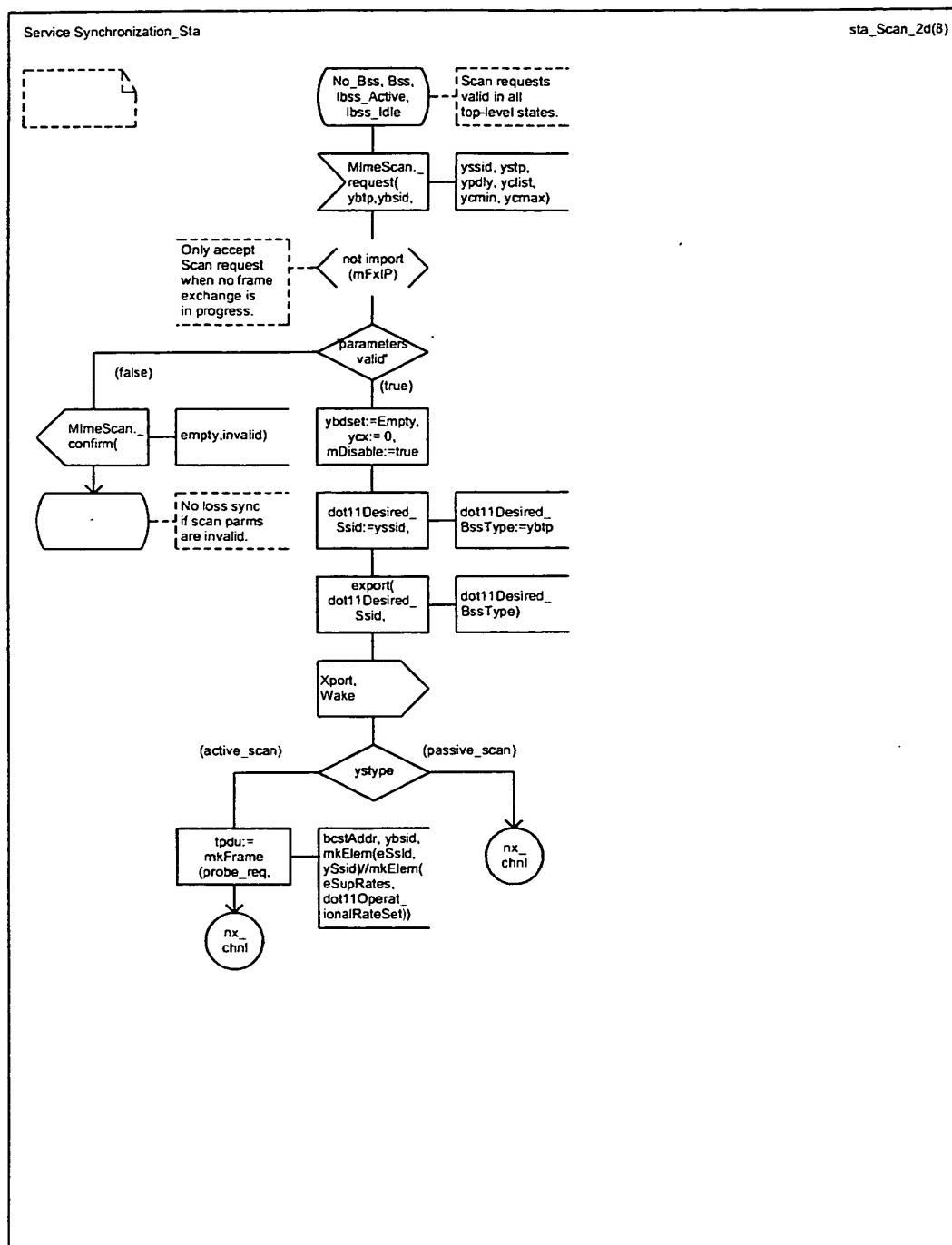


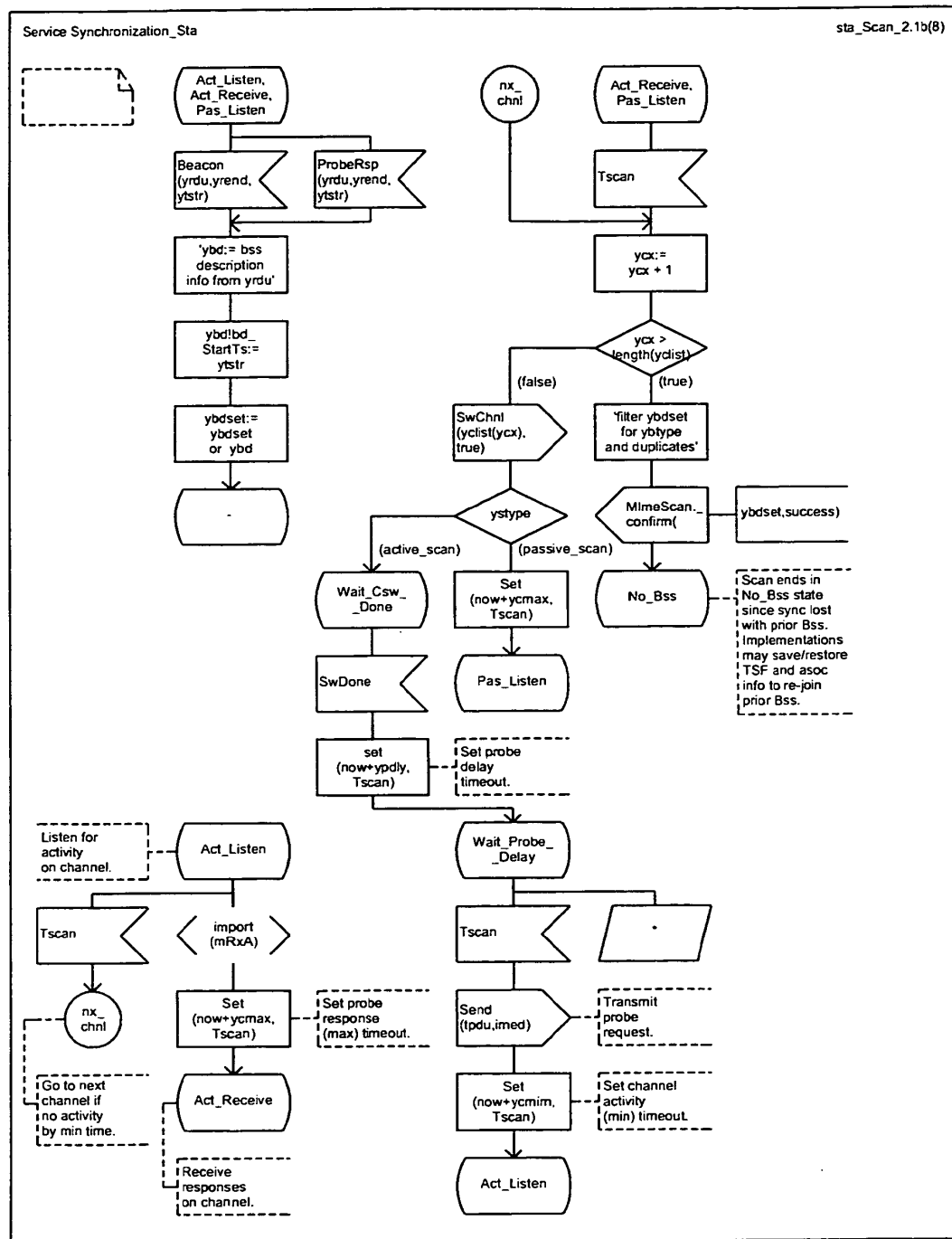


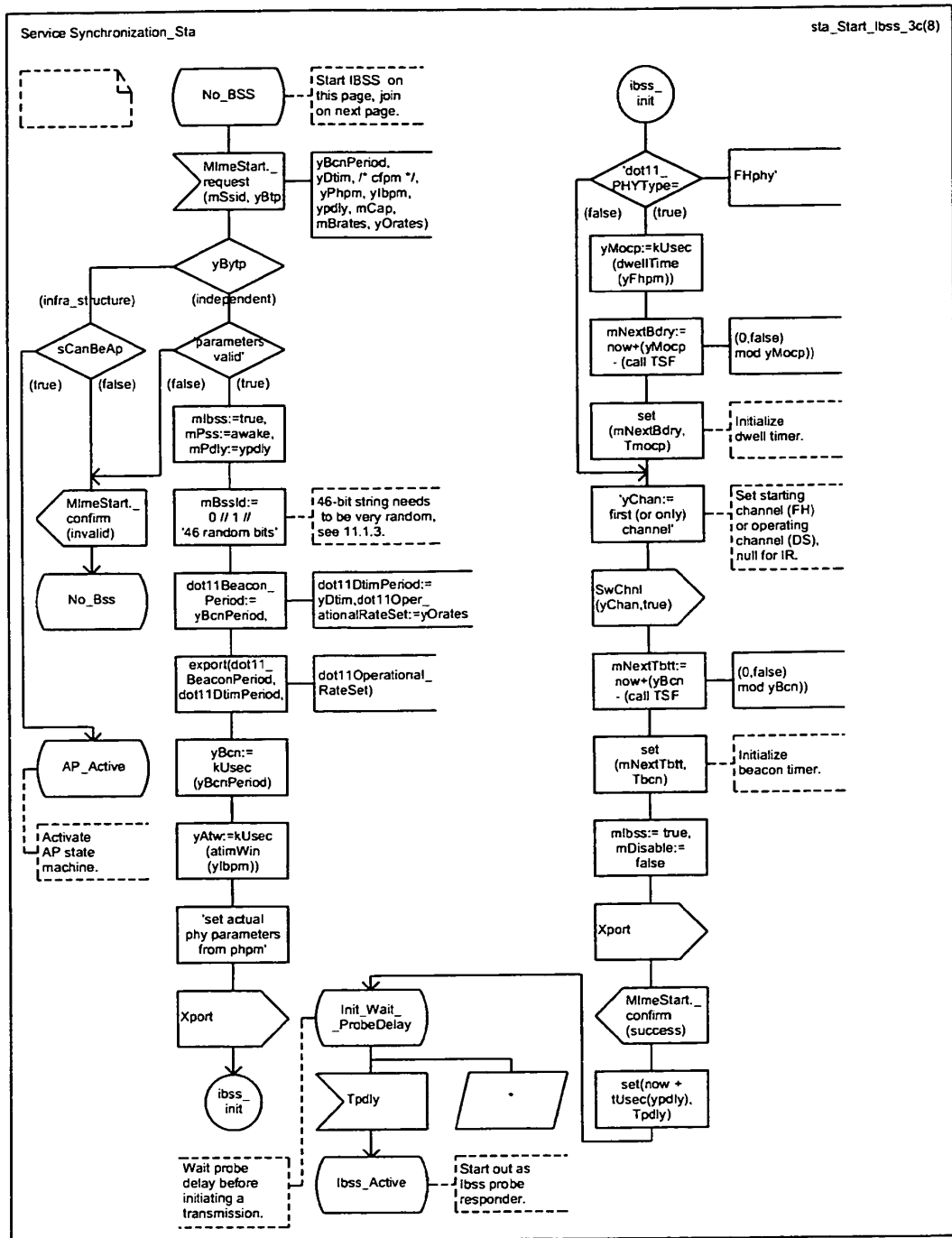


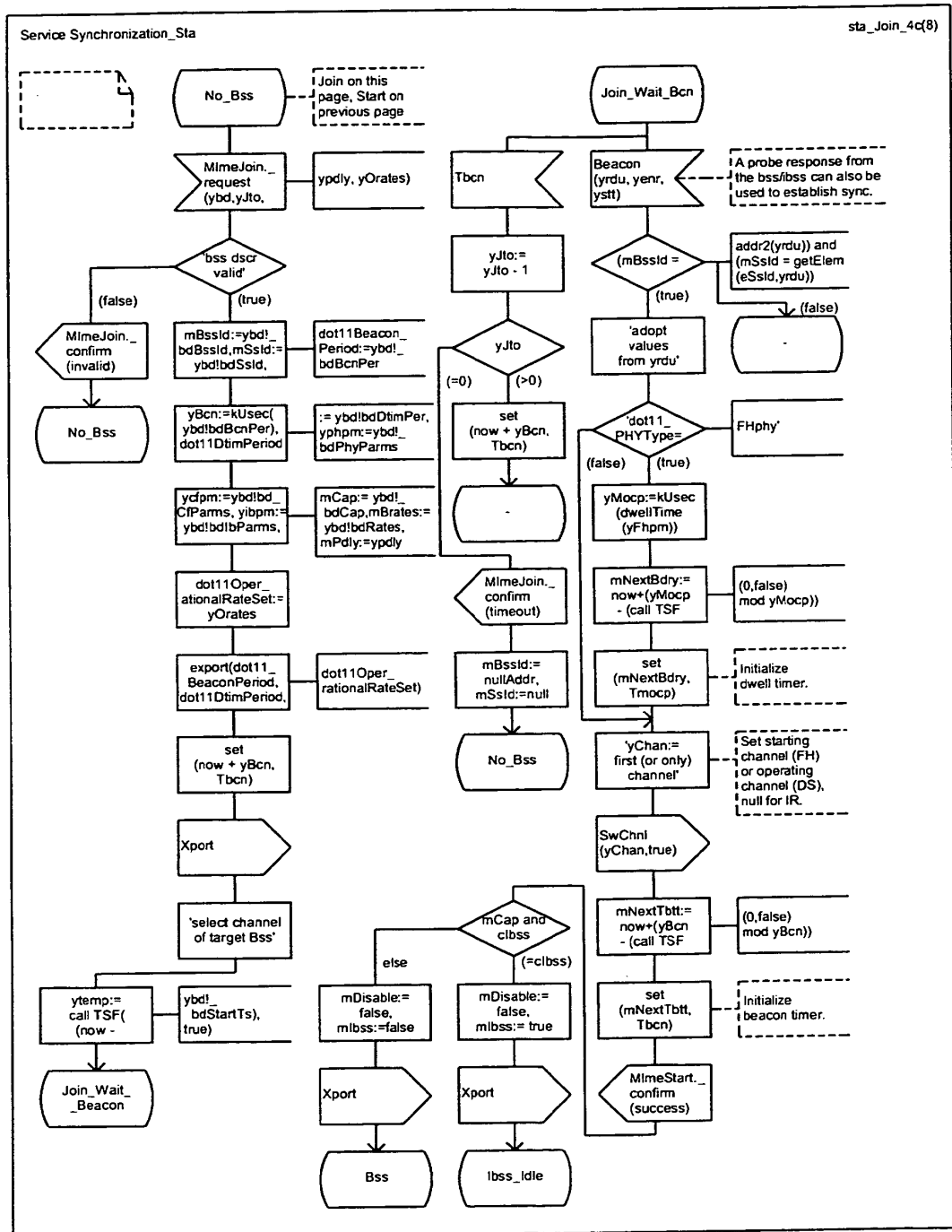


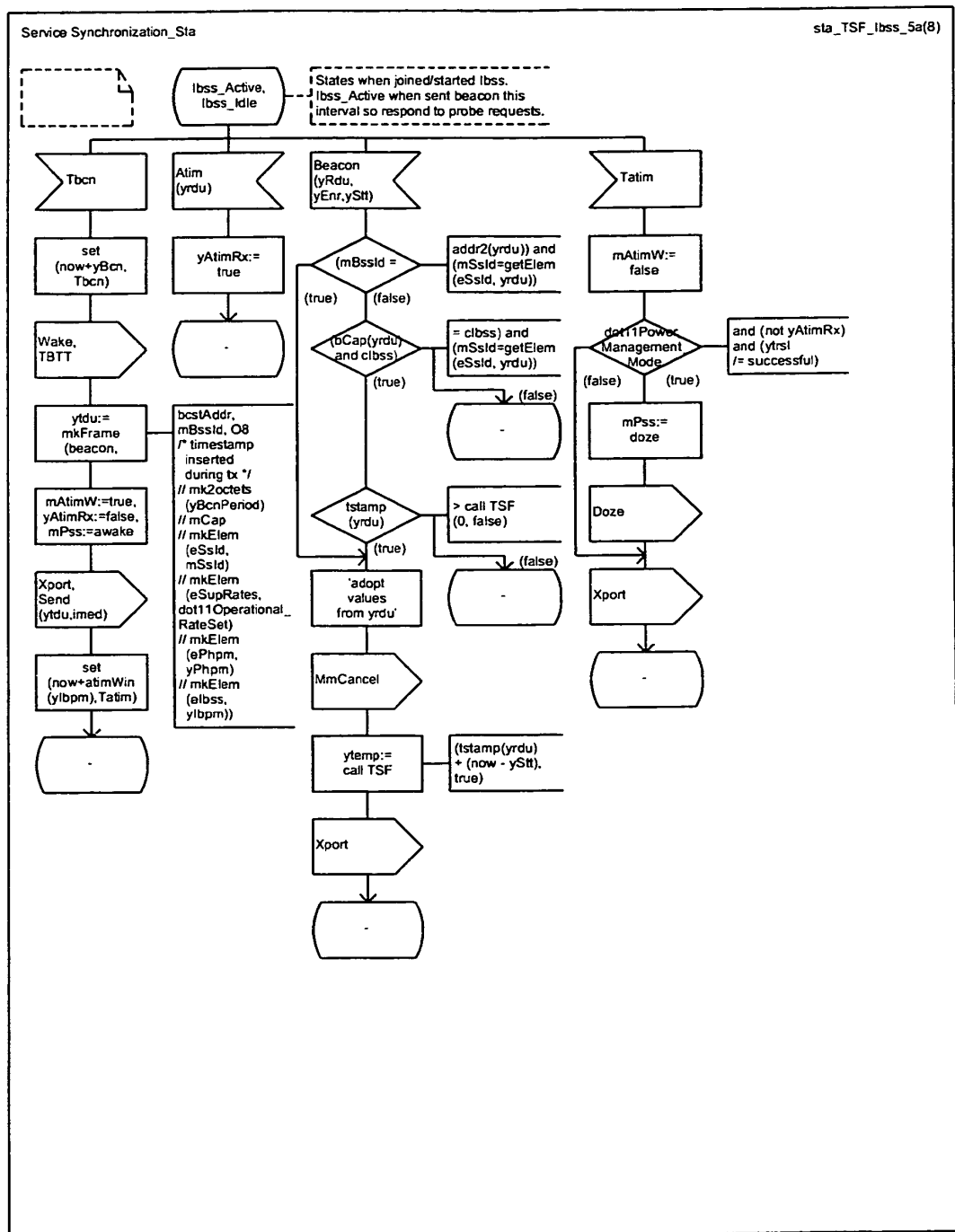


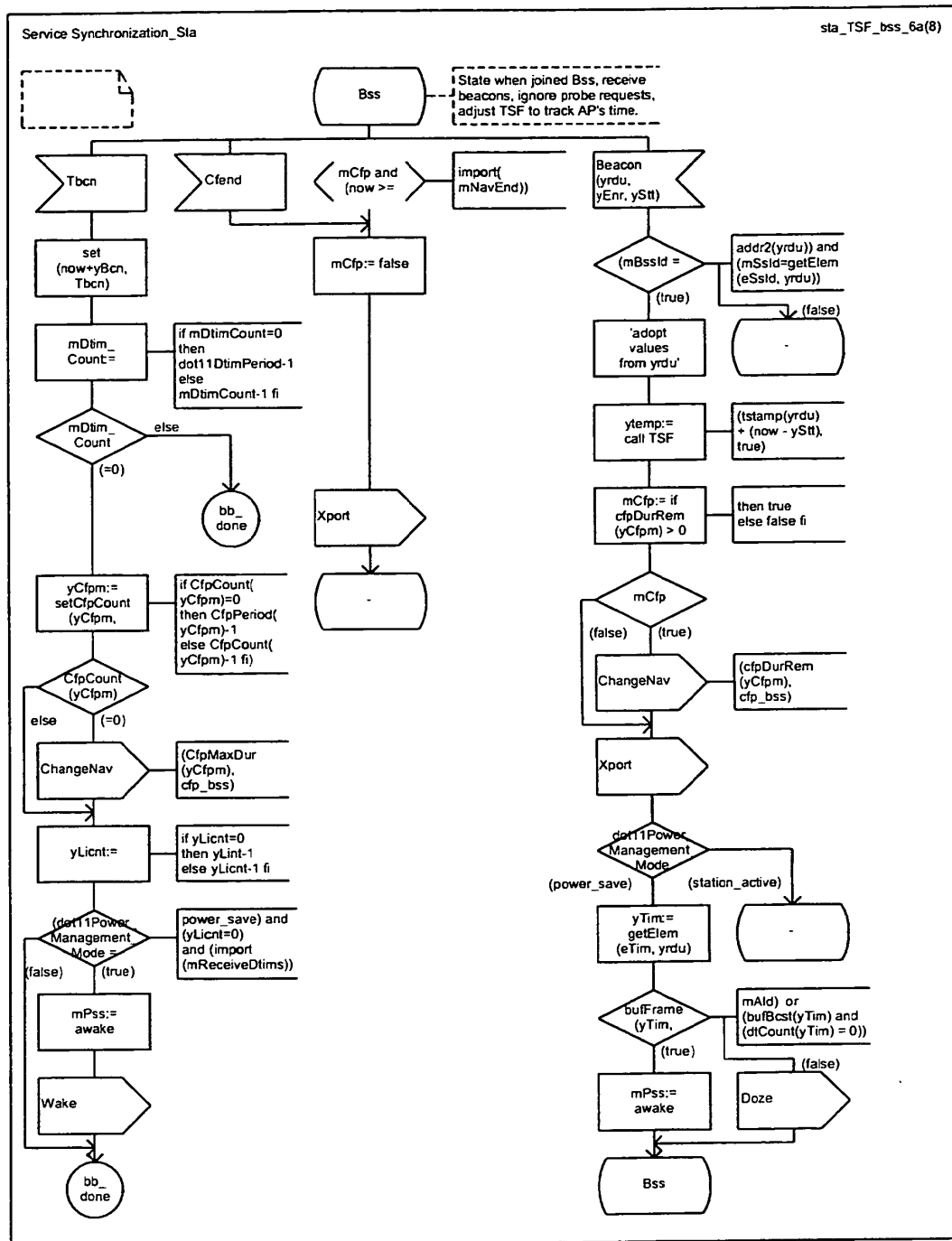


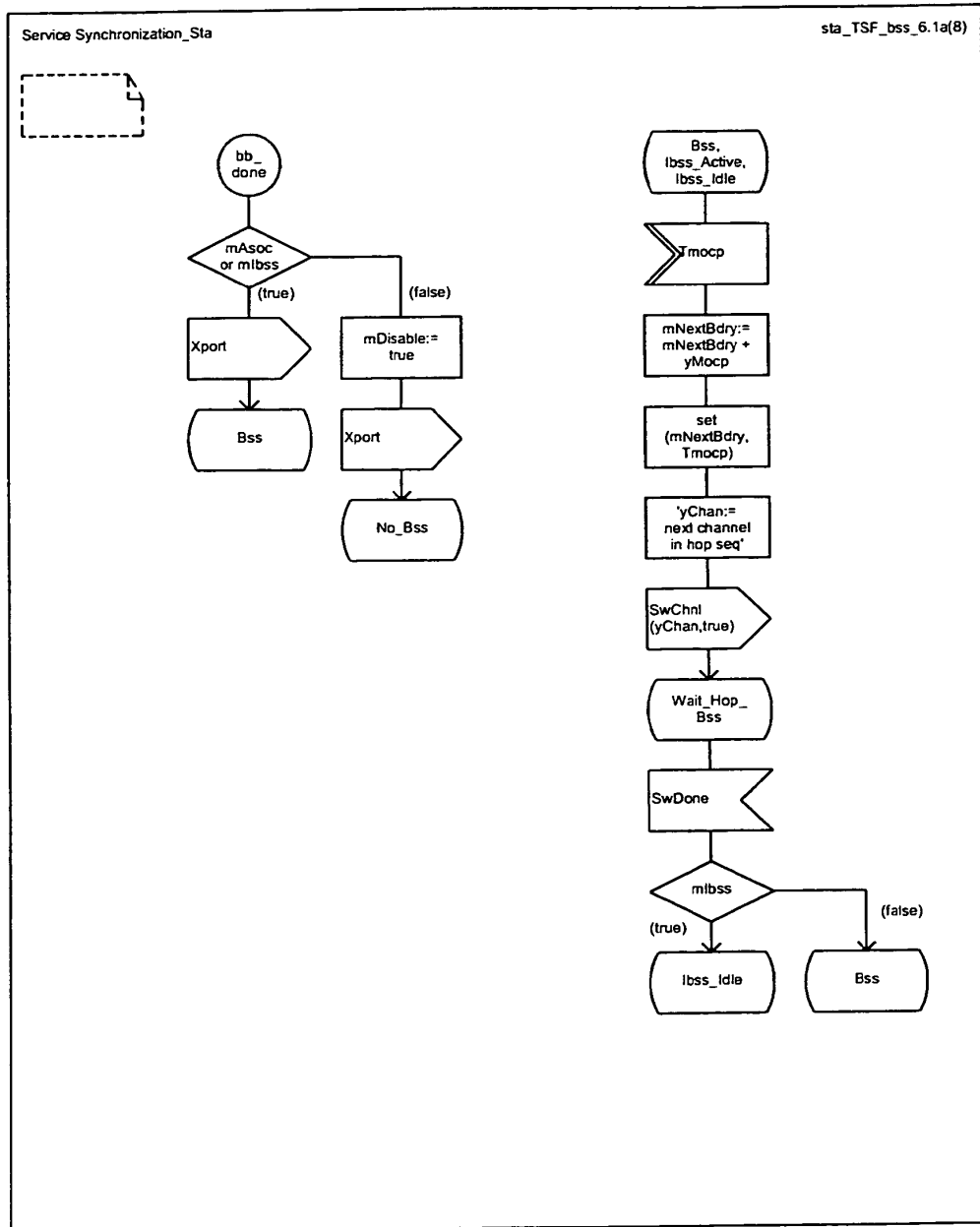






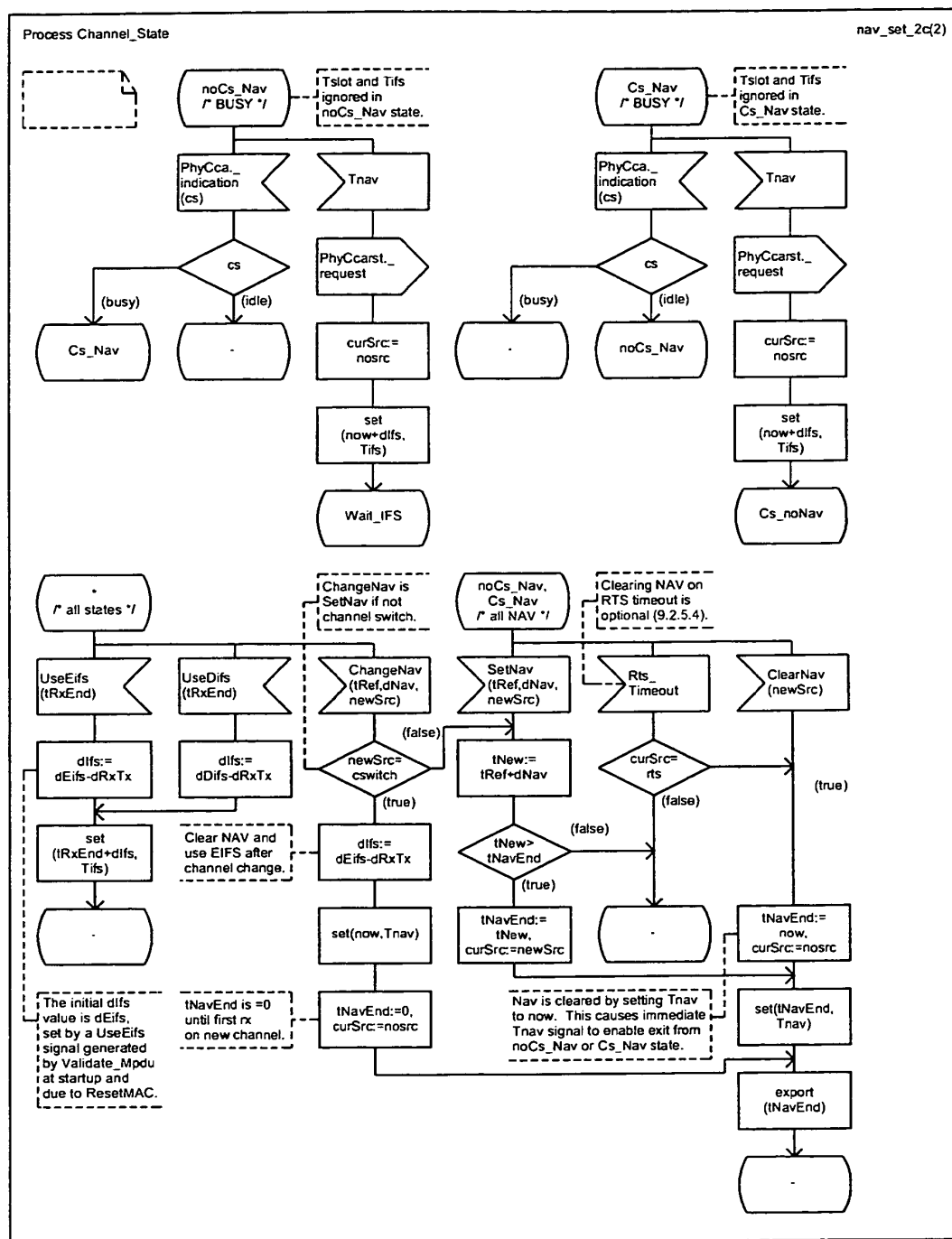


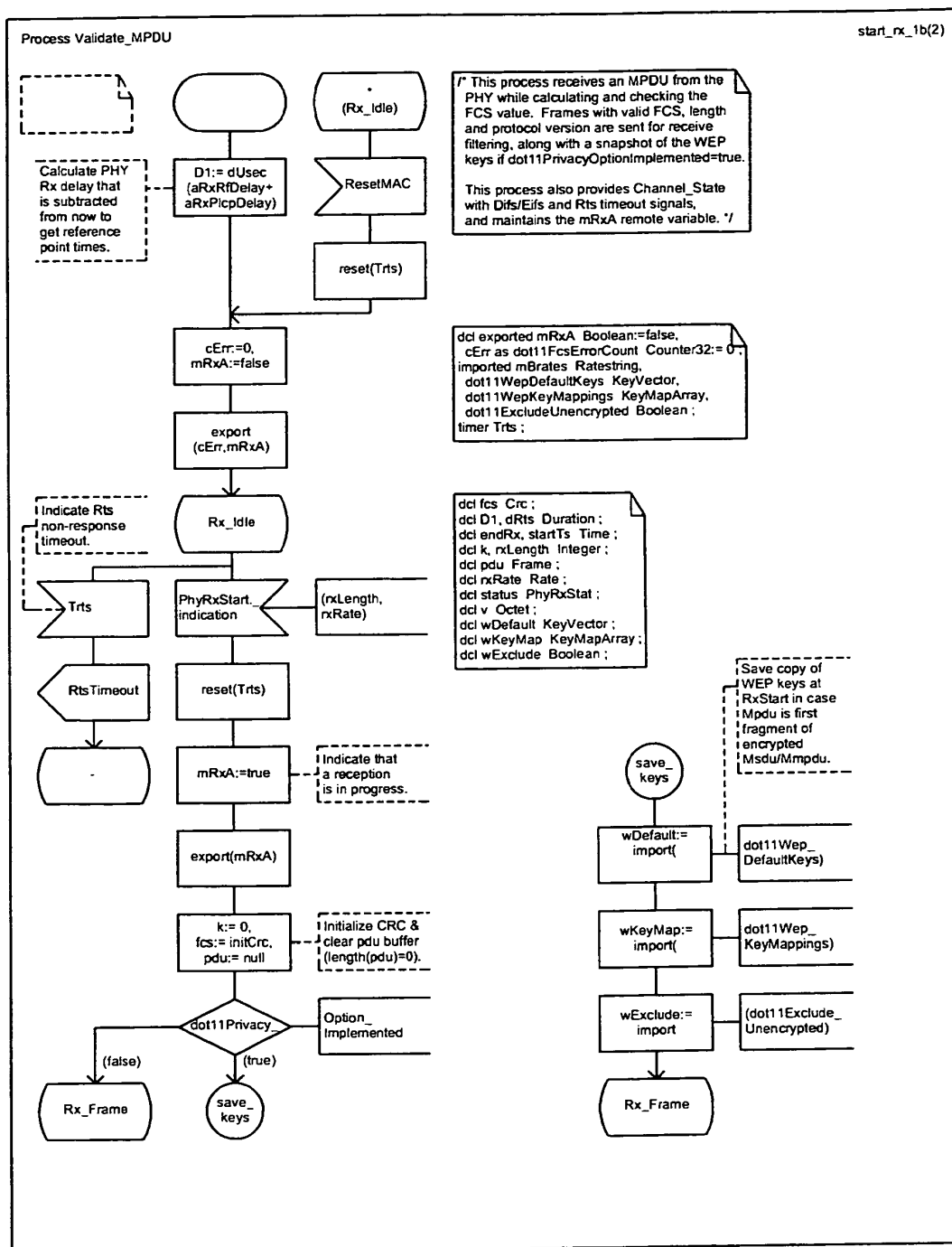




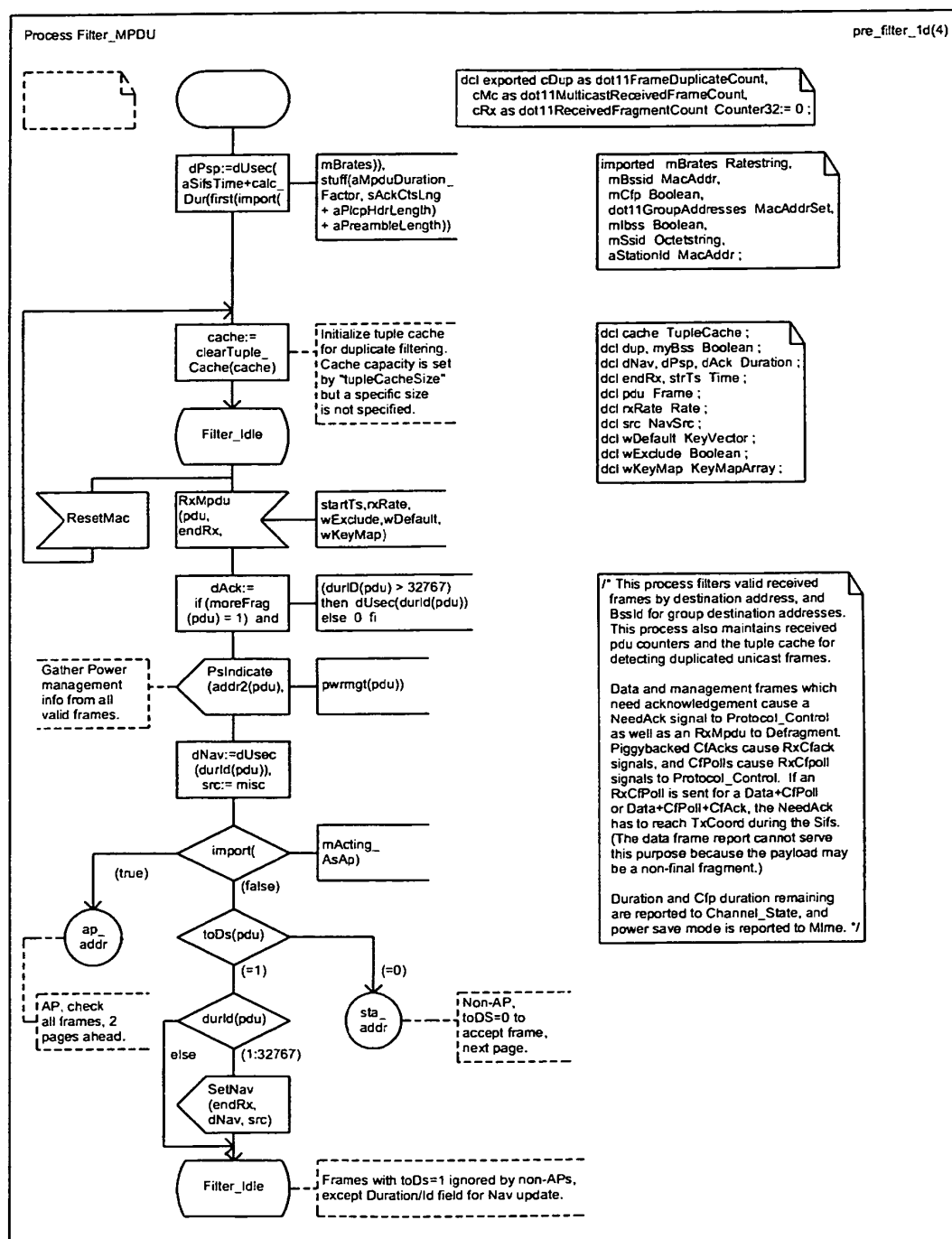






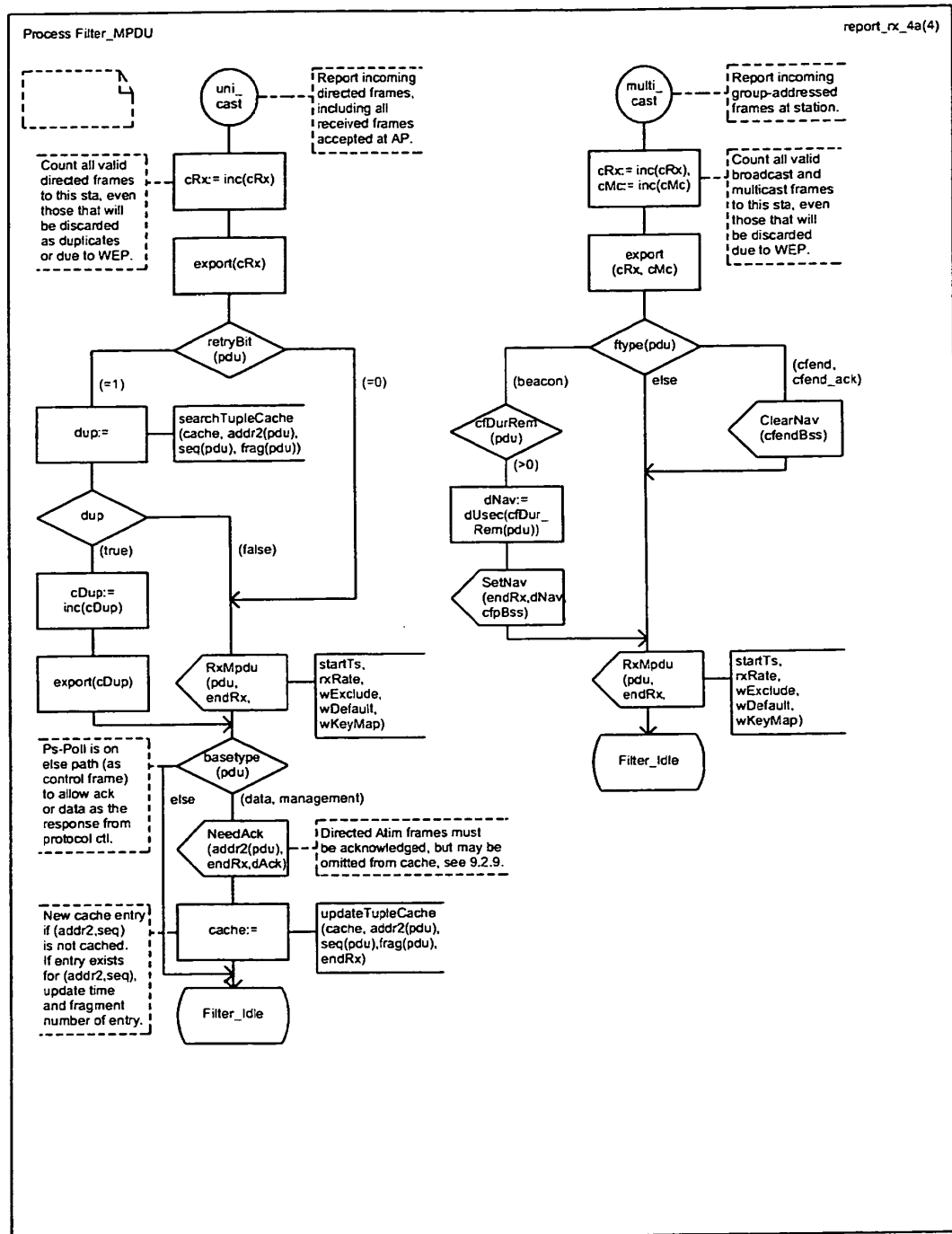


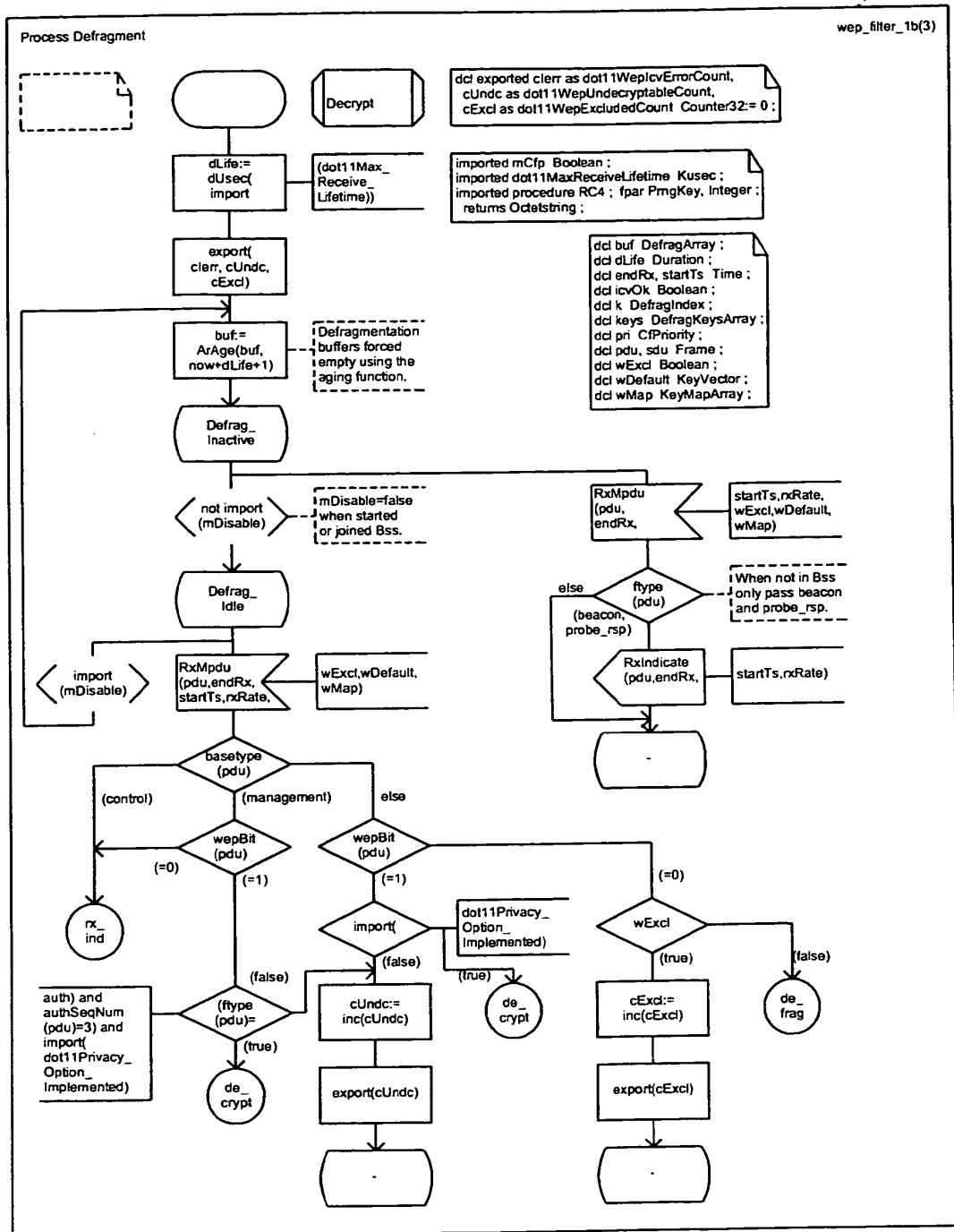


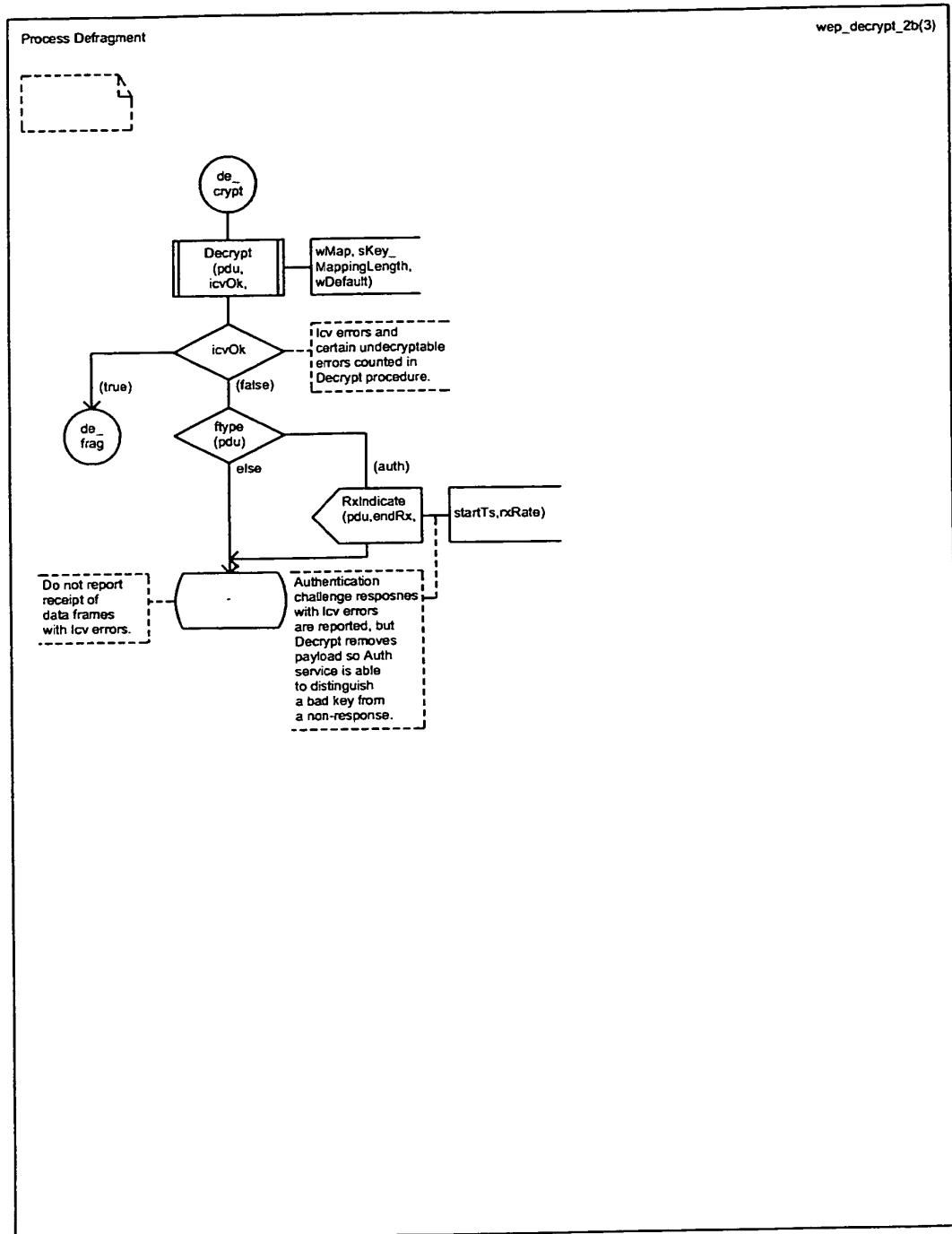


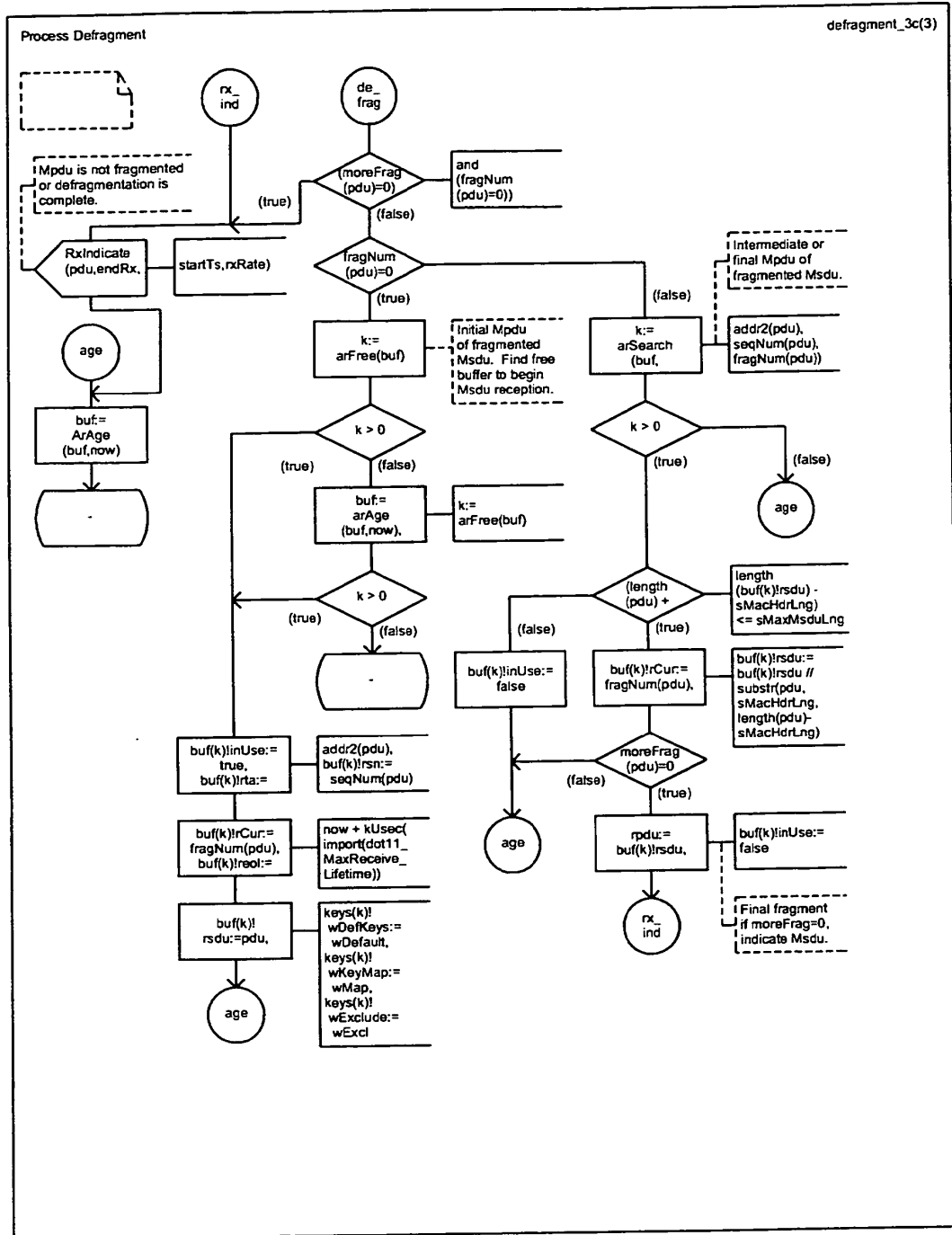










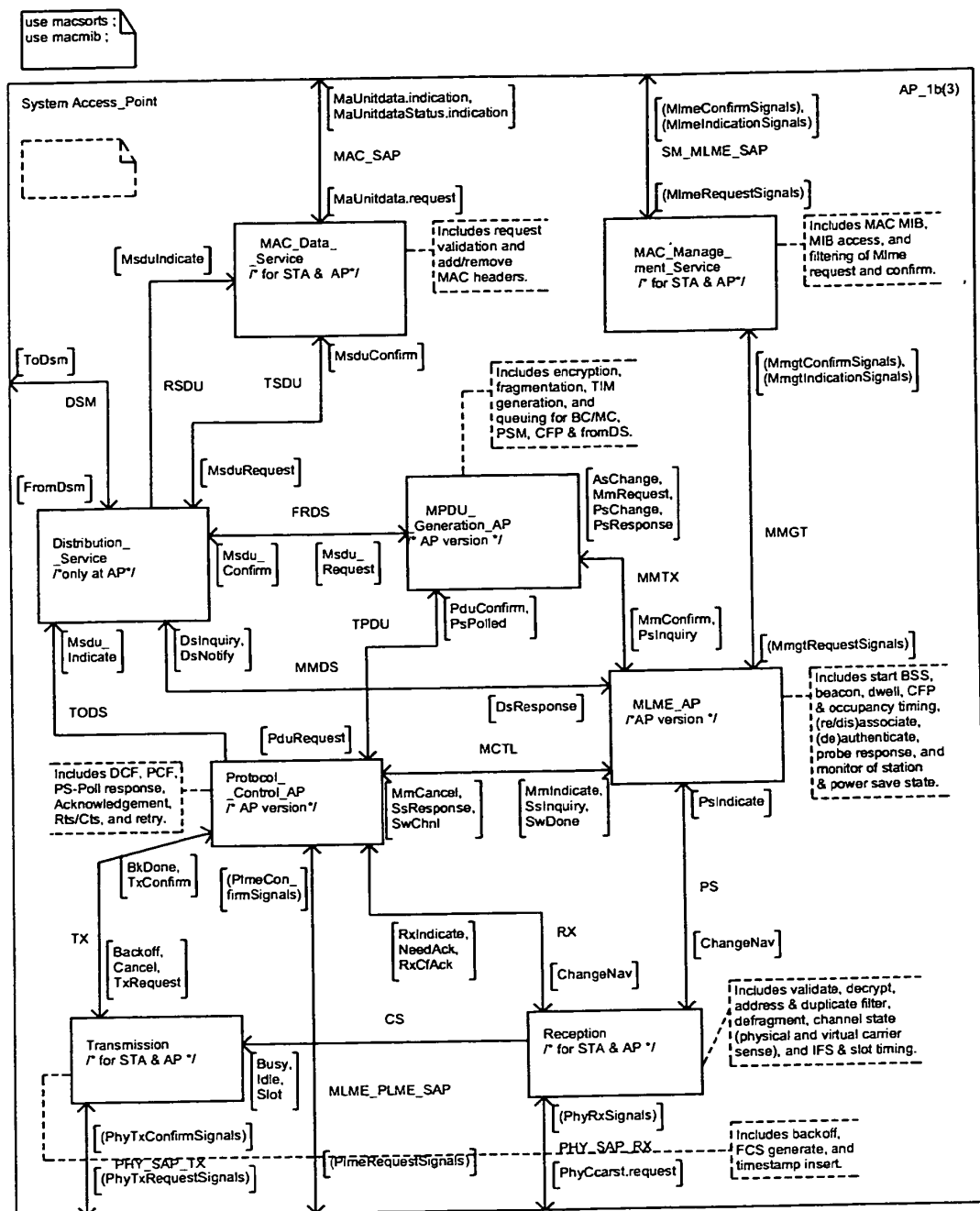


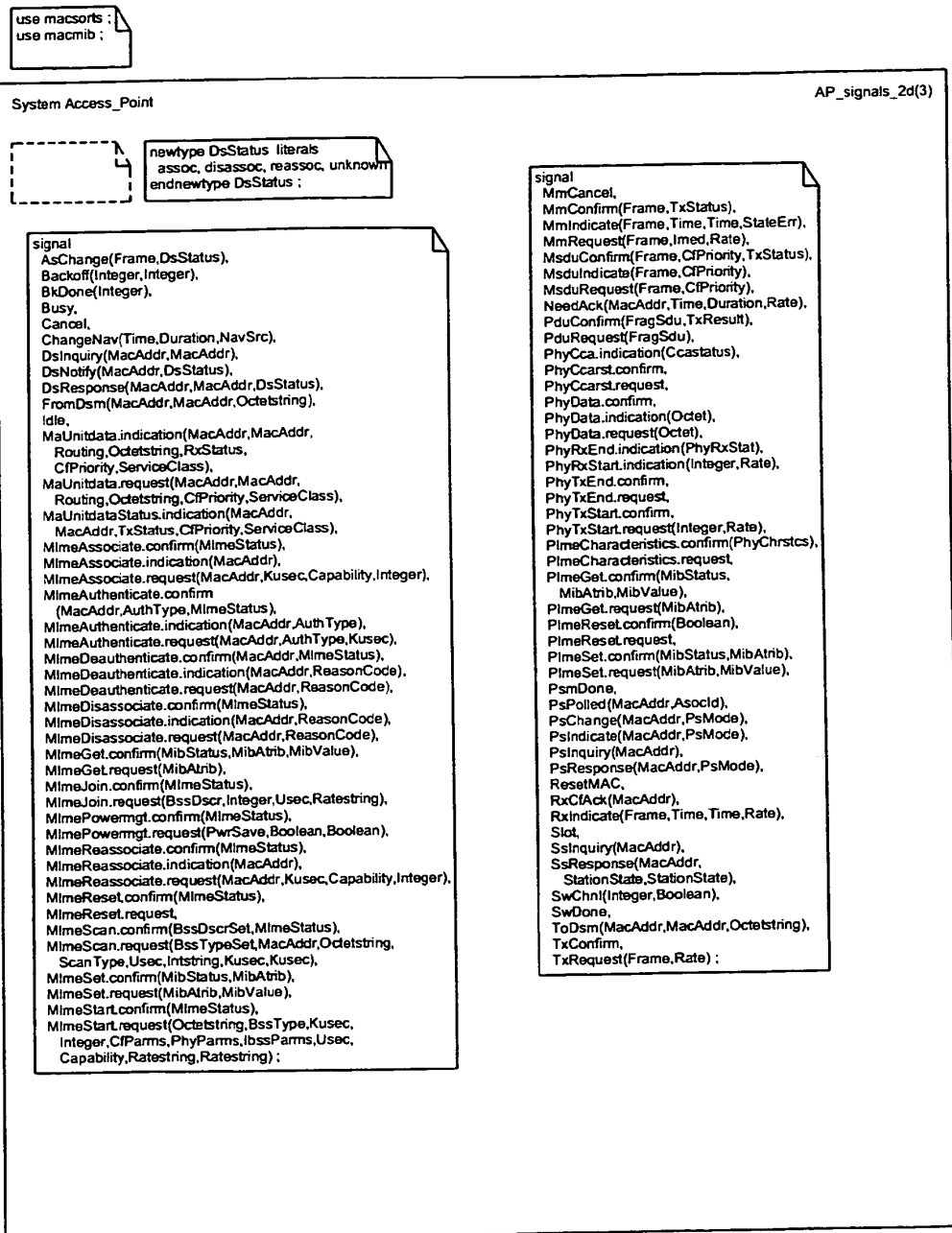


C.4 State machines for MAC access point

The following SDL-92 system specification defines operation of the MAC protocol at an IEEE 802.11 AP. Many aspects of AP operation are identical to the STA operation. These are defined in blocks and processes referenced from both the STA and AP system specifications. Blocks and processes used in both STA and AP are identifiable by the SDL comment `/* for STA & AP */` below the block or process name. Blocks and processes specific to AP operation are identifiable by the SDL comment `/* AP version */` below the block or process name. Definitions for the `/* AP version */` and the `/* STA & AP */` blocks and processes appear in this subclause.

The remainder of this clause is the formal description, in SDL/GR, of an IEEE 802.11 AP.





use macsorts ;
use macmib ;

System Access_Point

AP_signallists_3b(3)



signallist
MimeRequestSignals=
MimeAssociate.request,
MimeAuthenticate.request,
MimeDeauthenticate.request,
MimeDisassociate.request,
MimeGet.request,
MimeJoin.request,
MimePowermgmt.request,
MimeReassociate.request,
MimeReset.request,
MimeScan.request,
MimeSet.request,
MimeStart.request ;

signallist
MimeConfirmSignals=
MimeAssociate.confirm,
MimeAuthenticate.confirm,
MimeDeauthenticate.confirm,
MimeDisassociate.confirm,
MimeGet.confirm,
MimeJoin.confirm,
MimePowermgmt.confirm,
MimeReassociate.confirm,
MimeReset.confirm,
MimeScan.confirm,
MimeSet.confirm,
MimeStart.confirm ;

signallist
MimeIndicationSignals=
MimeAuthenticate.indication,
MimeDeauthenticate.indication,
MimeDisassociate.indication,
MimeAssociate.indication,
MimeReassociate.indication ;

signallist
SmtRequestSignals=
MimeAssociate.request,
MimeAuthenticate.request,
MimeDeauthenticate.request,
MimeDisassociate.request,
MimeJoin.request,
MimeReassociate.request,
MimeScan.request,
MimeStart.request ;

signallist
SmtConfirmSignals=
MimeAssociate.confirm,
MimeAuthenticate.confirm,
MimeDeauthenticate.confirm,
MimeDisassociate.confirm,
MimeJoin.confirm,
MimeReassociate.confirm,
MimeScan.confirm,
MimeStart.confirm ;

signallist
SmtIndicationSignals=
MimeAuthenticate.indication,
MimeDeauthenticate.indication,
MimeDisassociate.indication,
MimeAssociate.indication,
MimeReassociate.indication ;

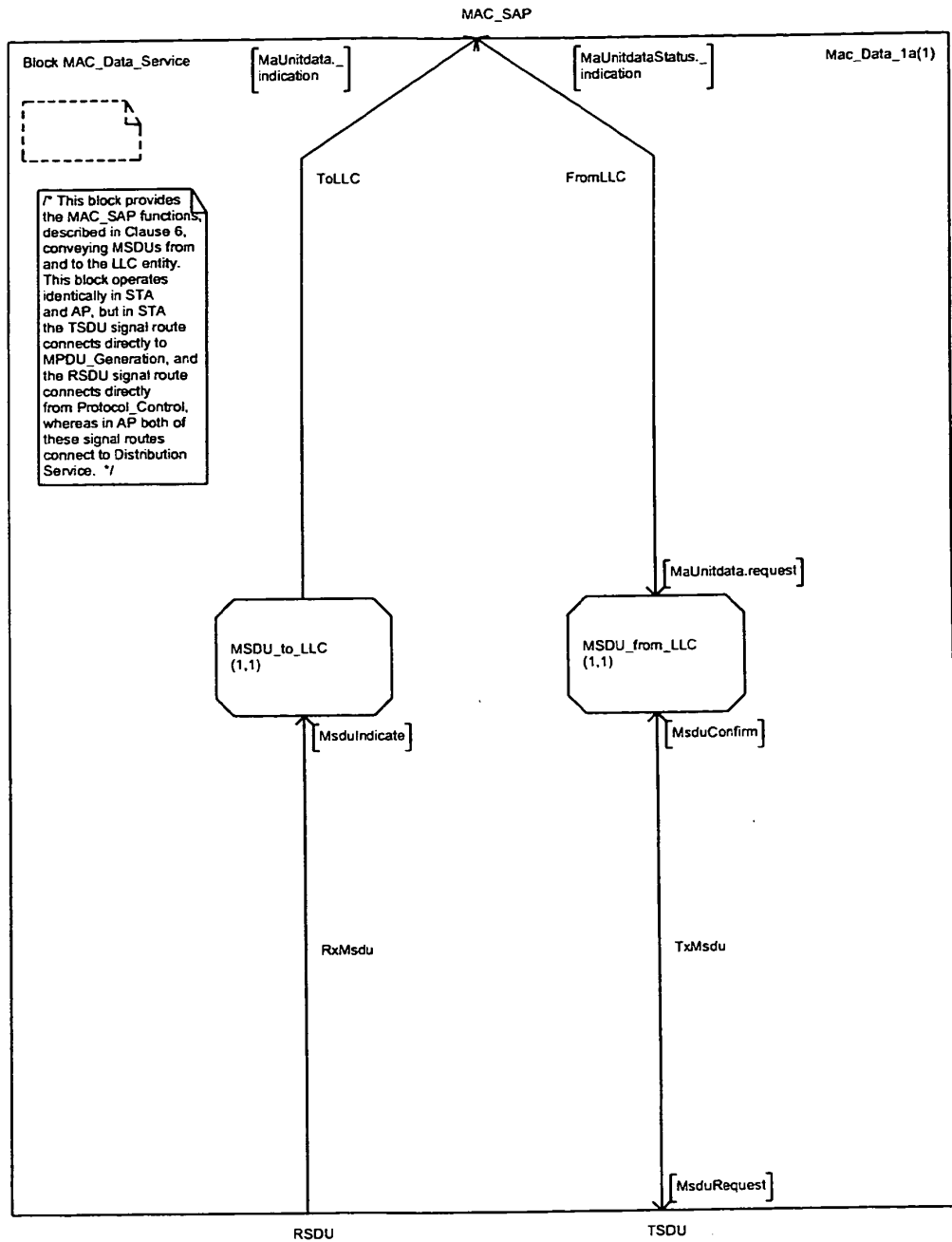
signallist
PhyTxRequestSignals=
PhyTxStart.request,
PhyTxEnd.request,
PhyData.request ;

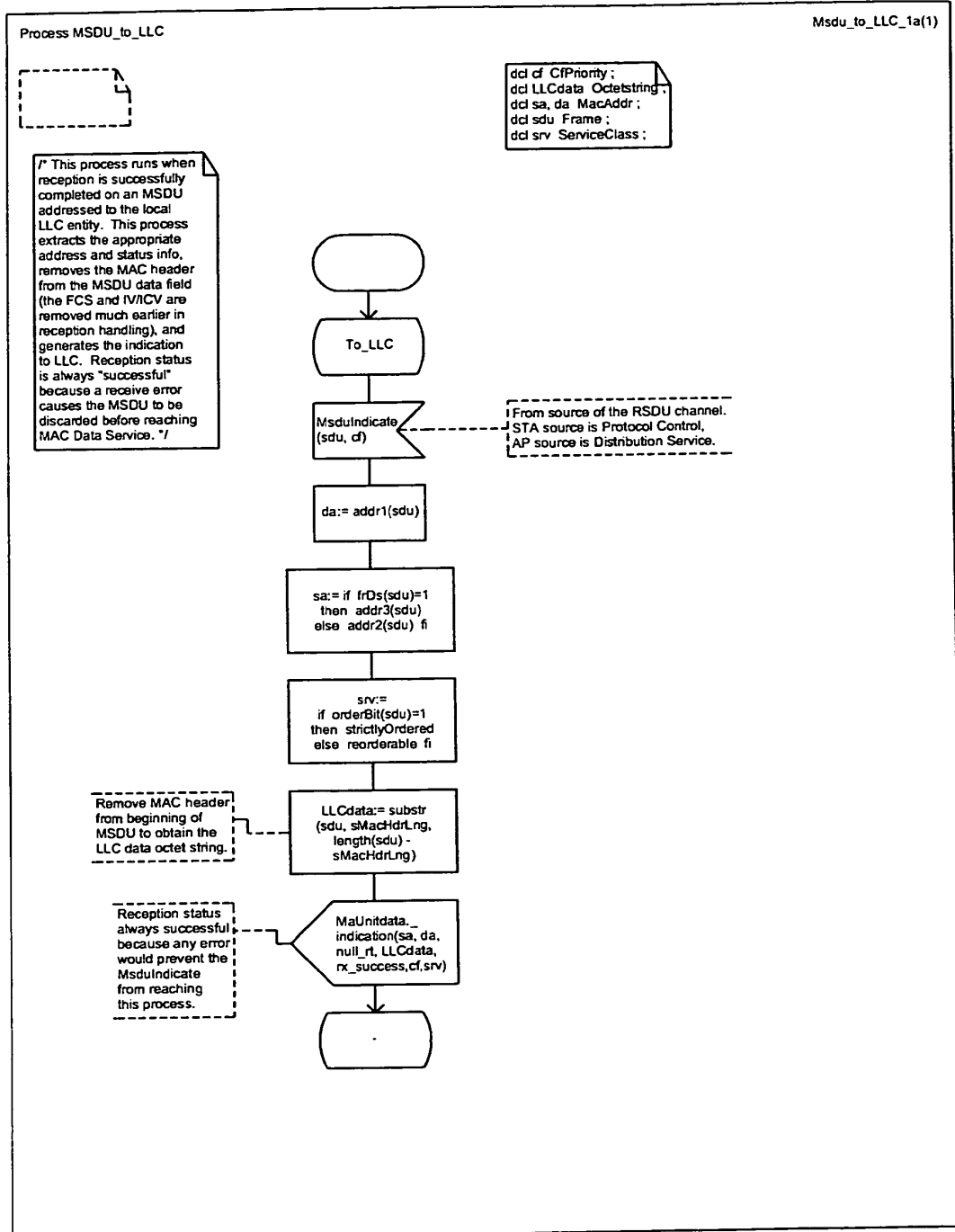
signallist
PhyTxConfirmSignals=
PhyTxStart.confirm,
PhyTxEnd.confirm,
PhyData.confirm ;

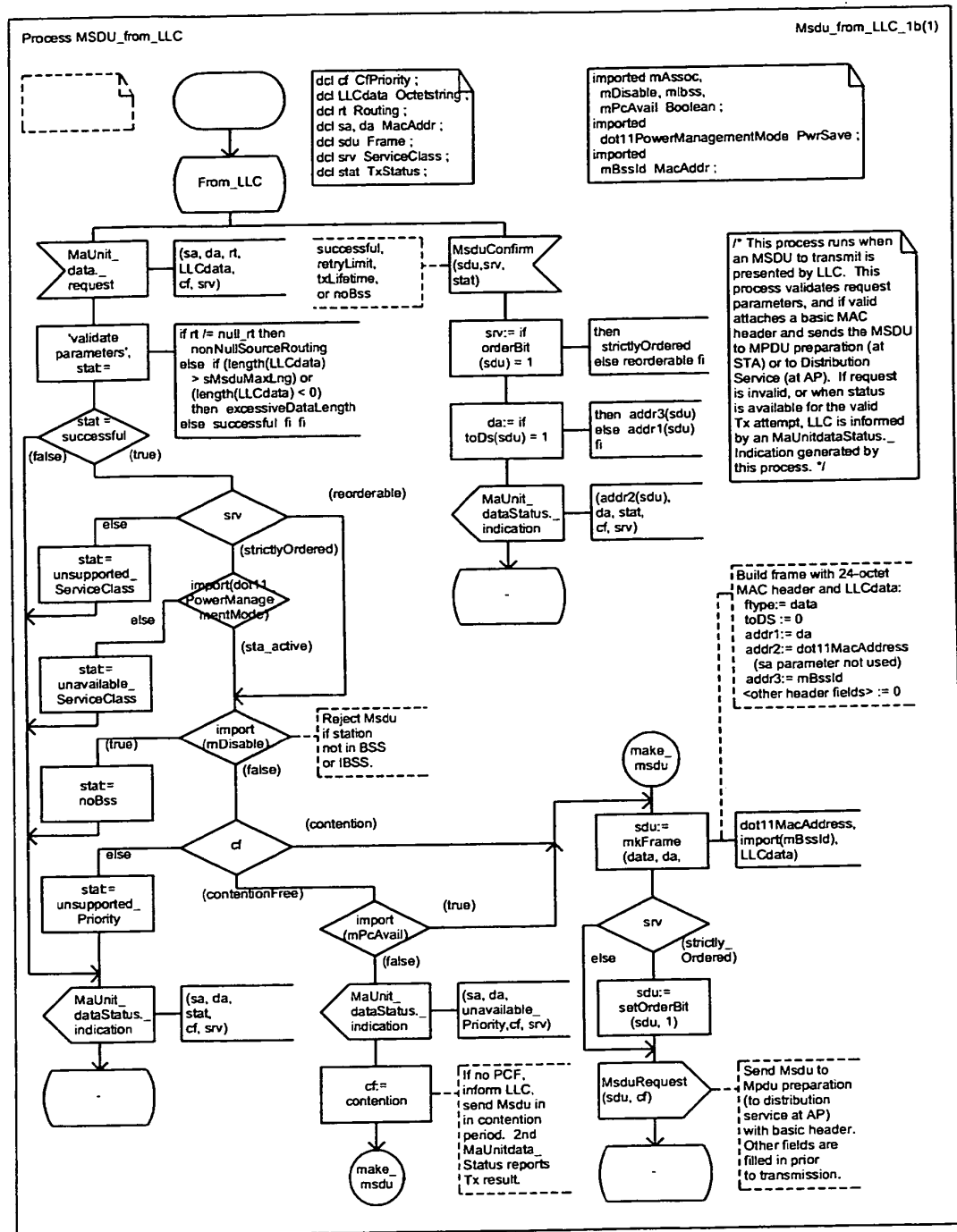
signallist
PhyRxSignals=
PhyRxStart.indication,
PhyRxEnd.indication,
PhyData.indication,
PhyCca.indication,
PhyCcarst.confirm ;

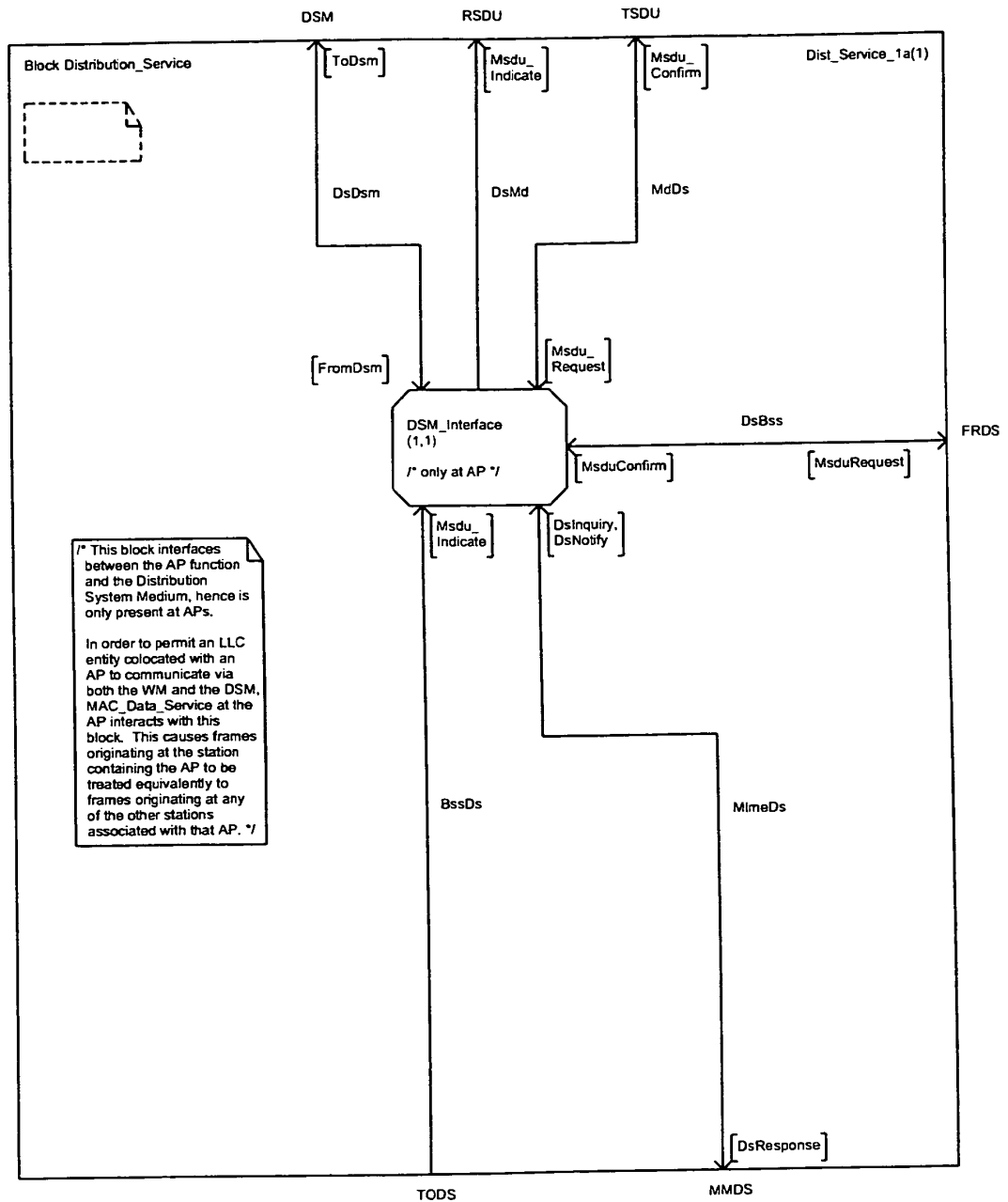
signallist
PimeRequestSignals=
PimeCharacteristics.request,
PimeGet.request,
PimeSet.request,
PimeReset.request ;

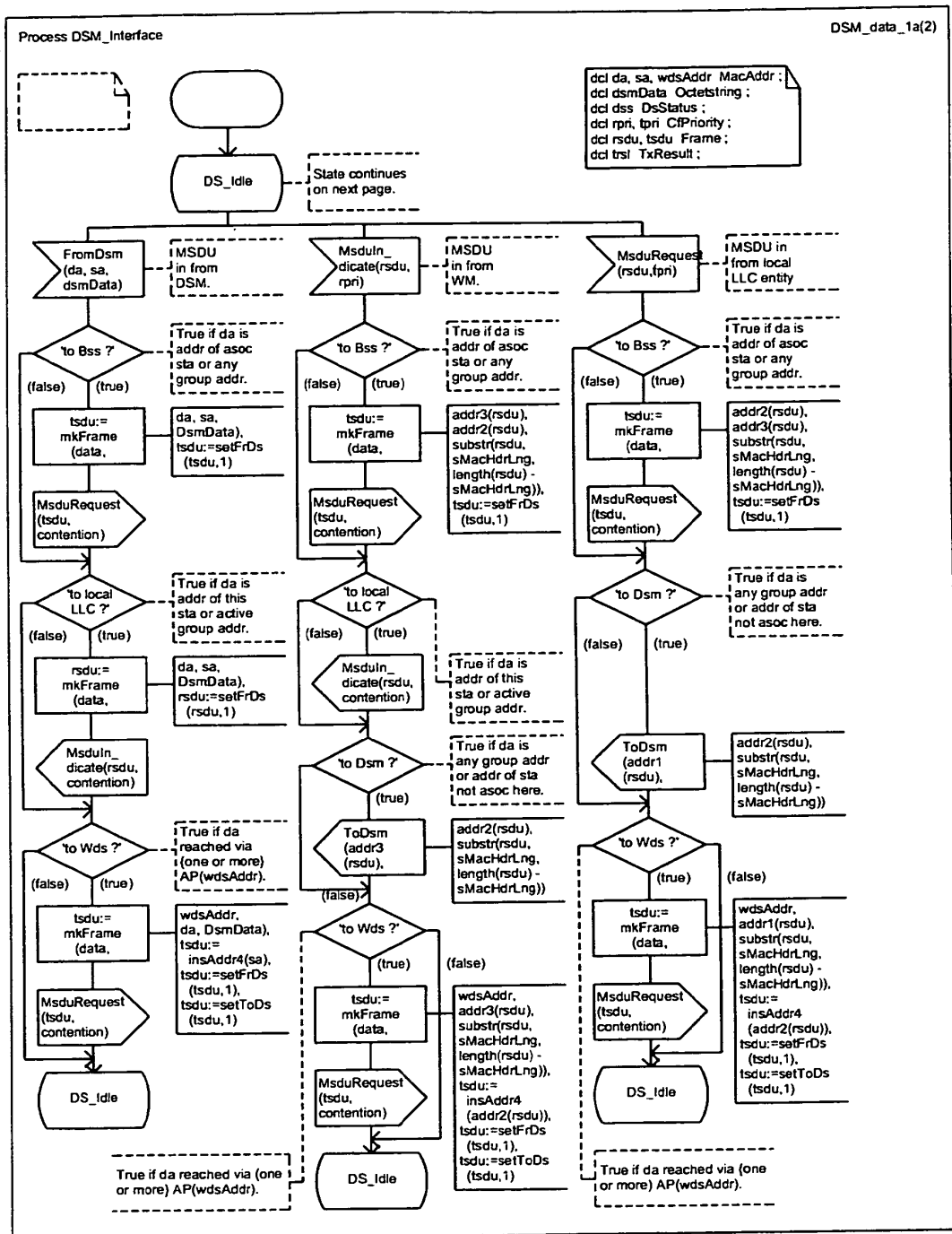
signallist
PimeConfirmSignals=
PimeCharacteristics.confirm,
PimeGet.confirm,
PimeSet.confirm,
PimeReset.confirm ;

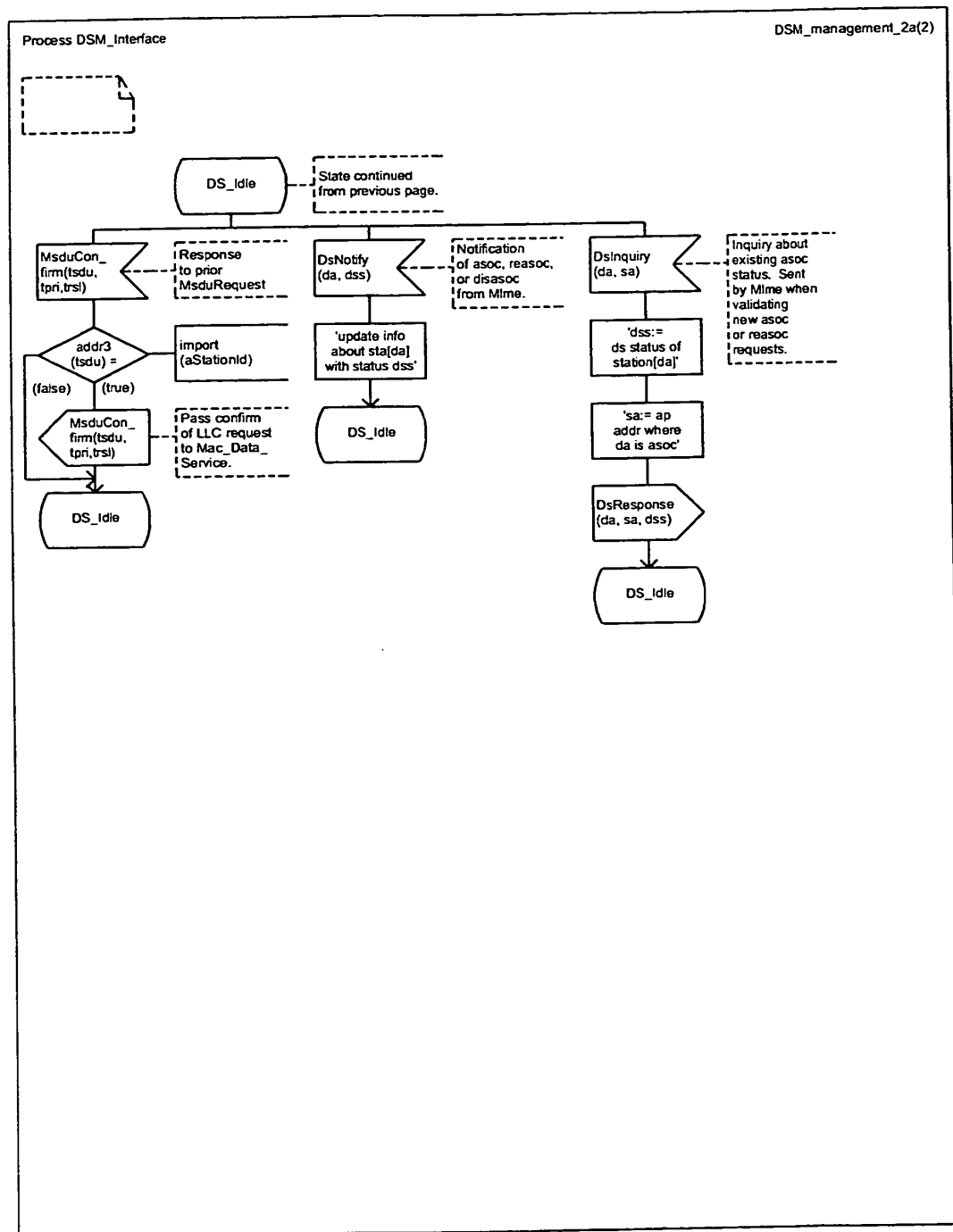


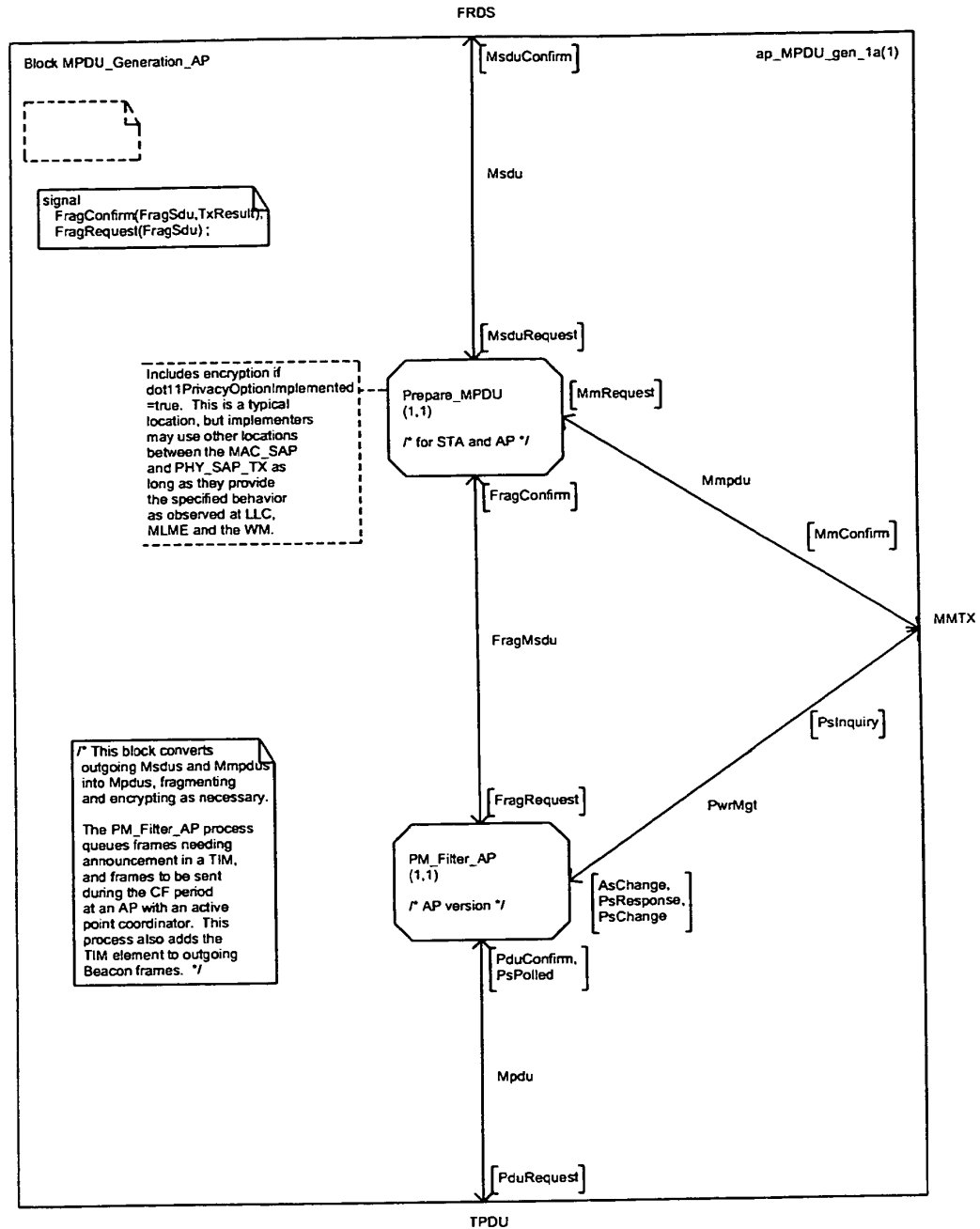


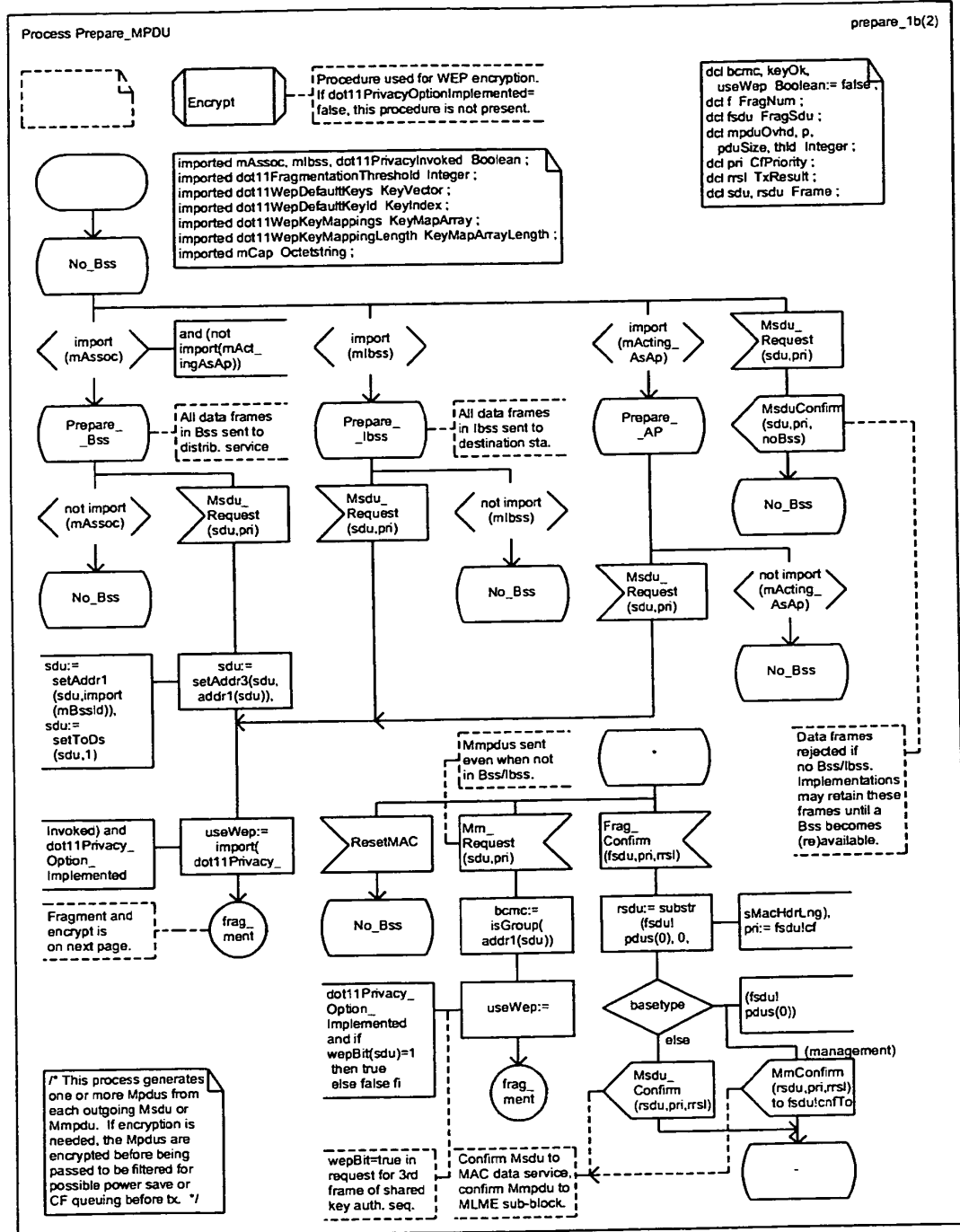


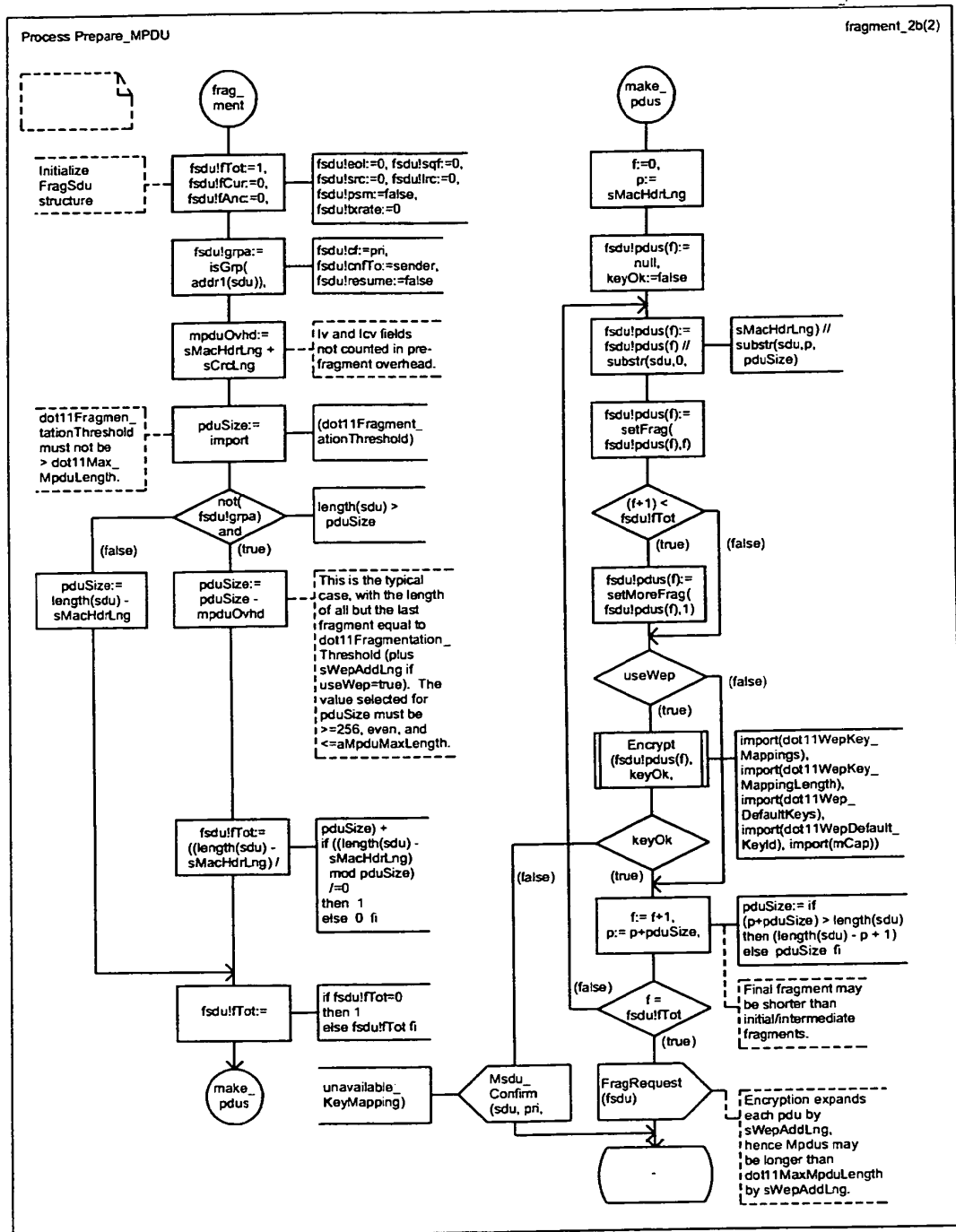


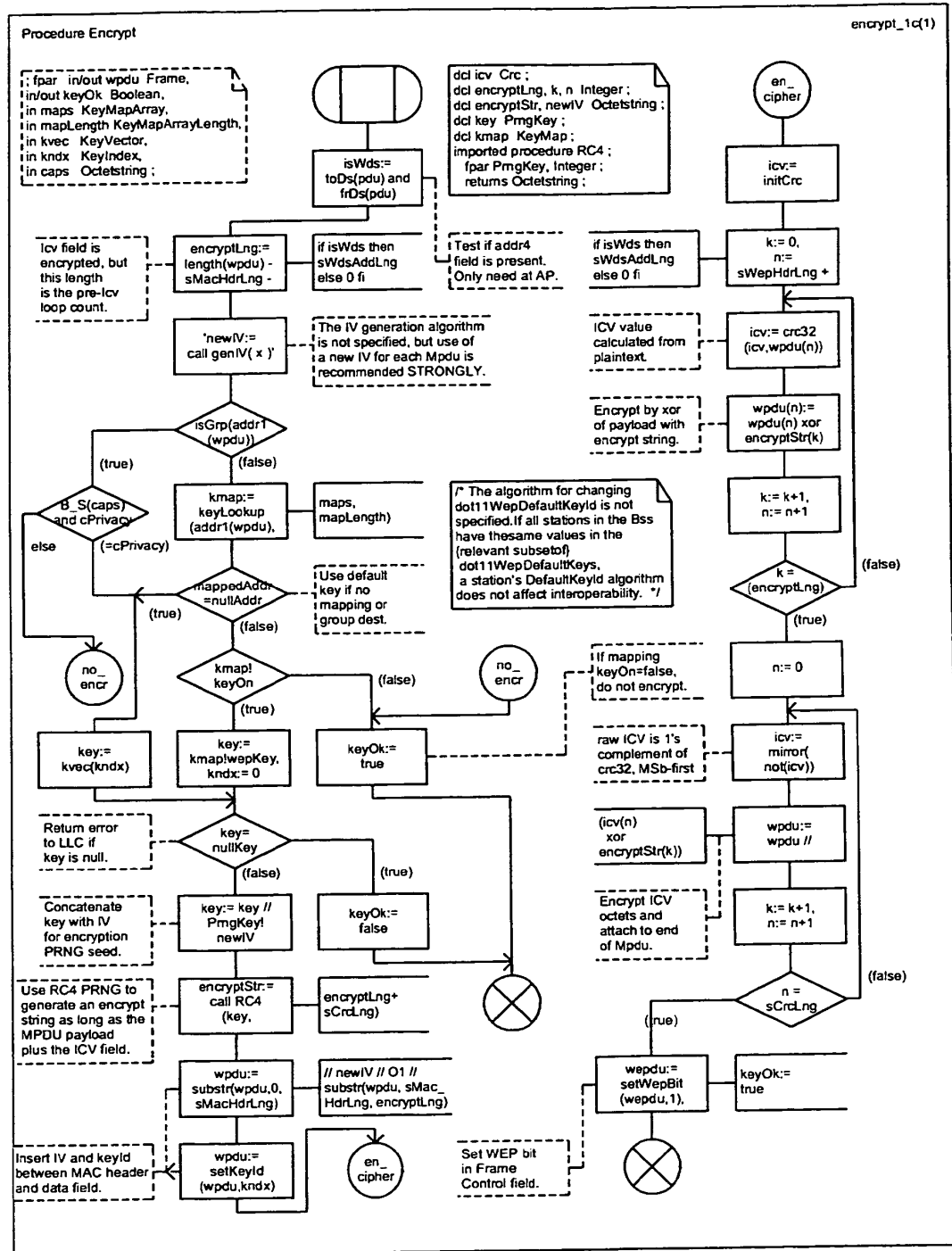


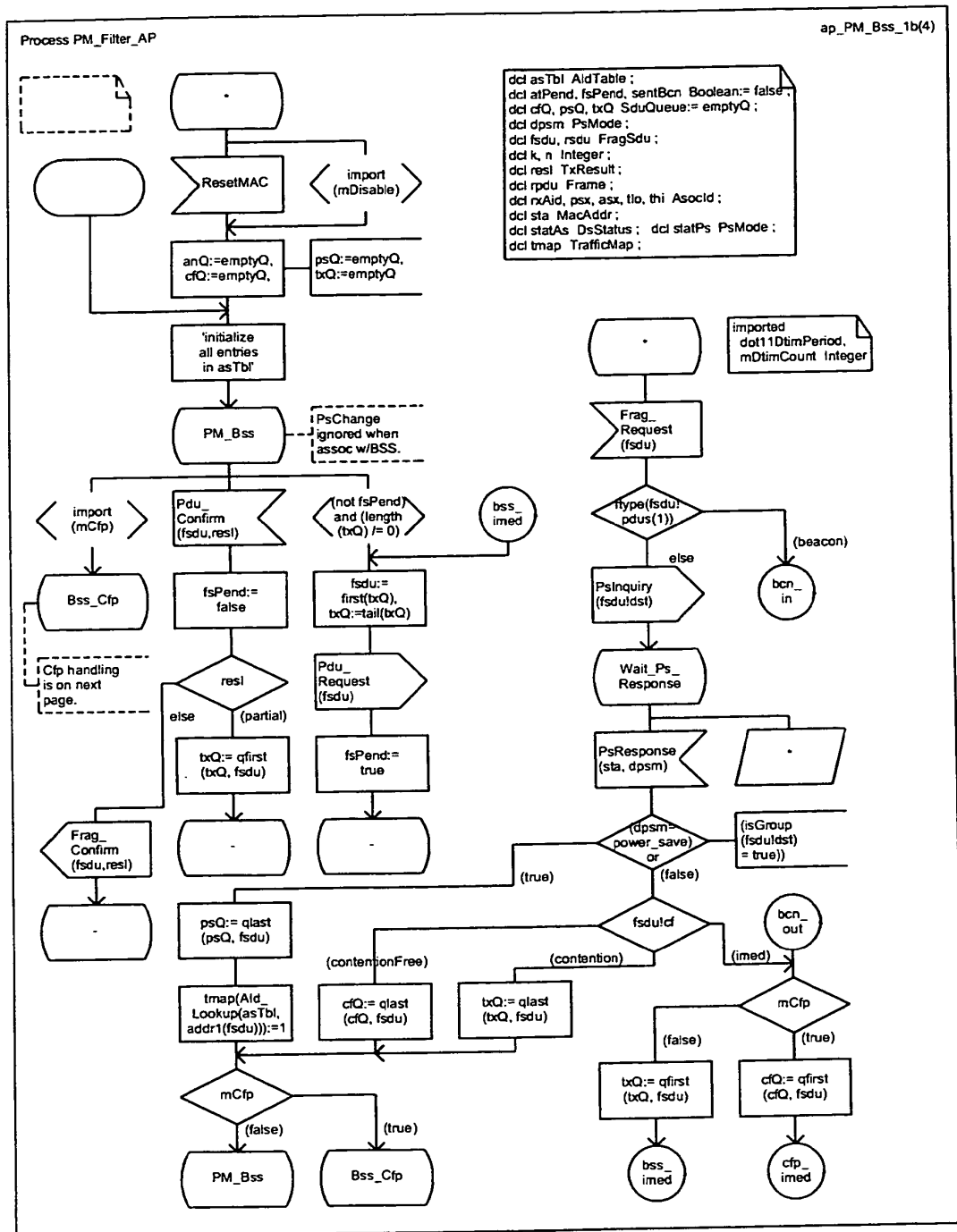


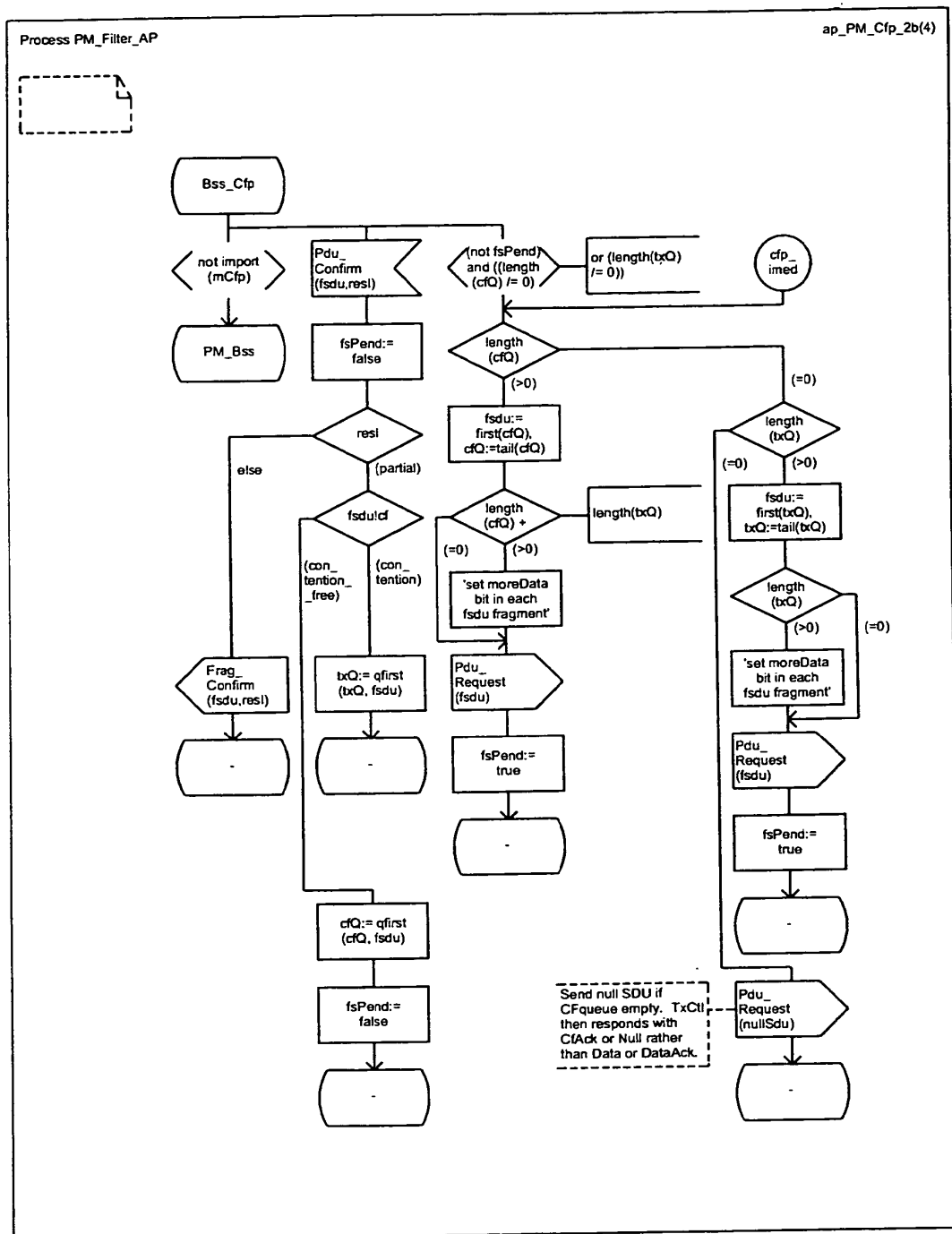


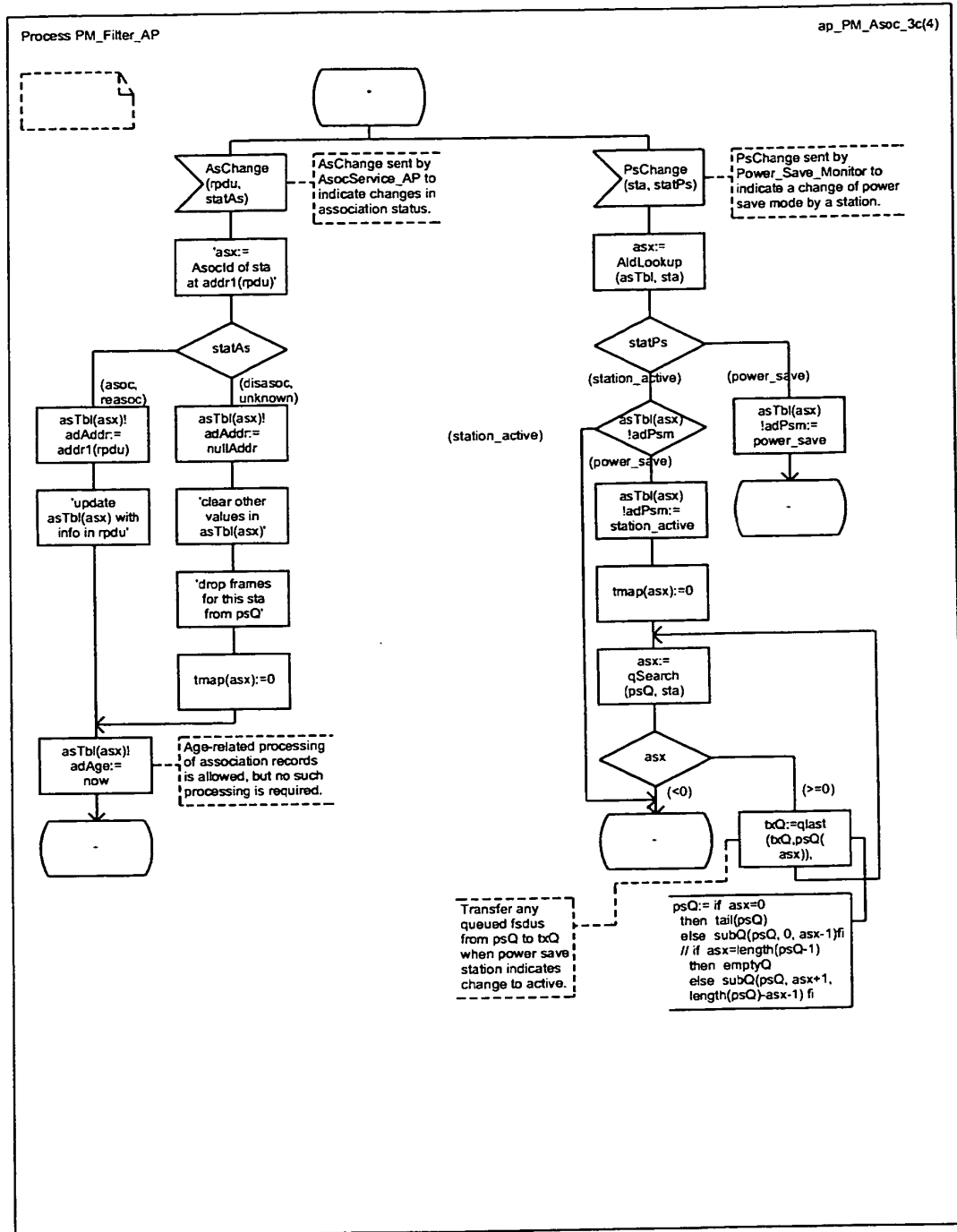


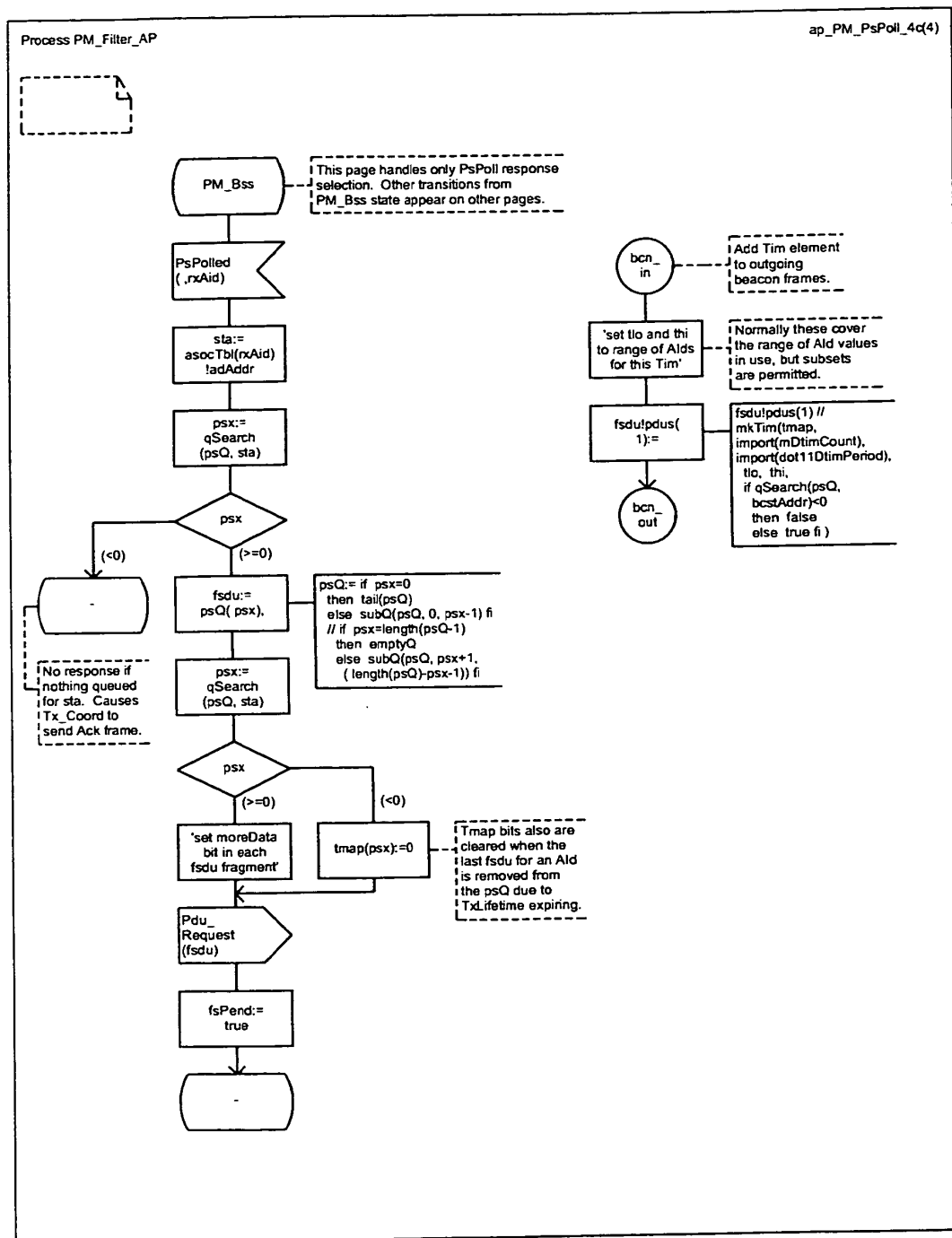


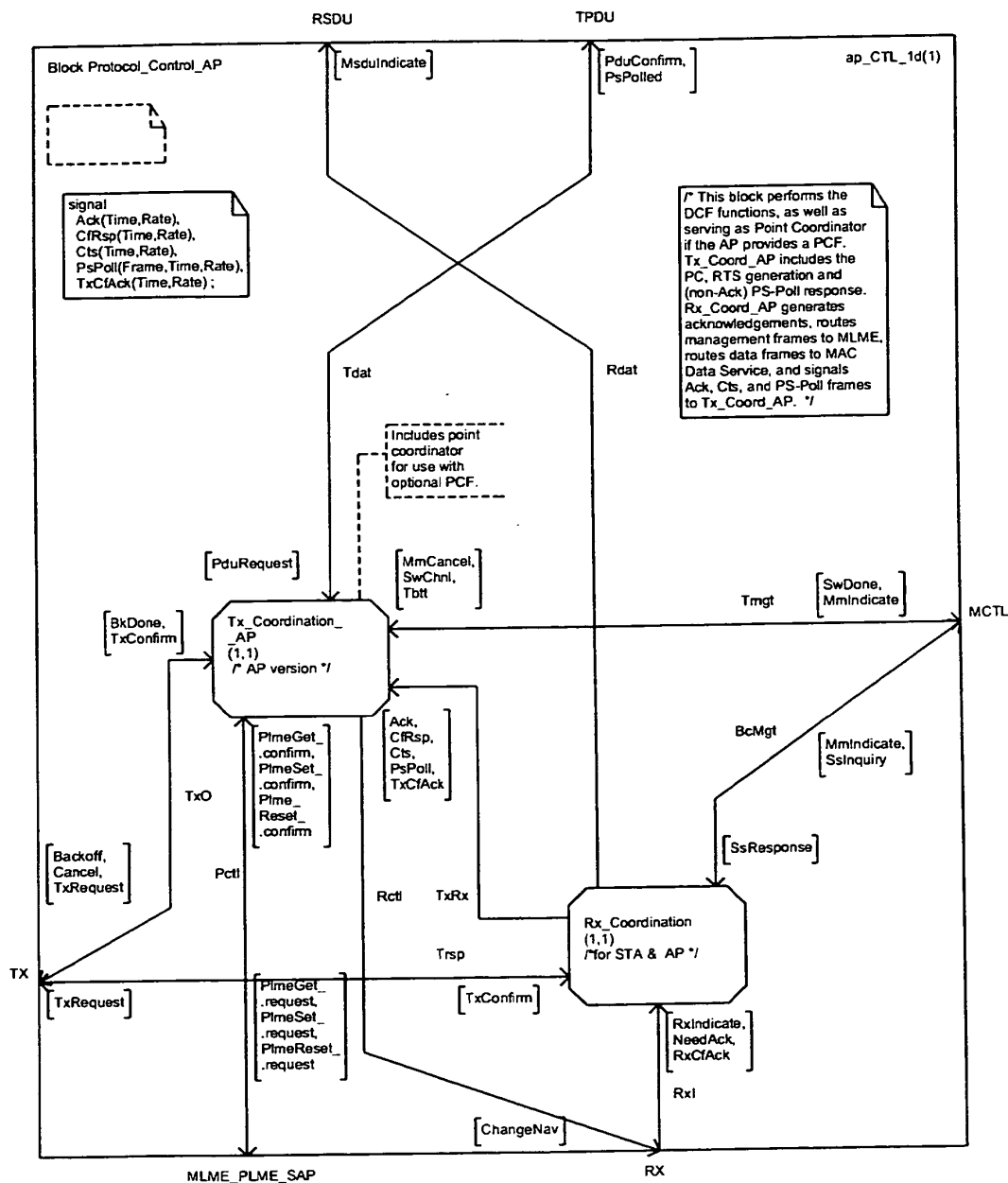


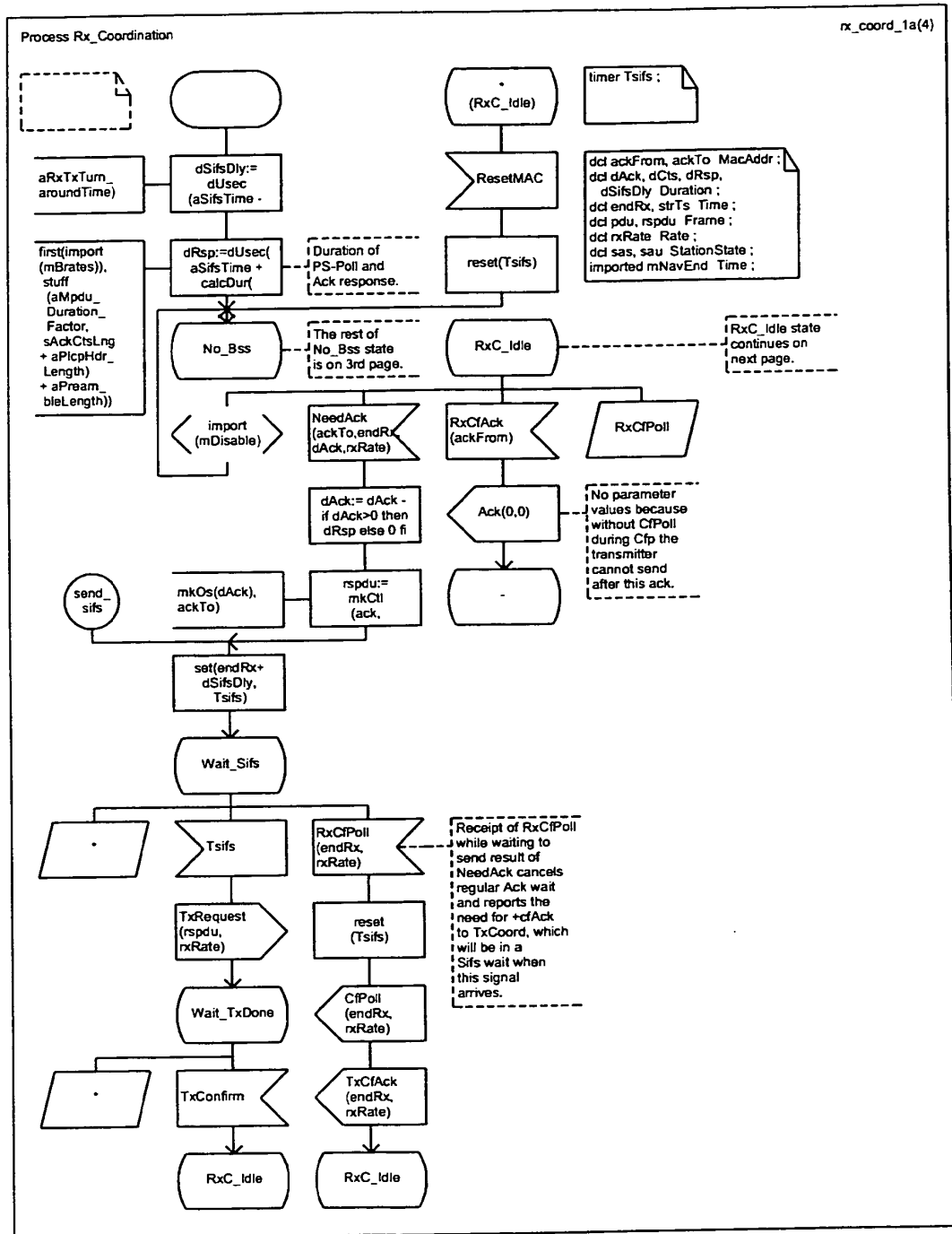


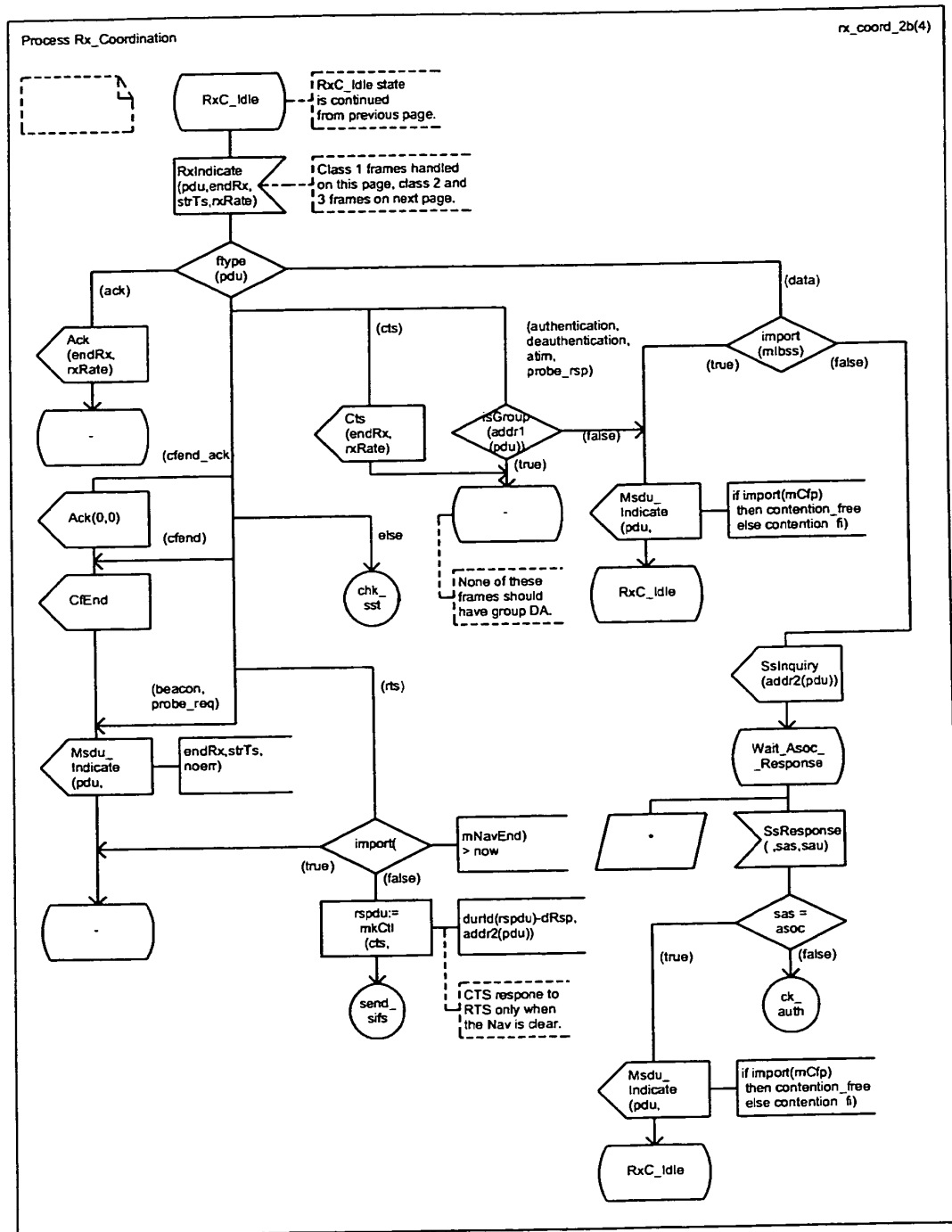




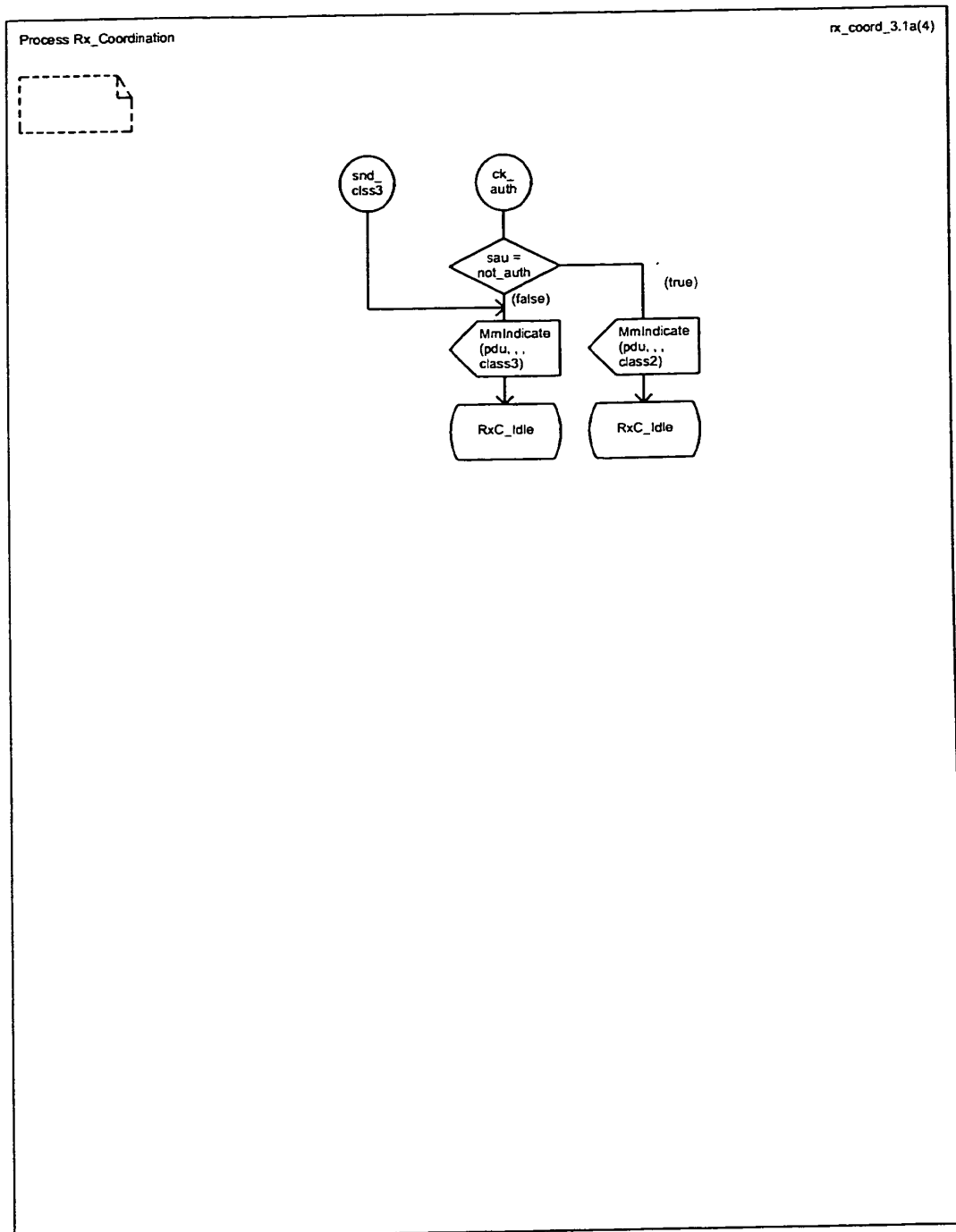


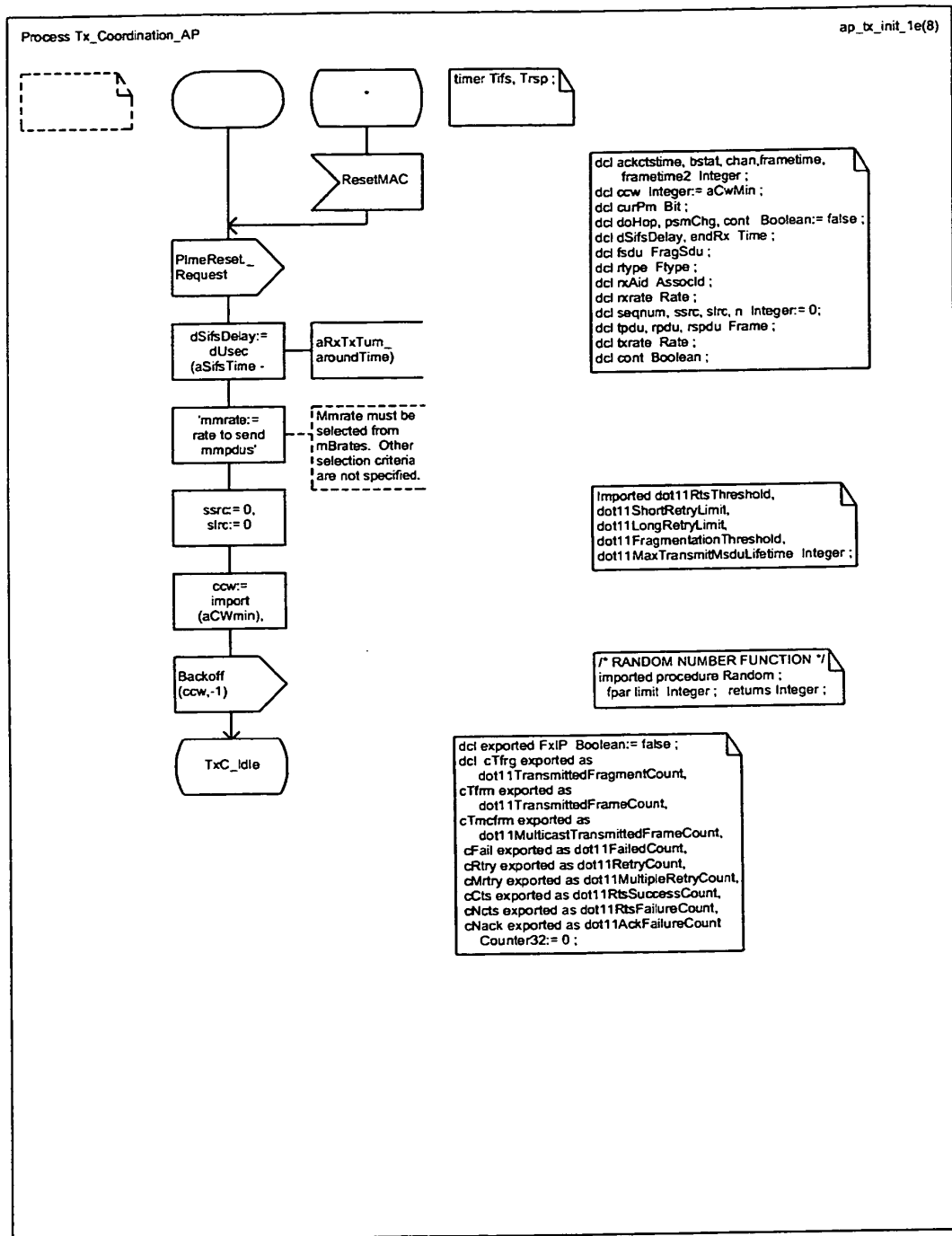




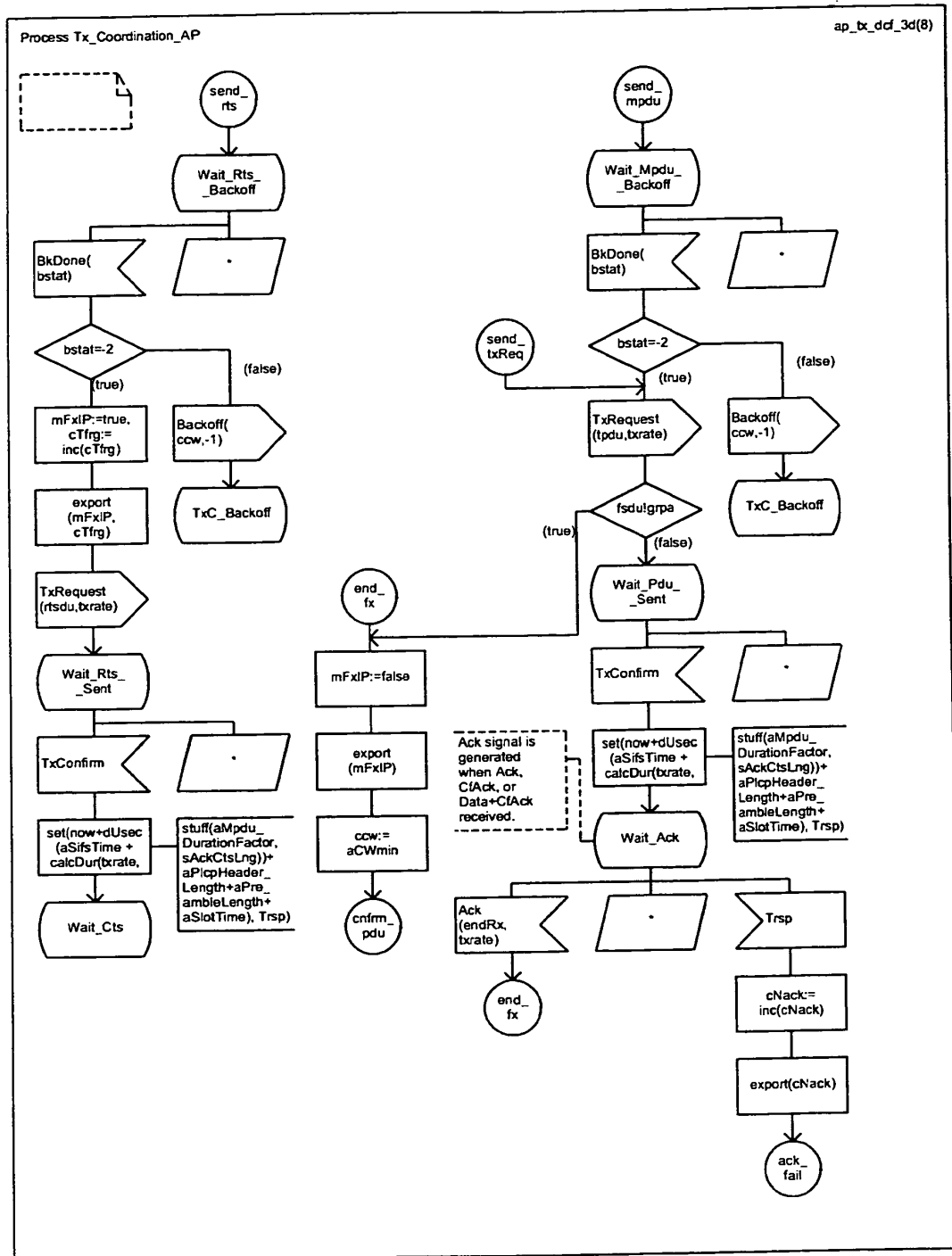


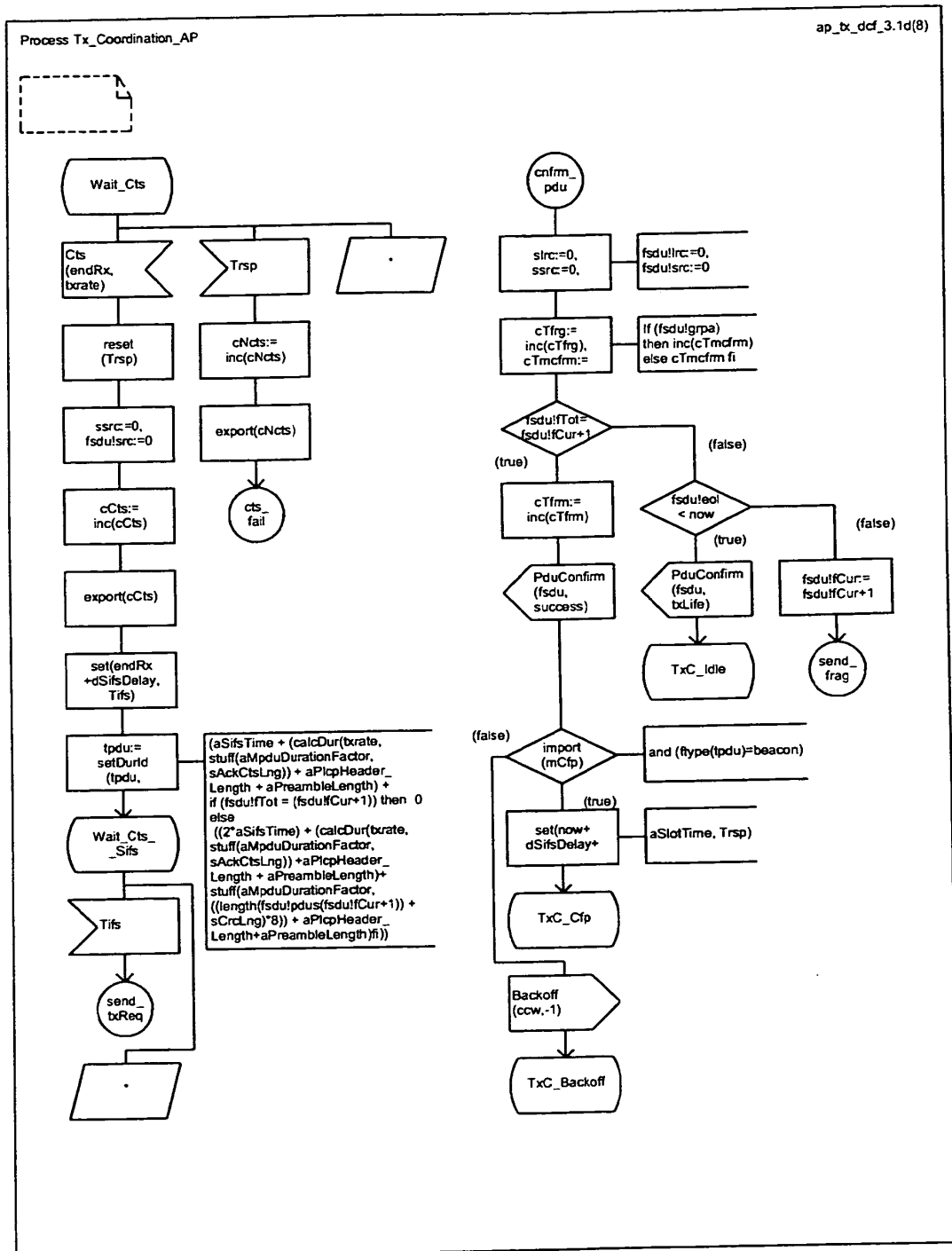




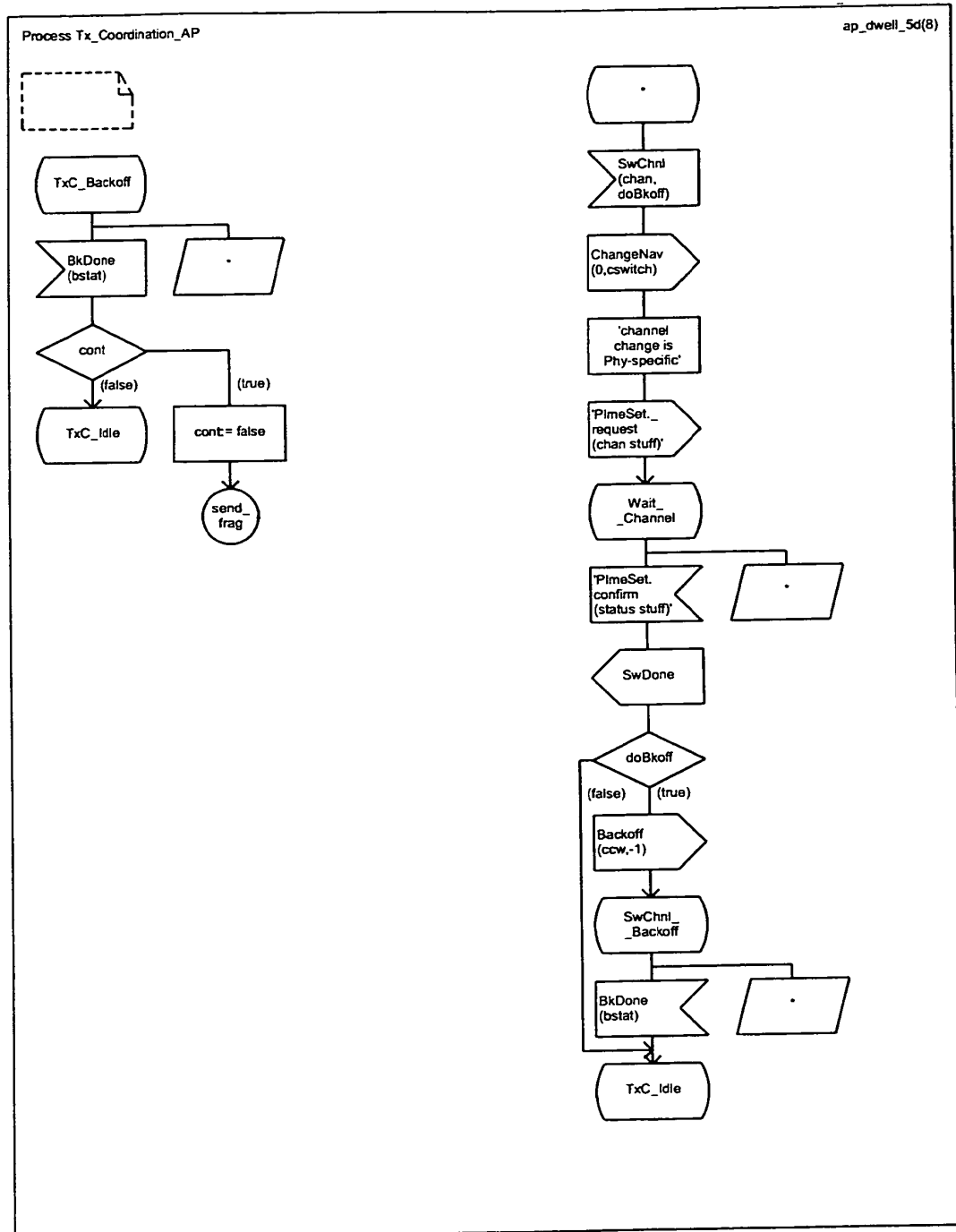






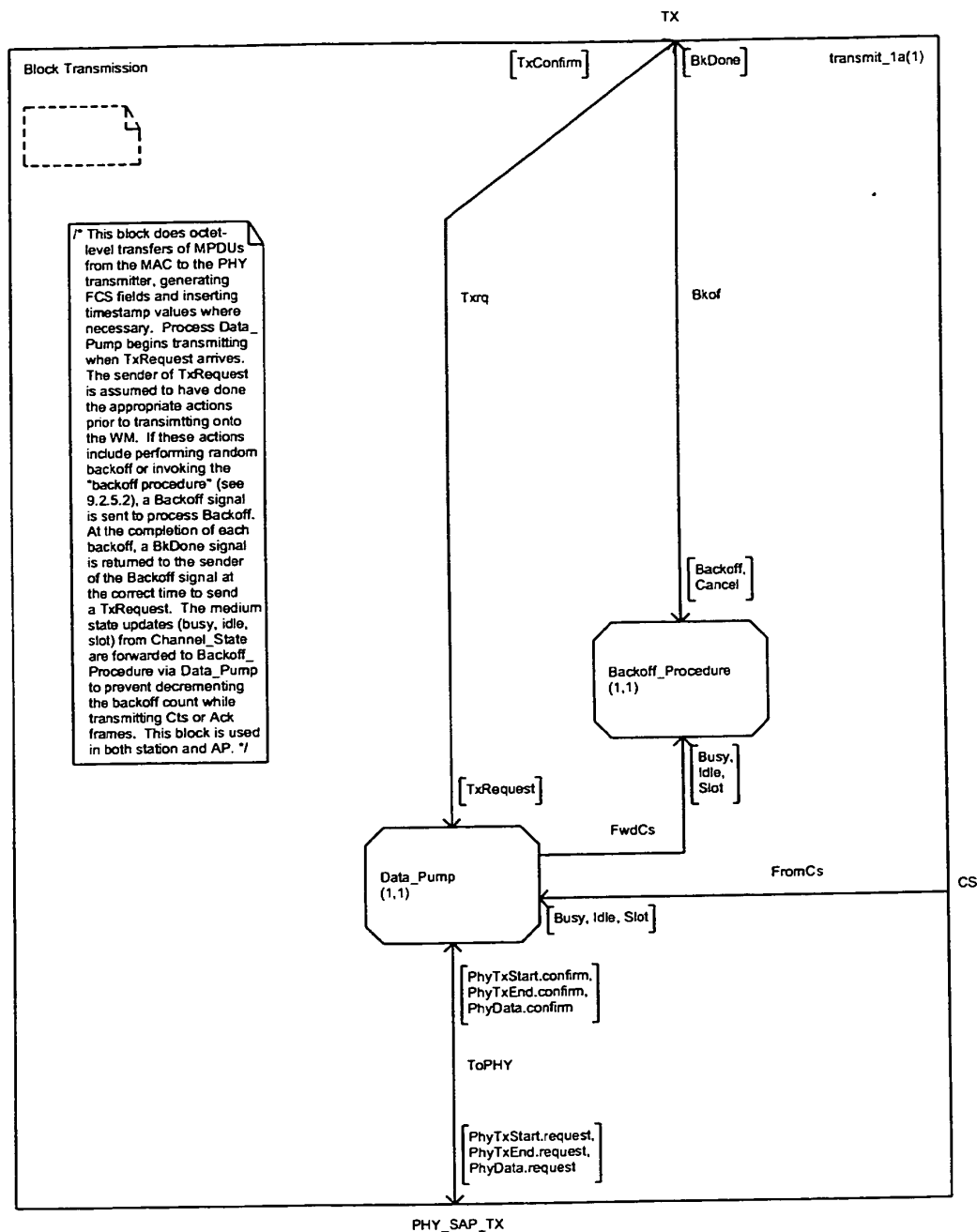


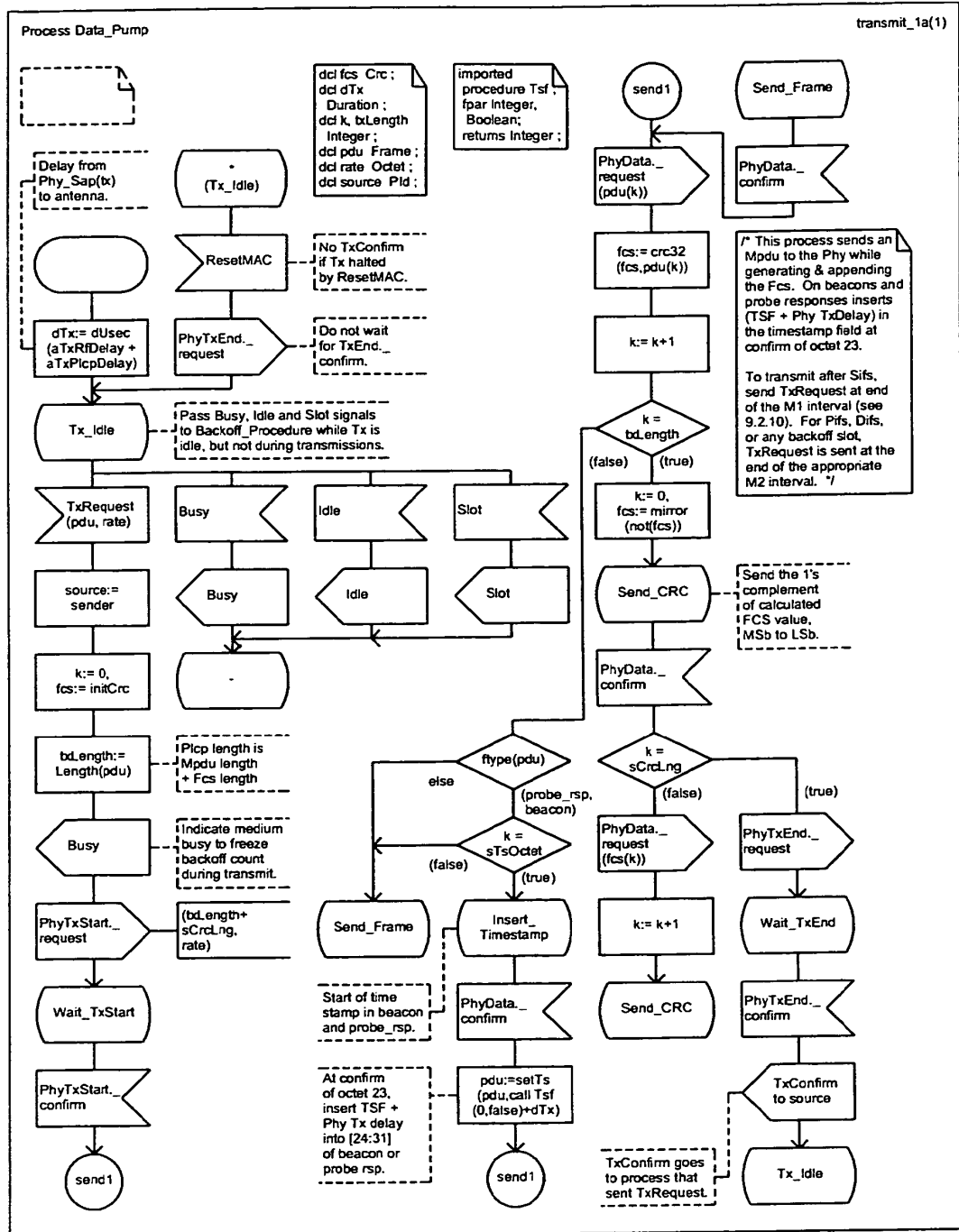


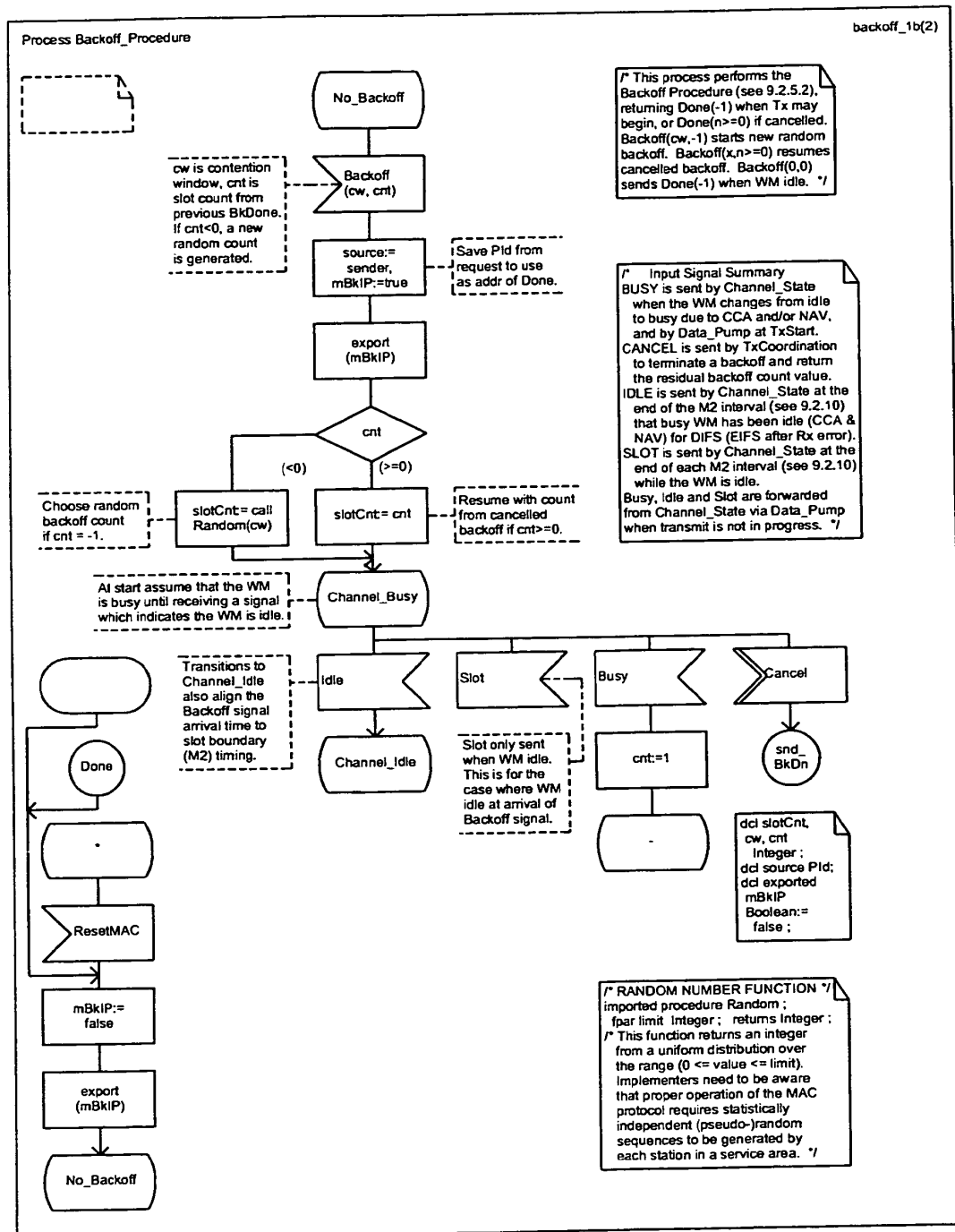


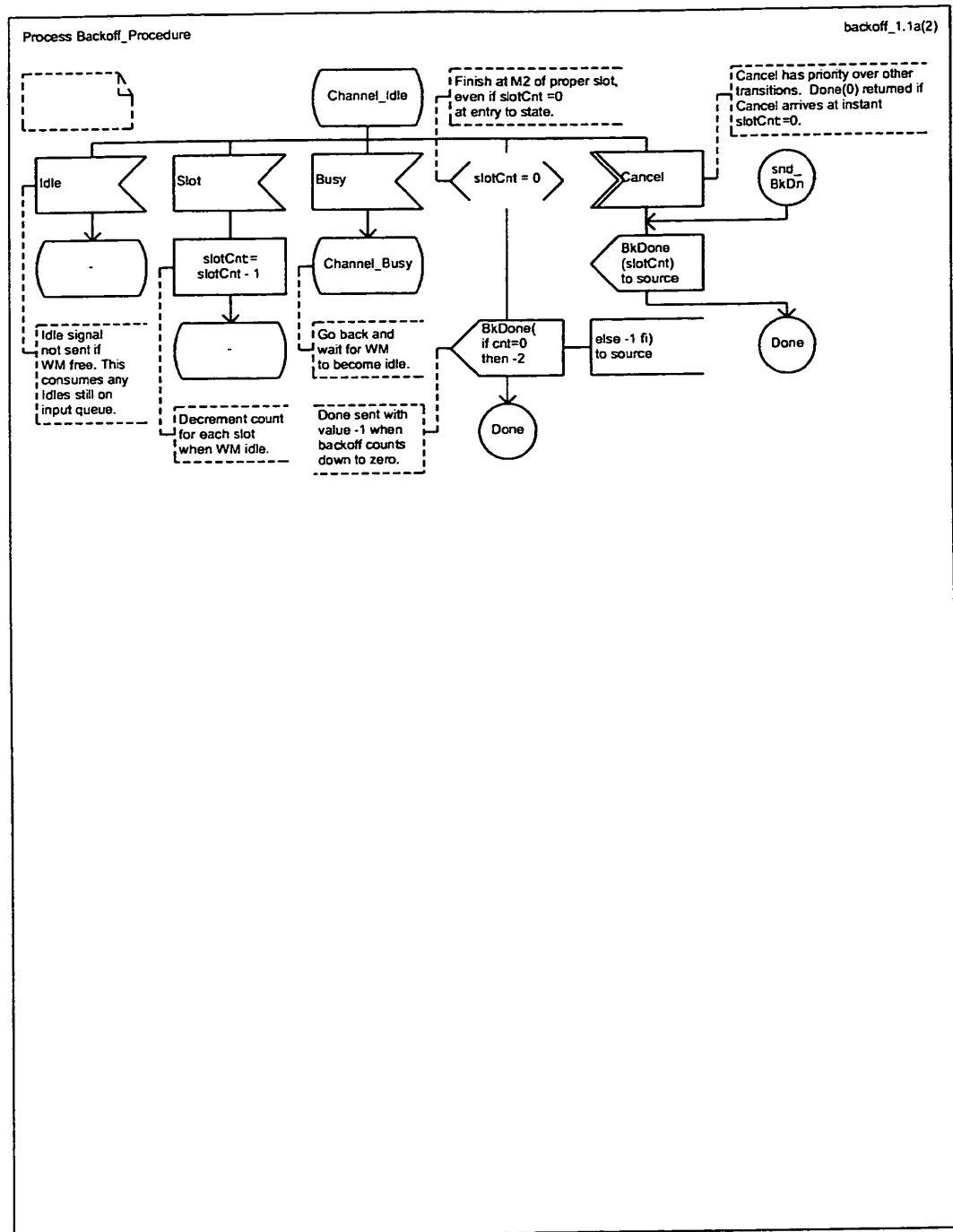


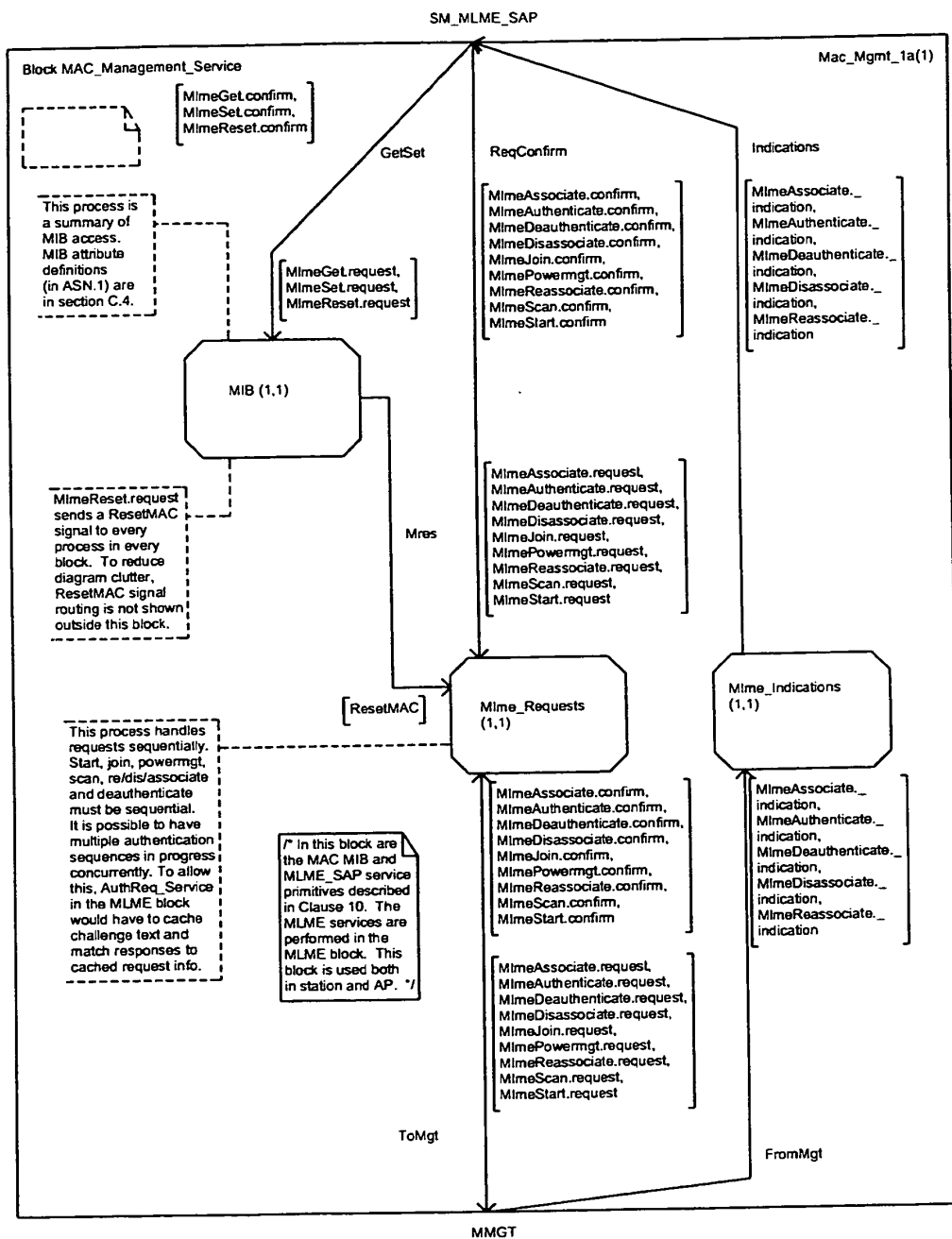


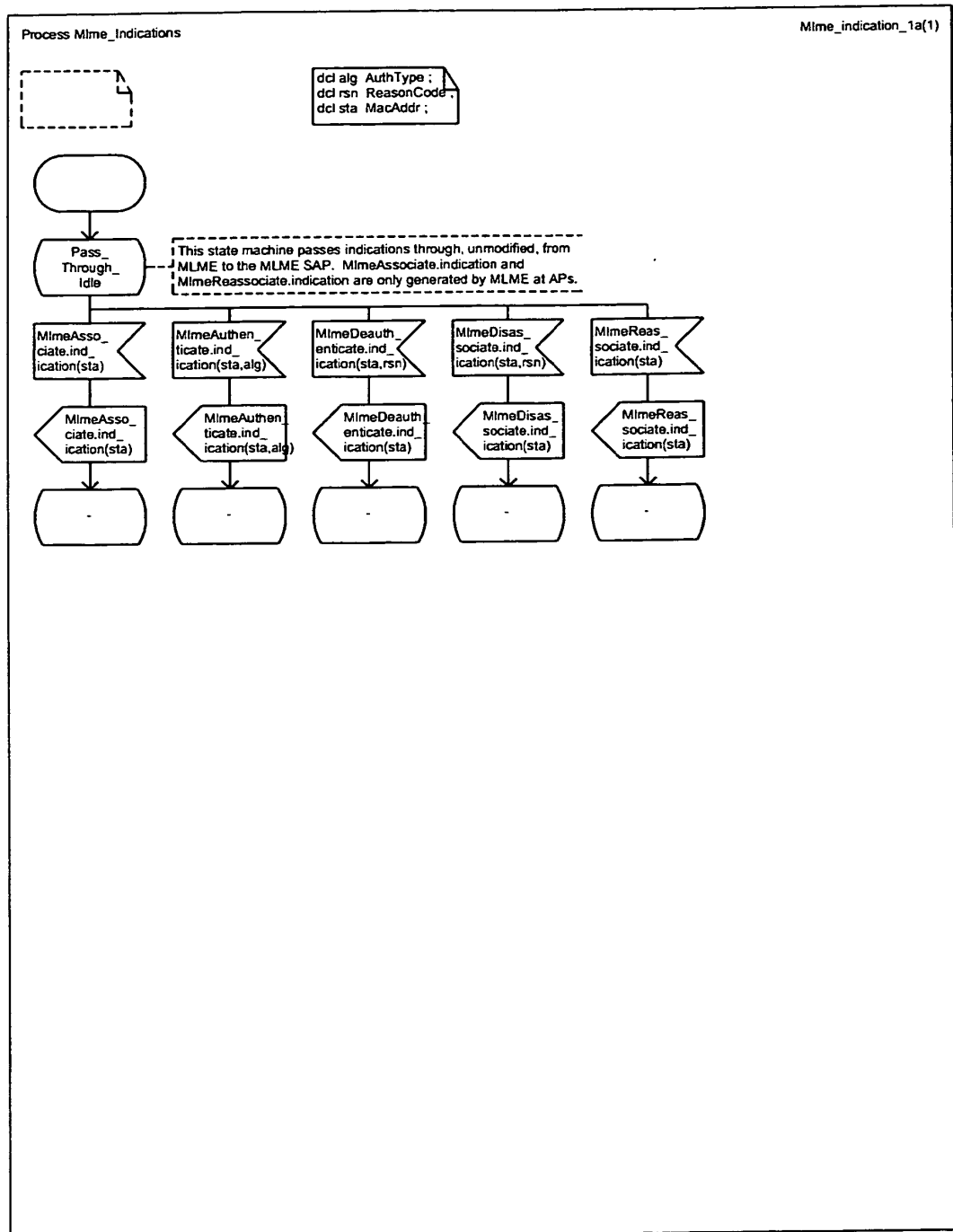


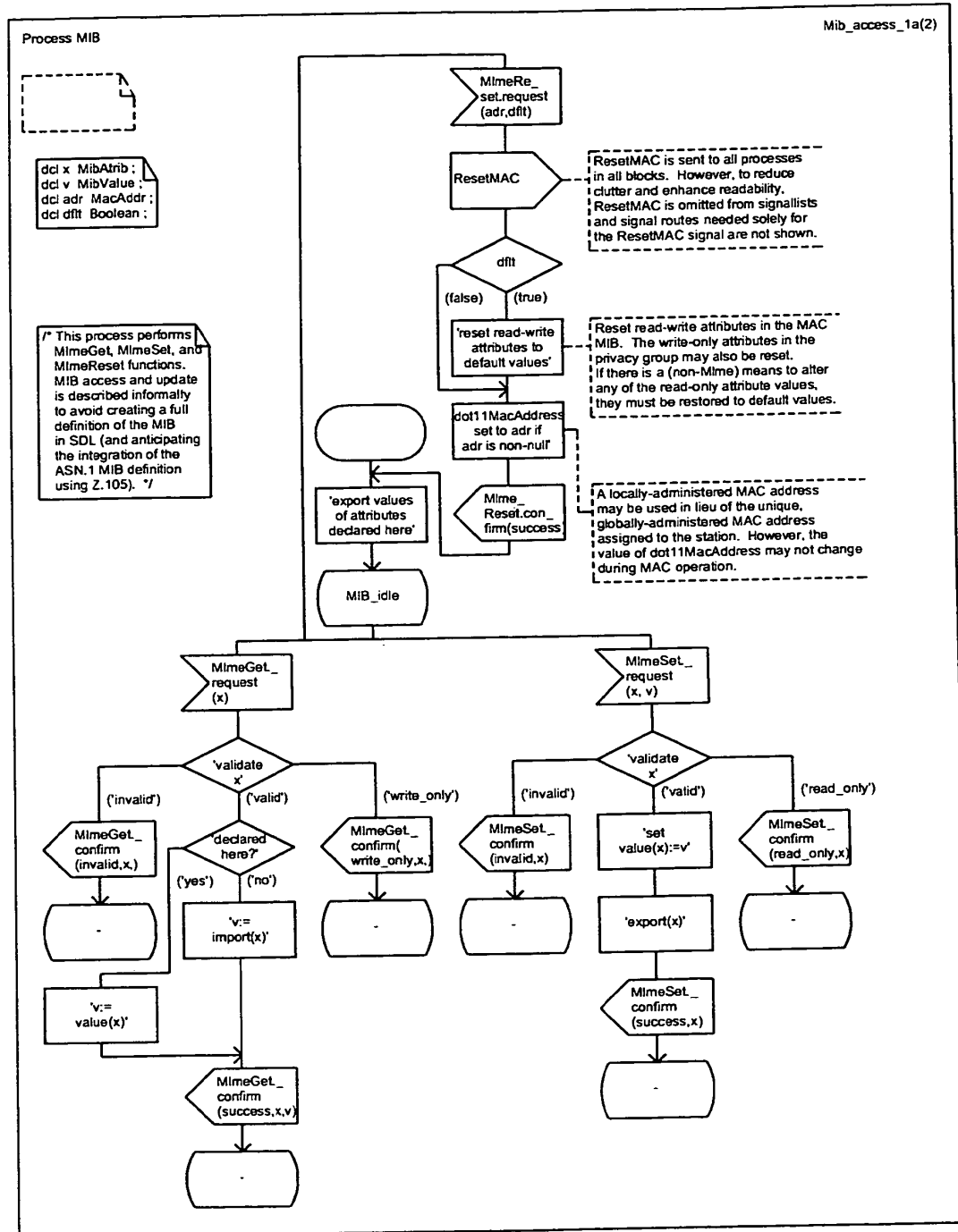












Process MIB

Mib_import_export_2b(2)



```
/* Import of (Read-Only) MIB counter
values exported from other processes */
imported
dot11AckFailureCount,
dot11FailedCount,
dot11FcsErrorCount,
dot11FrameDuplicateCount,
dot11MulticastReceivedFrameCount,
dot11MulticastTransmittedFrameCount,
dot11MultipleRetryCount,
dot11ReceivedFragmentCount,
dot11RetryCount,
dot11RtsFailureCount,
dot11RtsSuccessCount,
dot11TransmittedFragmentCount,
dot11WepExcludedCount,
dot11WepIcvErrorCount,
dot11WepUndecryptableCount Counter32 ;
```

```
/* Declarations of MIB attributes exported from
this process */

/* Read-Write attributes */
dcl exported
dot11AuthenticationAlgorithms AuthTypeSet=
ind(open_system, shared_key),
dot11ExcludeUnencrypted Boolean:= false,
dot11FragmentationThreshold Integer:= 2346,
dot11GroupAddresses MacAddrSet= empty,
dot11LongRetryLimit Integer:= 4,
dot11MaxReceiveLifetime Kusec:= 512,
dot11MaxTransmitMsdulifetime Kusec:= 512,
dot11MediumOccupancyLimit Kusec:= 100,
dot11PrivacyInvoked Boolean:= false,
mReceiveDTIMs Boolean:= true,
dot11CfpPeriod Integer:= 1,
dot11CfpMaxDuration Kusec:= 200,
dot11AuthenticationResponseTimeout Kusec:= 512,
dot11RtsThreshold Integer:= 3000,
dot11ShortRetryLimit Integer:= 7,
dot11WepDefaultKeyid KeyIndex:= 0,
dot11CurrentChannelNumber Integer:= 0,
dot11CurrentSet Integer:= 0,
dot11CurrentPattern Integer:= 0,
dot11CurrentIndex Integer:= 0 ;
```

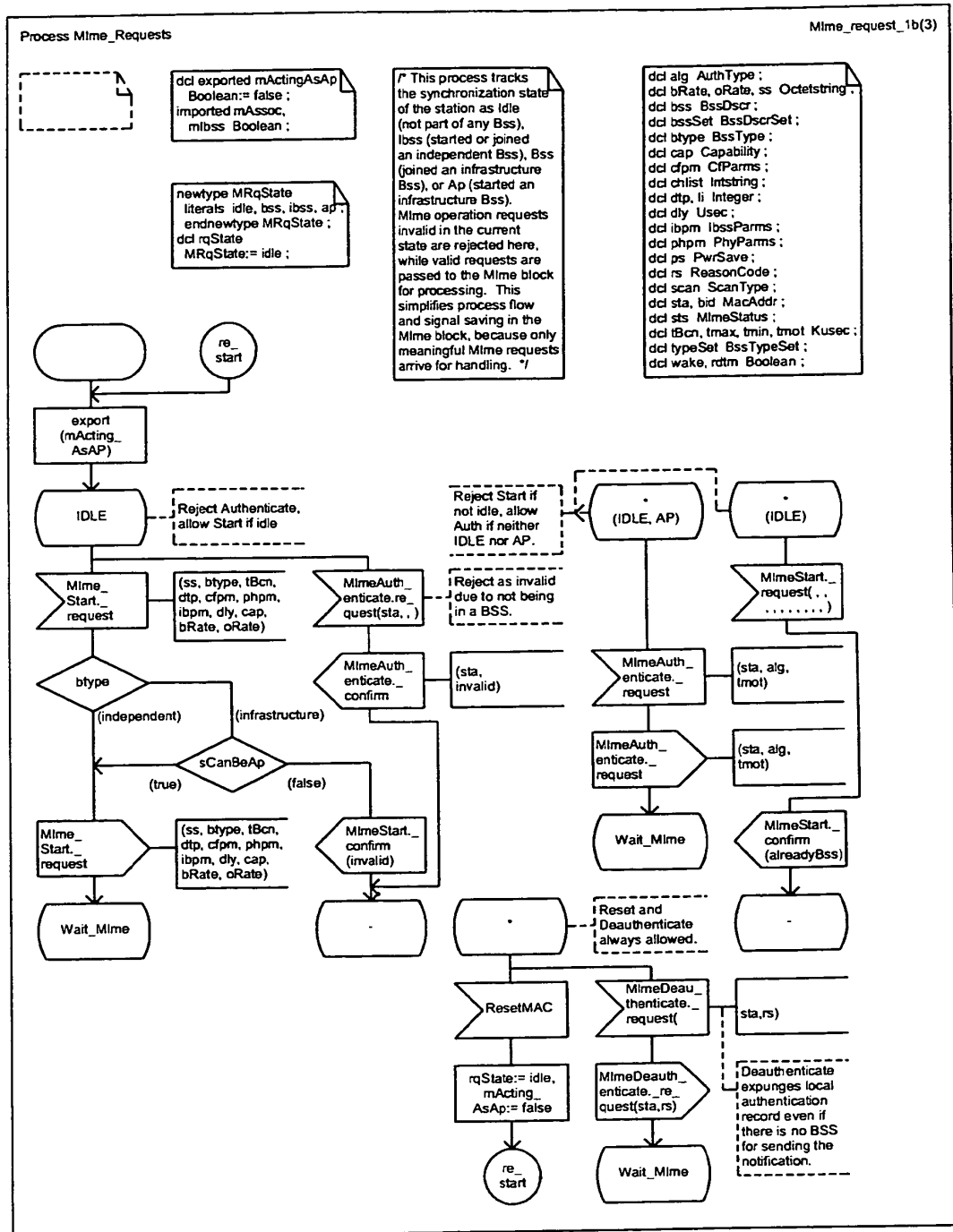
```
/* Write-Only attributes */
dcl exported
dot11WepDefaultKeys KeyVector:= nullKey,
dot11WepKeyMappings
KeyMapArray:= (. nullAddr, false, nullKey .);
```

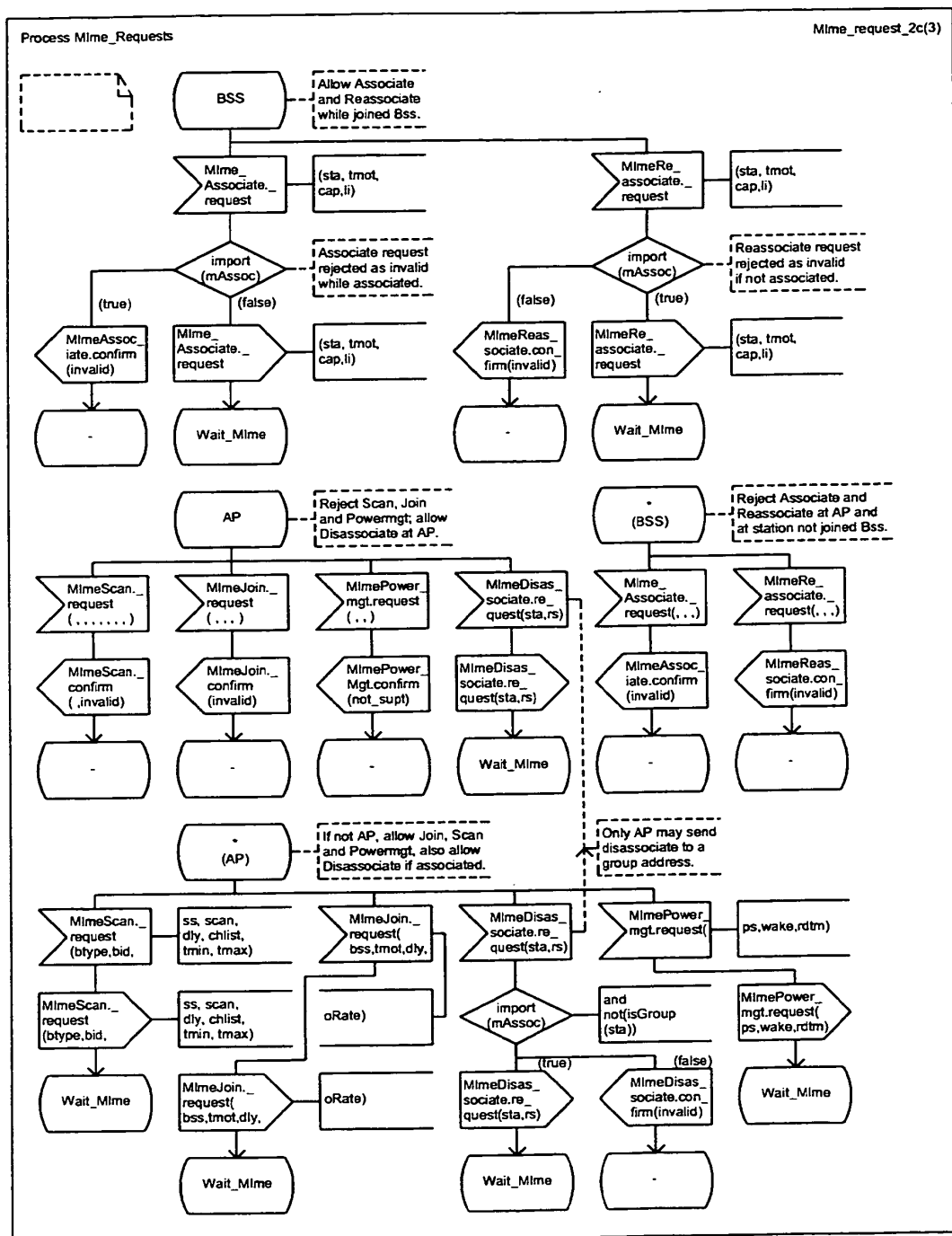
/* The following Read-Only attributes in the MAC MIB are defined as synonyms (named constants) rather than remote variables because they describe properties of the station which are static, at least during any single instance of MAC operation:

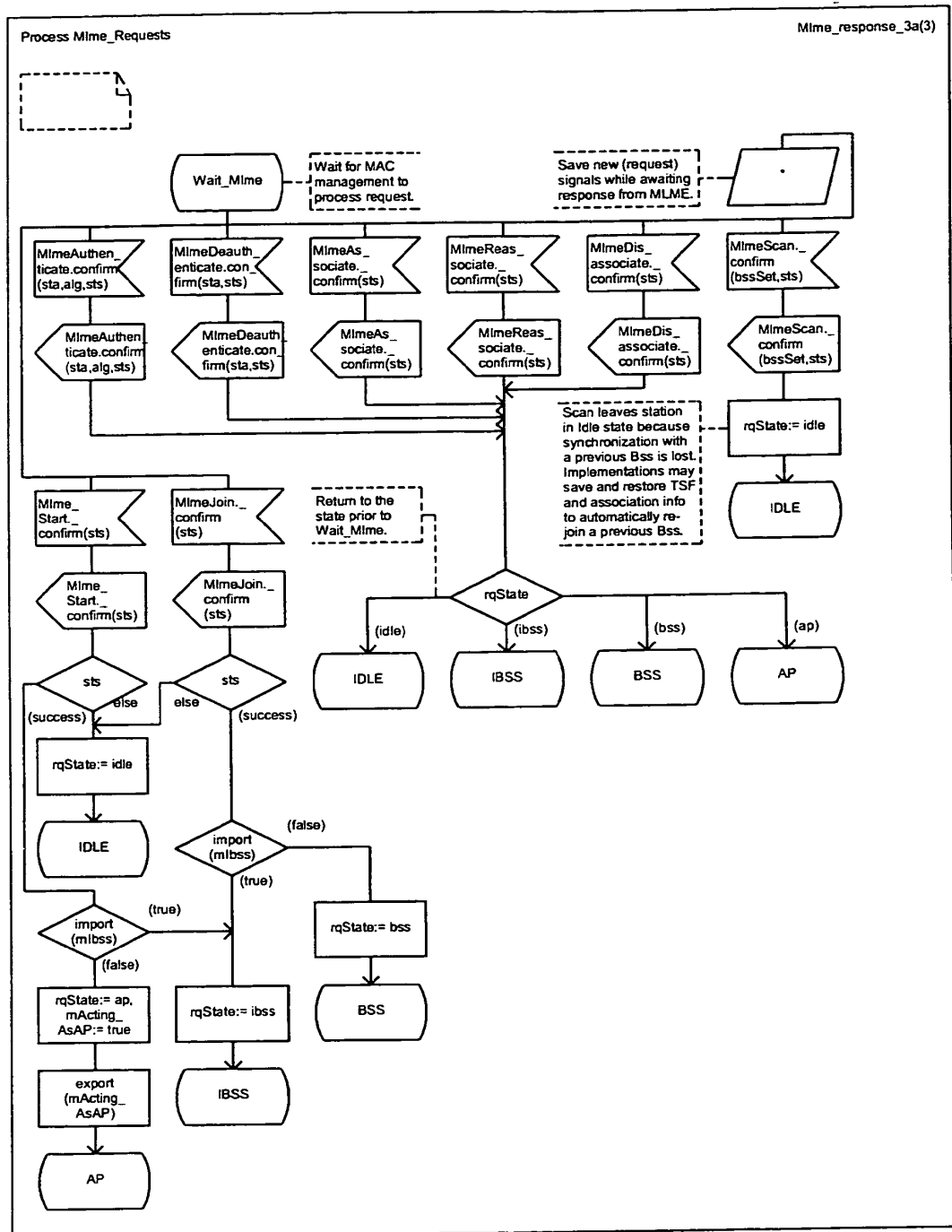
```
dot11AuthenticationAlgorithms AuthTypeSet,
dot11CfPollable Boolean,
dot11MacAddress MacAddr,
dot11ManufacturerID Octetstring,
dot11PrivacyOptionImplemented Boolean,
dot11ProductID Octetstring,
aStationID MacAddr,
dot11WepKeyMappingLength Integer ;
```

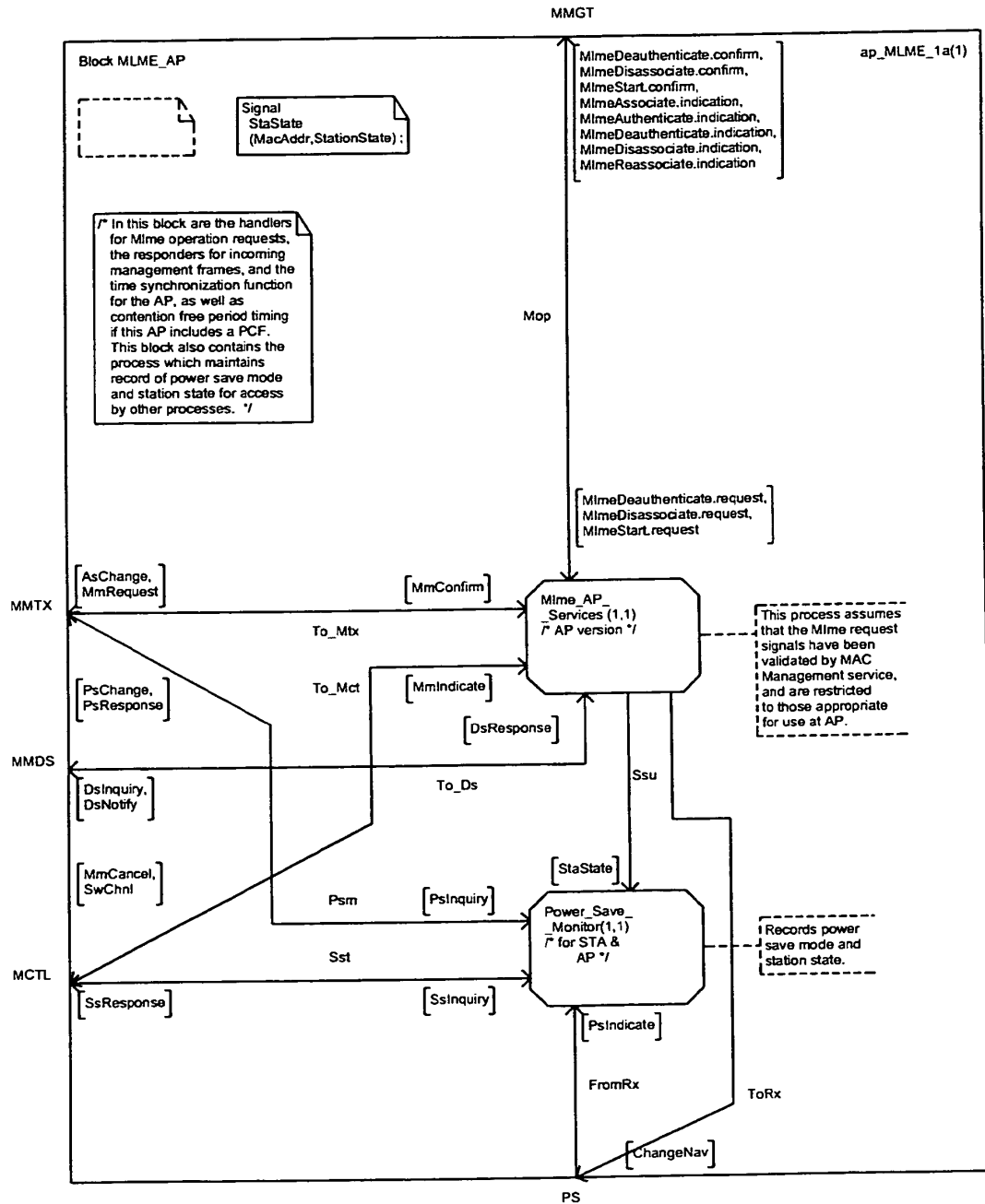
In addition, all Read-Only attributes in the PHY MIB which are accessed by the MAC are defined as synonyms.

/* NOTE:
The values listed for MAC MIB attributes are the specified default values for those attributes.
The values listed for PHY MIB attributes are either the default values for the FH PHY, or arbitrary values within the specified range. The specific values for PHY attributes in this SDL description of the MAC do not have normative significance.
*/

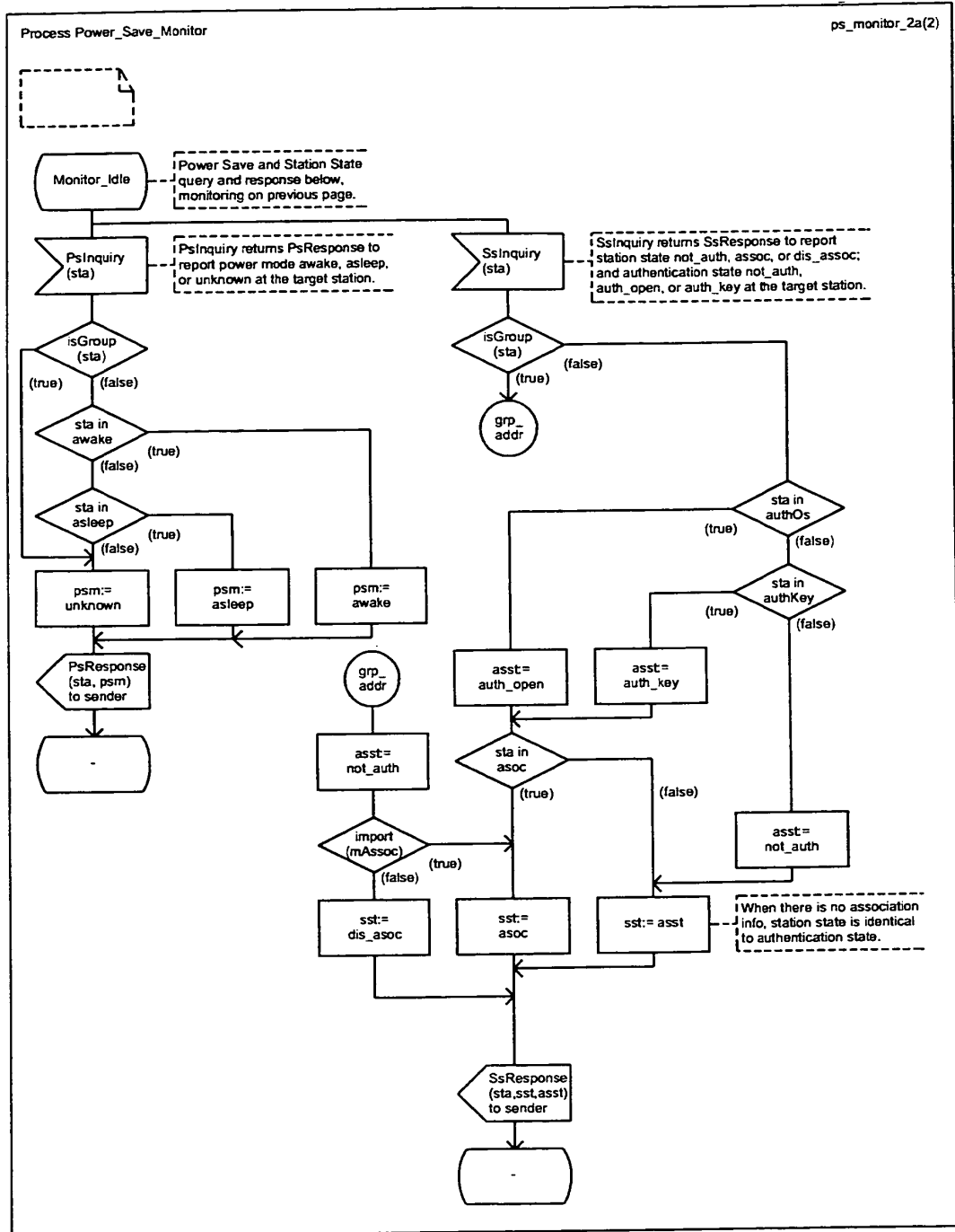


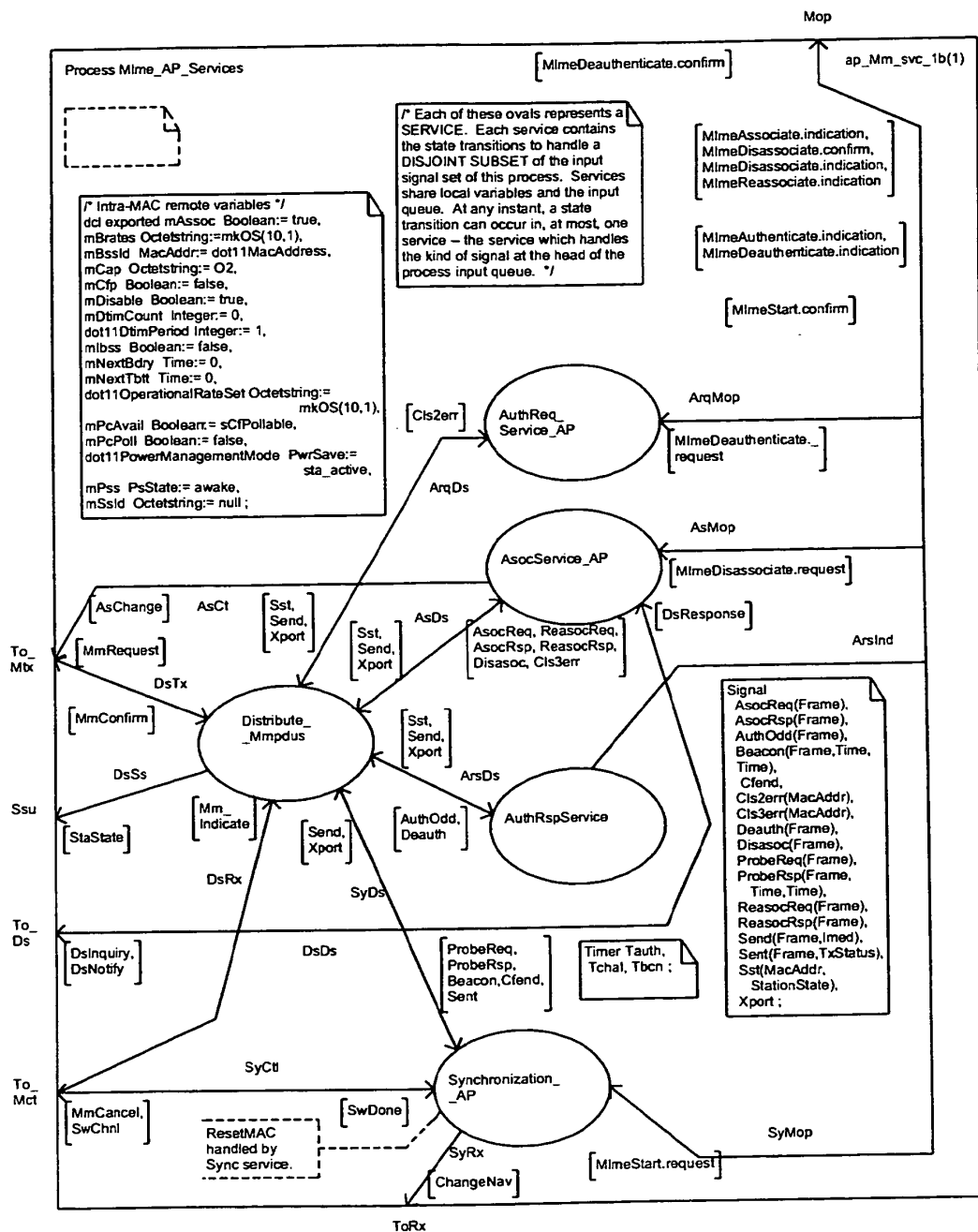


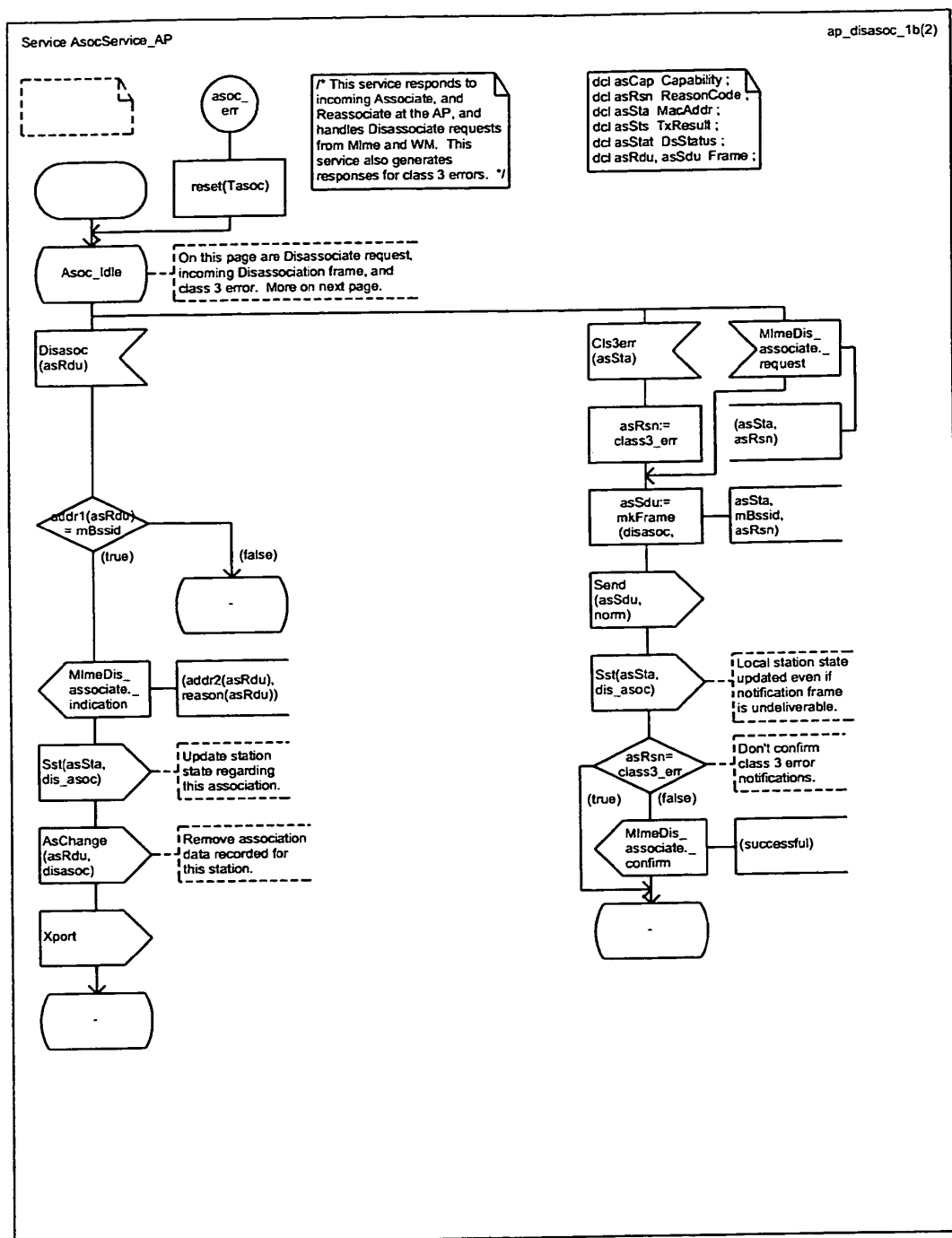


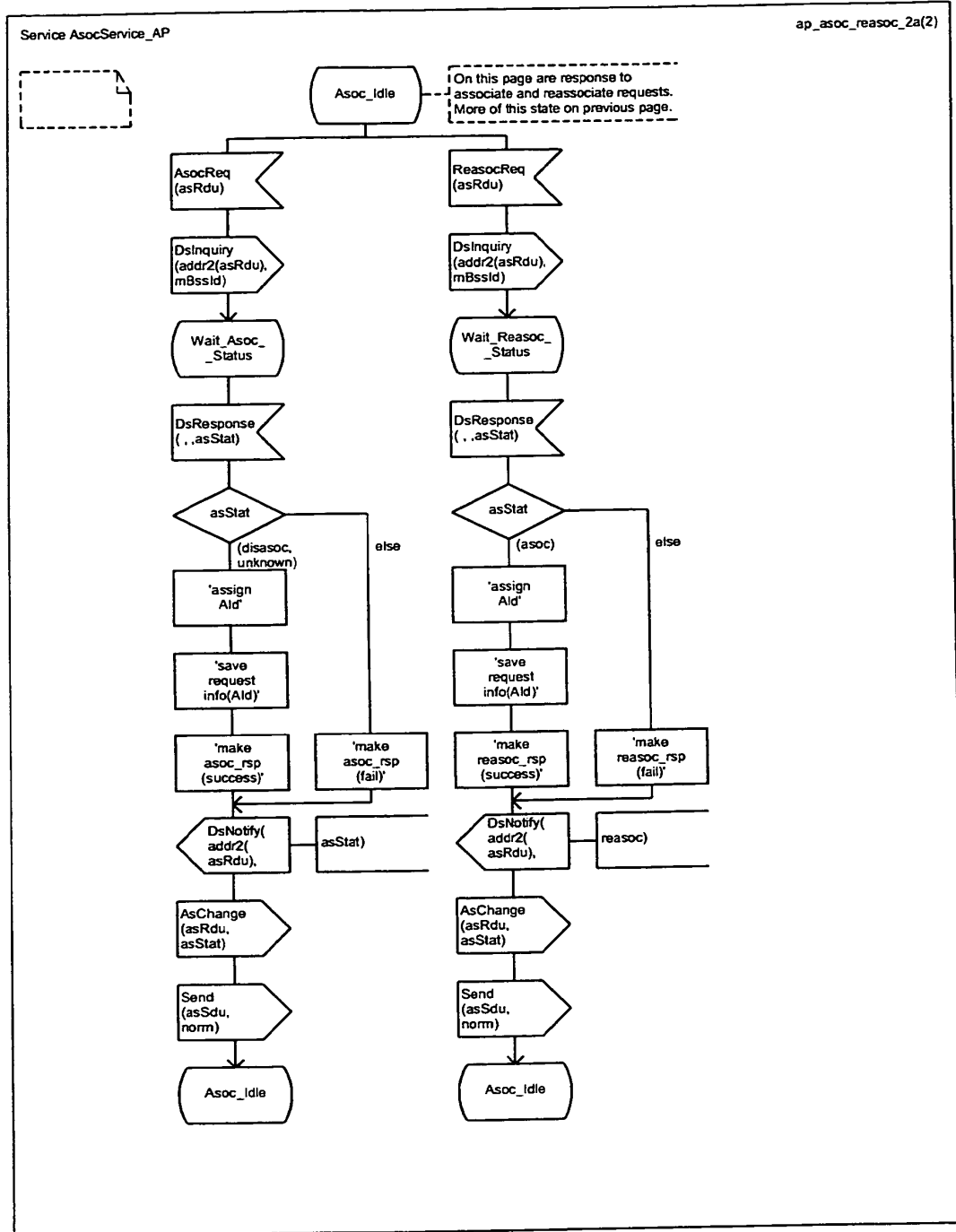


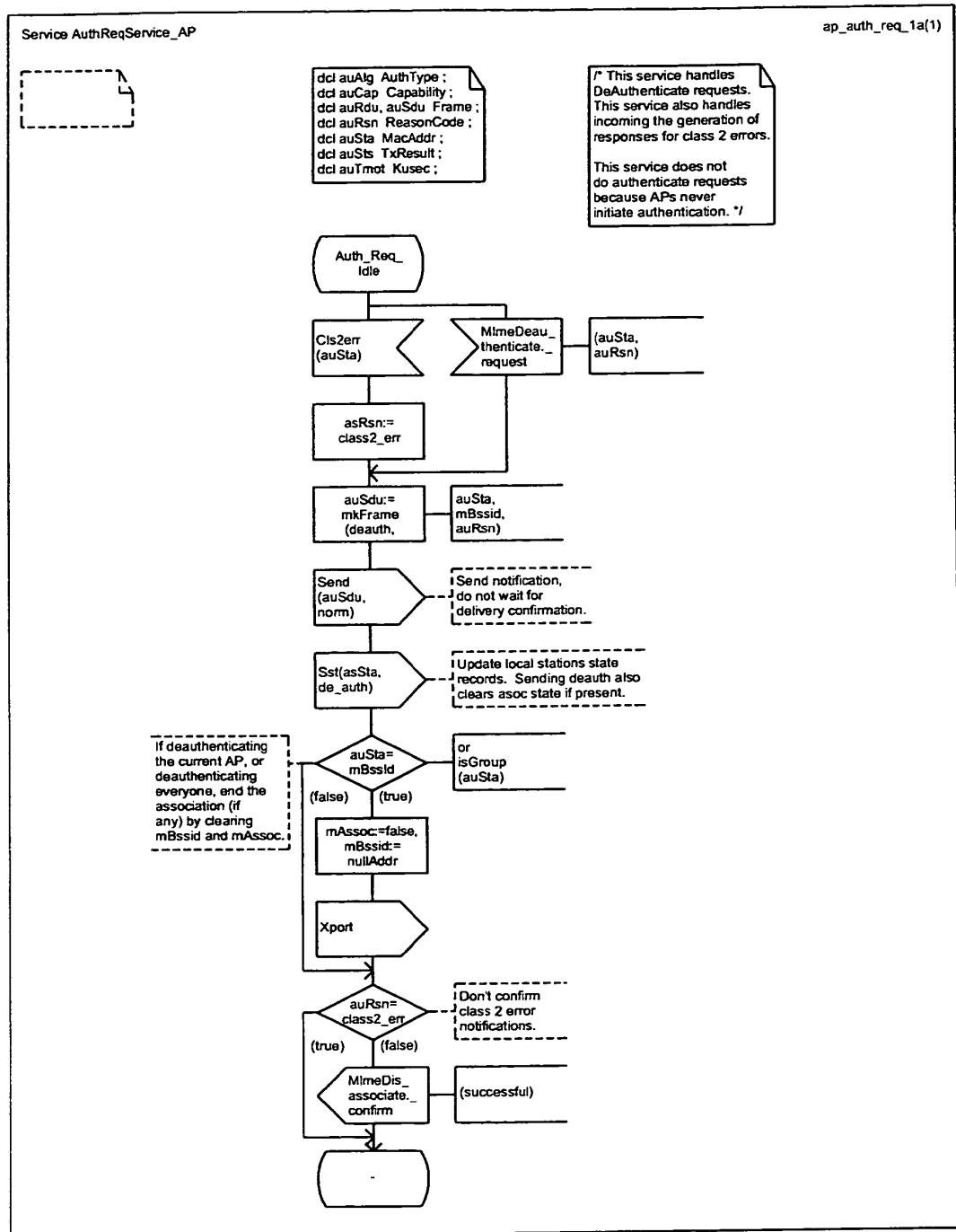


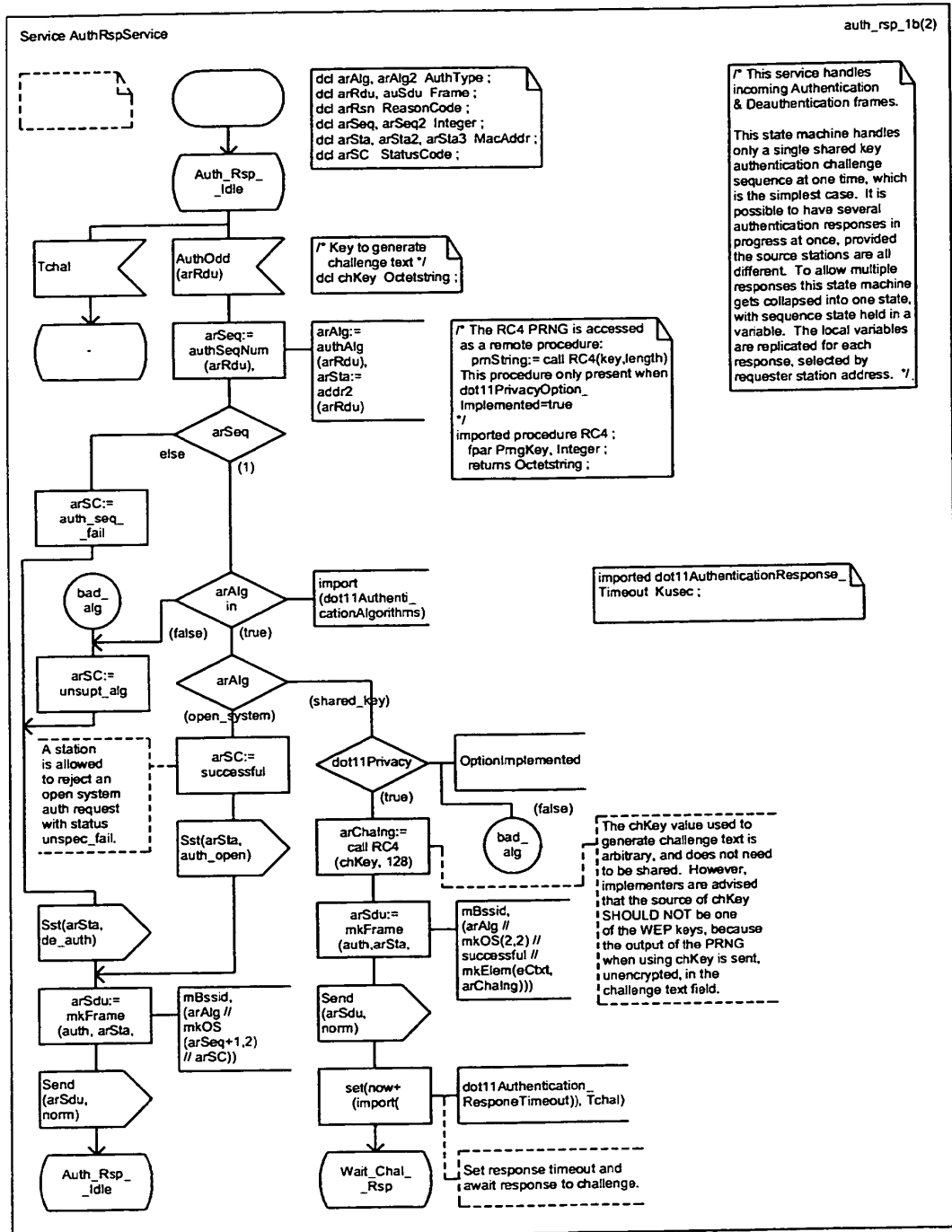


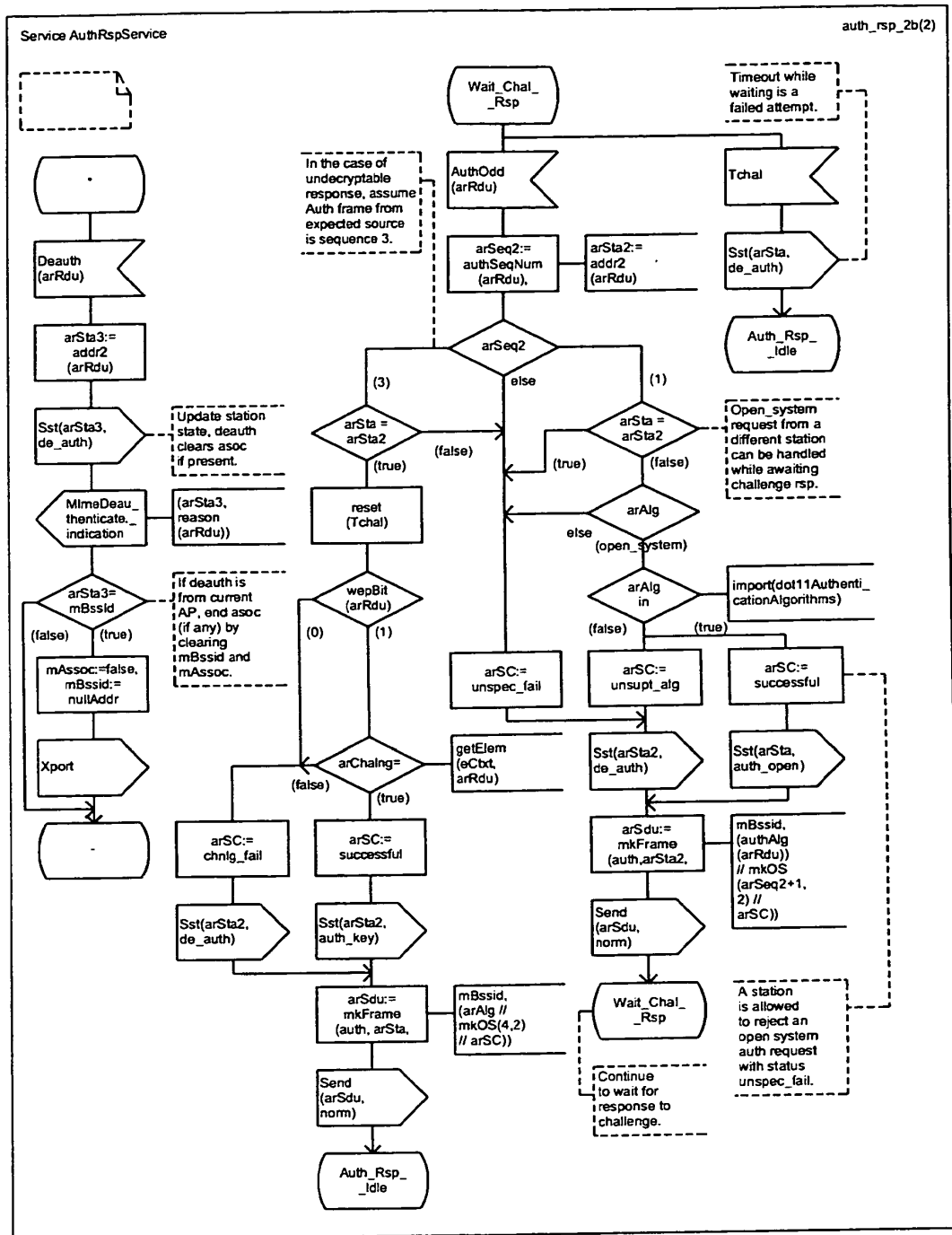


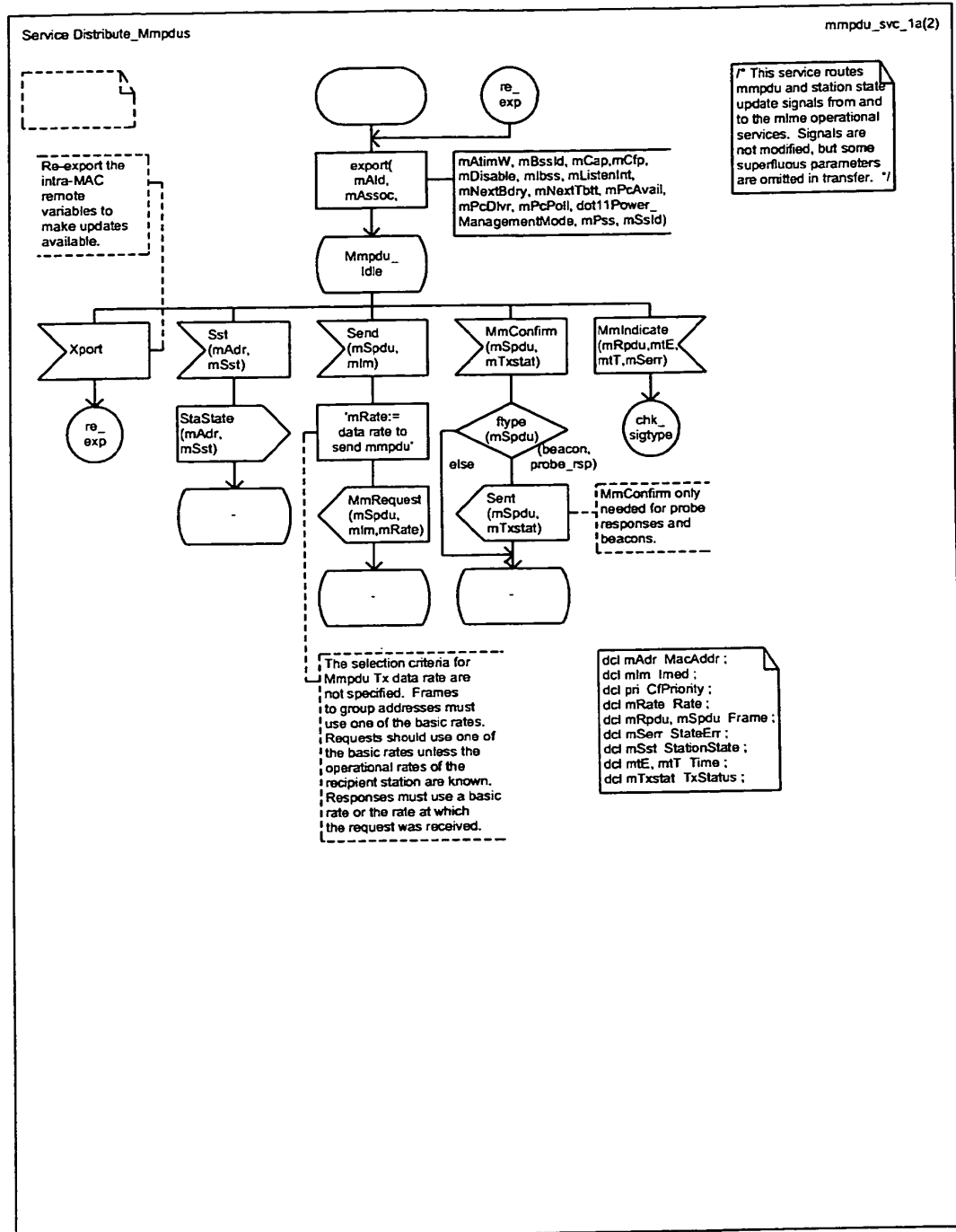


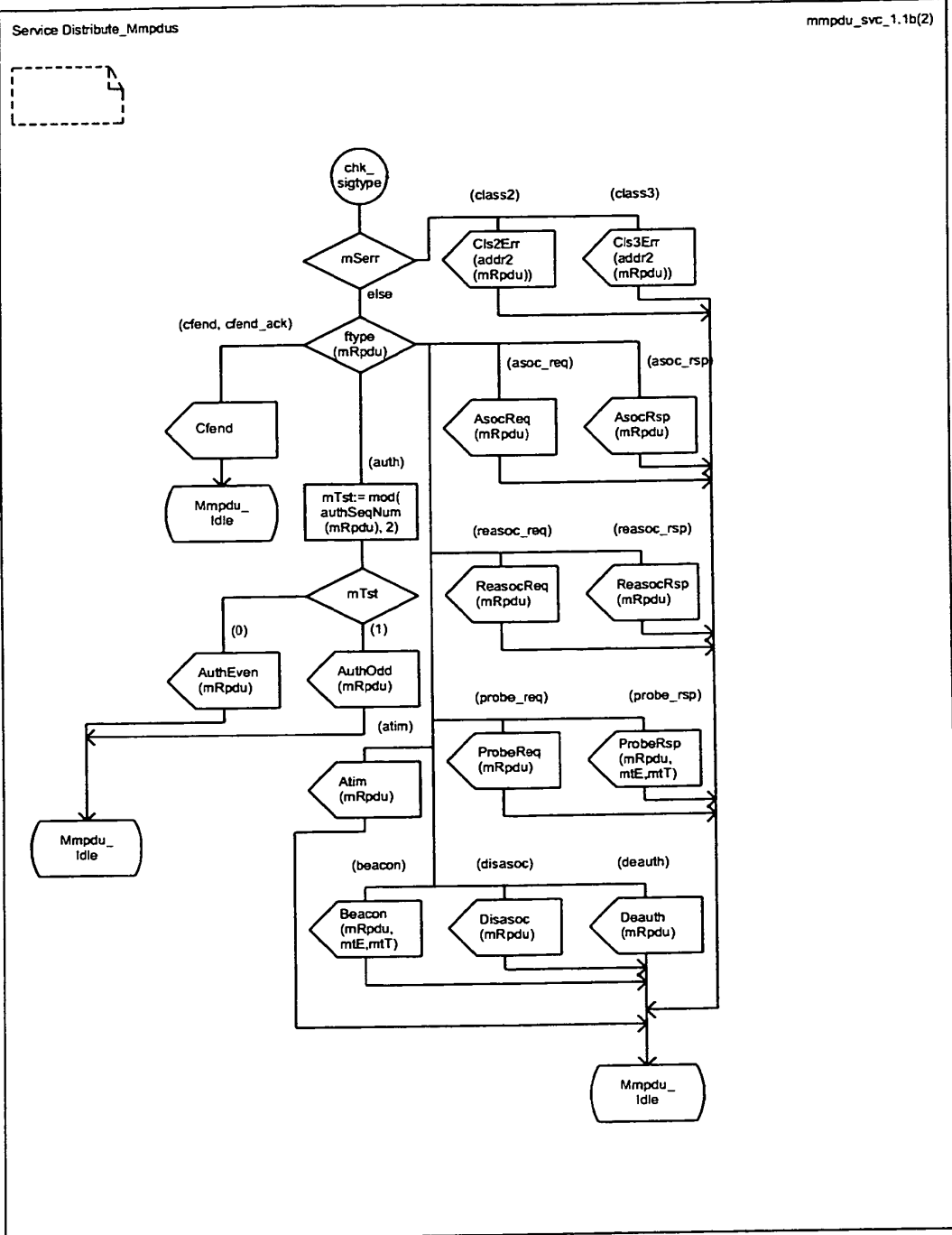












Service Synchronization_AP

ap_init_1b(3)

```

dcl yAtimRx, yPsm, yRdlim, yWake Boolean ;
dcl yAtw, yBcn, yMocp Time ;
dcl yBcnPeriod, yDtim, ycmx, ycmn Kusec ;
dcl ybd BssDescr ;
dcl ybdset BssDescrSet ;
dcl ybtp BssType ;
dcl ybsid MacAddr ;
dcl yclist Intstring ;
dcl ycx, yjto, ytemp Integer ;
dcl yDspm DsParms ;
dcl yFhpm FhParms ;
dcl ylbpm lssParms ;
dcl ypdly Usec ;

```

```

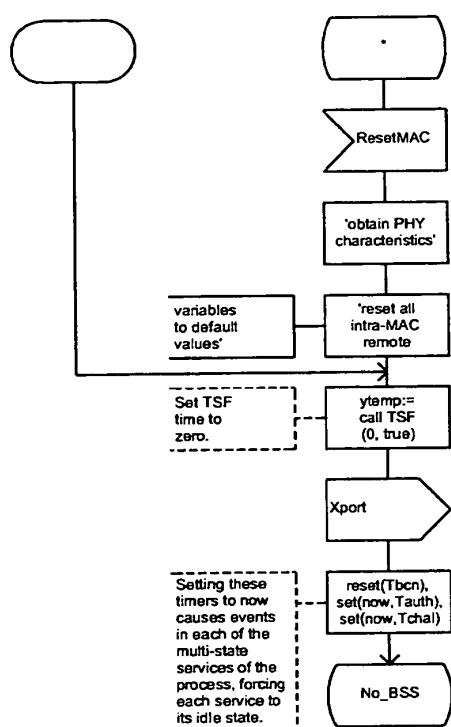
dcl yPhpm PhyParms ;
dcl yRdu, yTdu Frame ;
dcl yssid Octetstring ;
dcl yOrates Ratestring ;
dcl ystp ScanType ;
dcl ytrsl TxResult ;

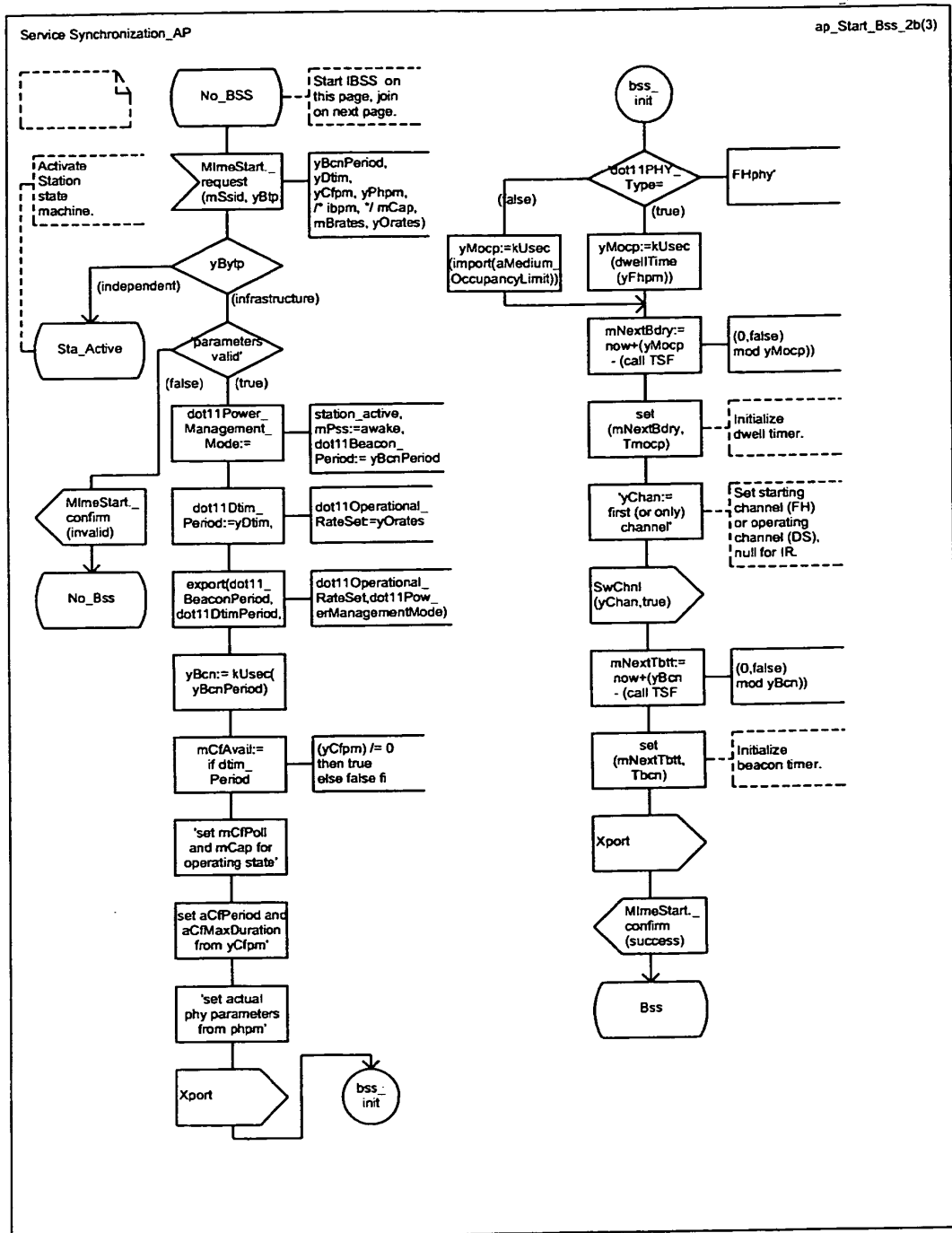
```

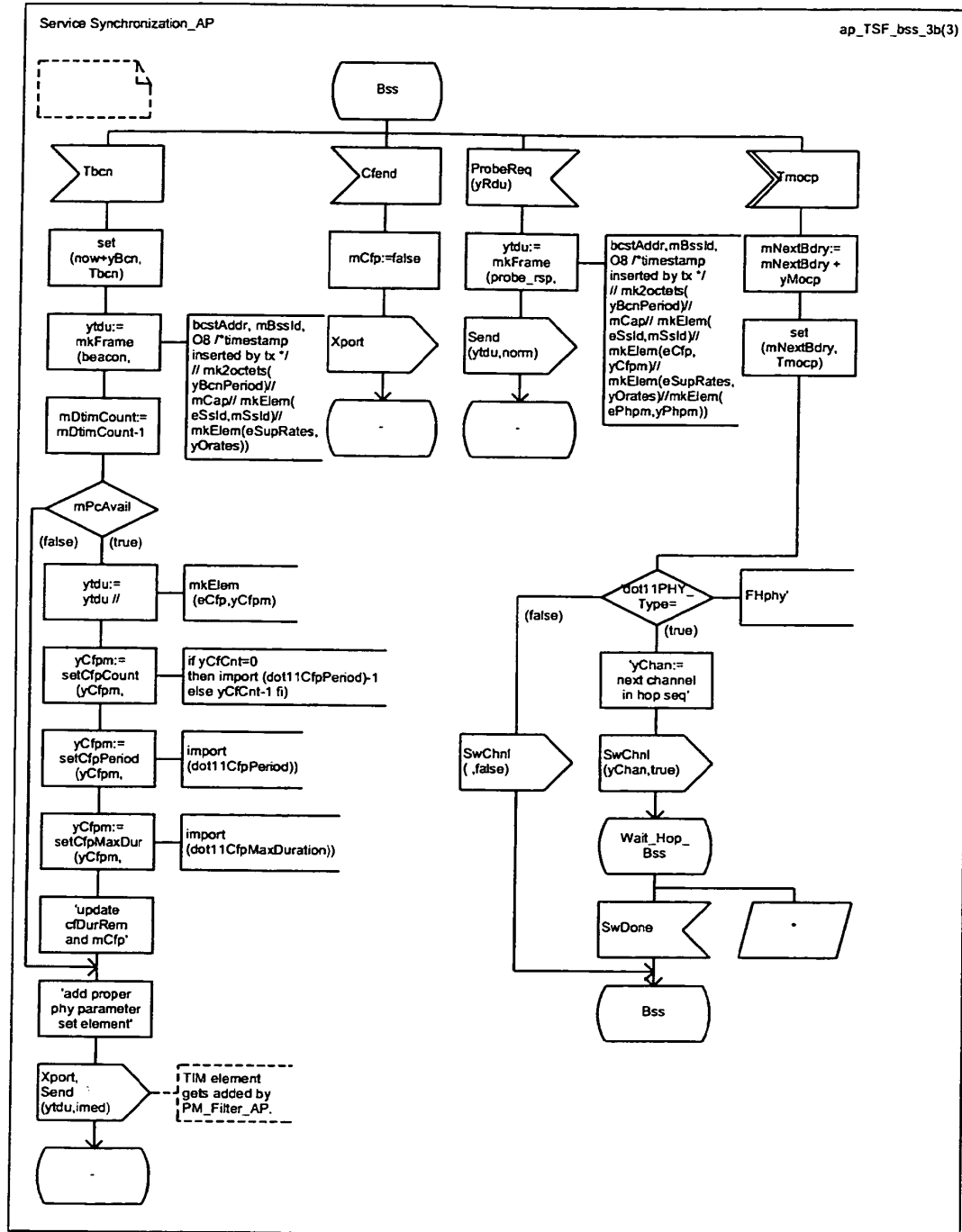
```

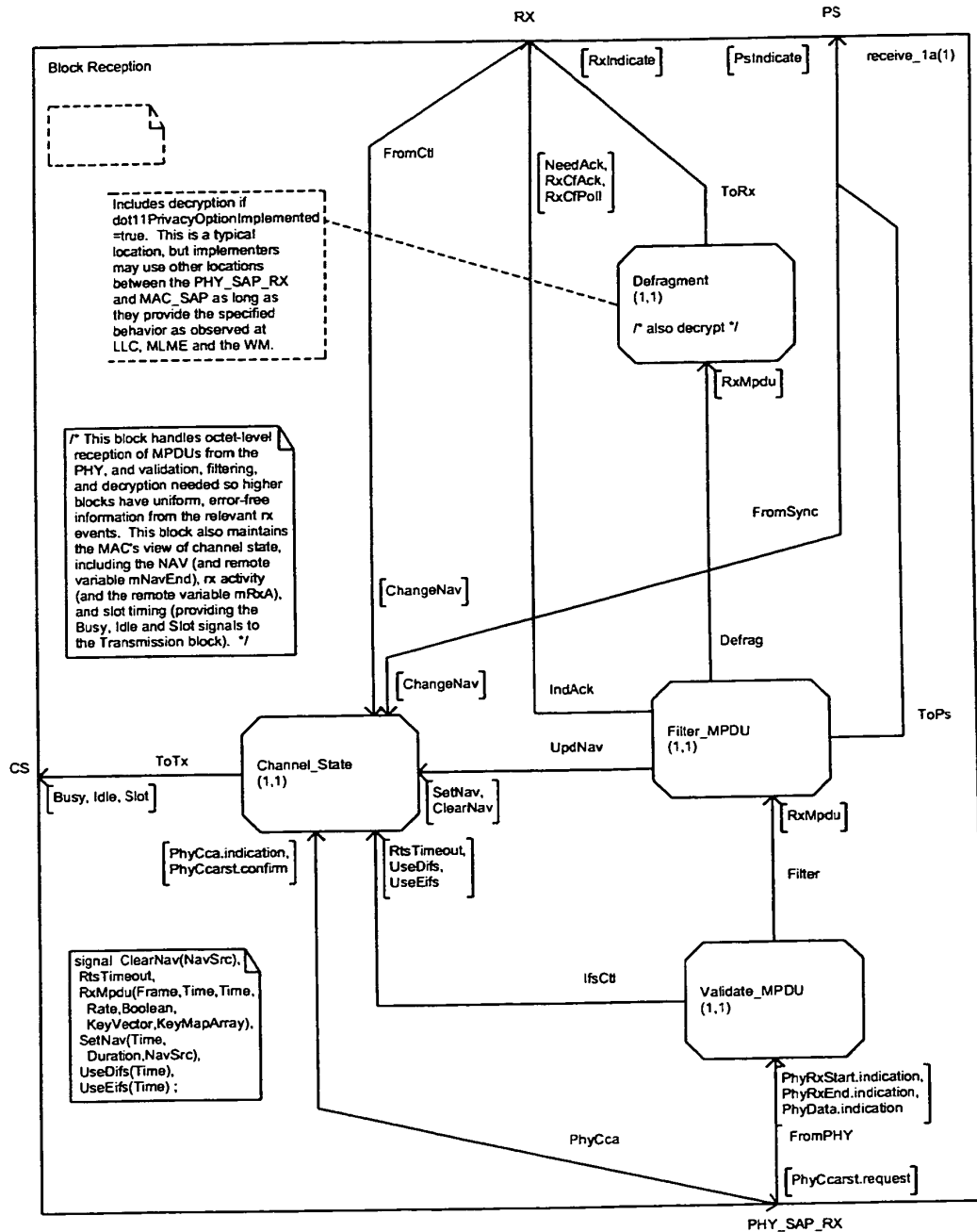
timer Tscan,
Tmocp ;

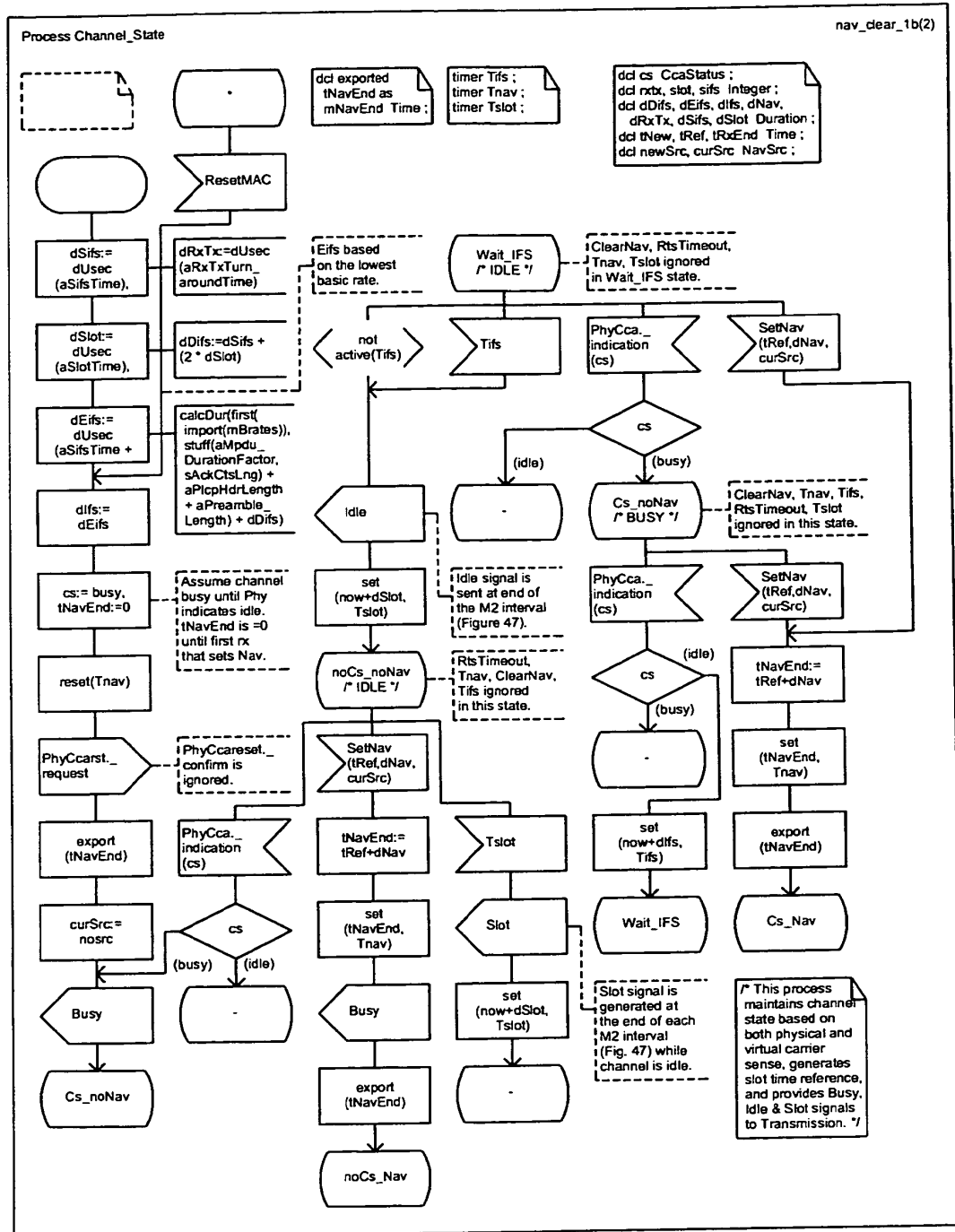
```

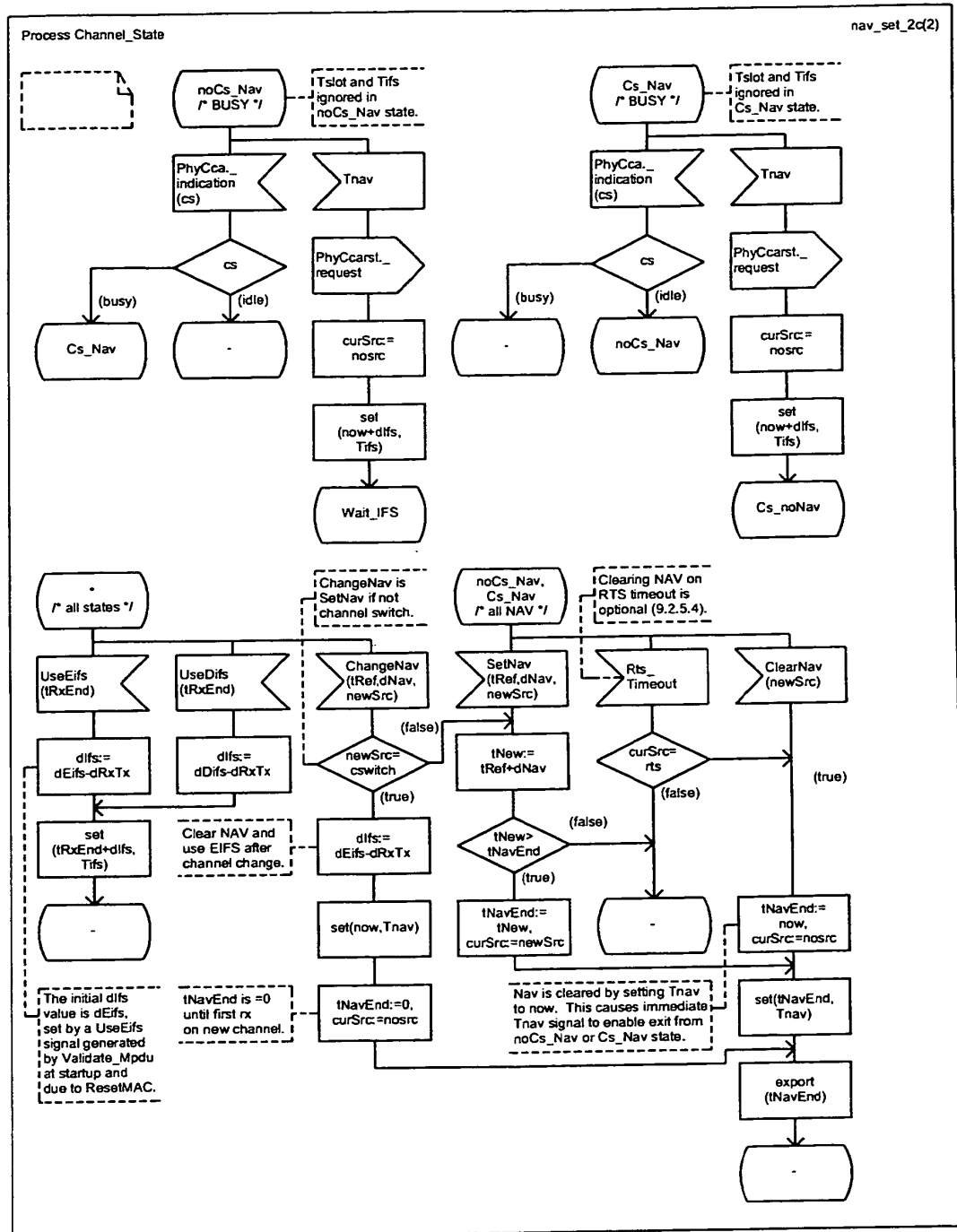


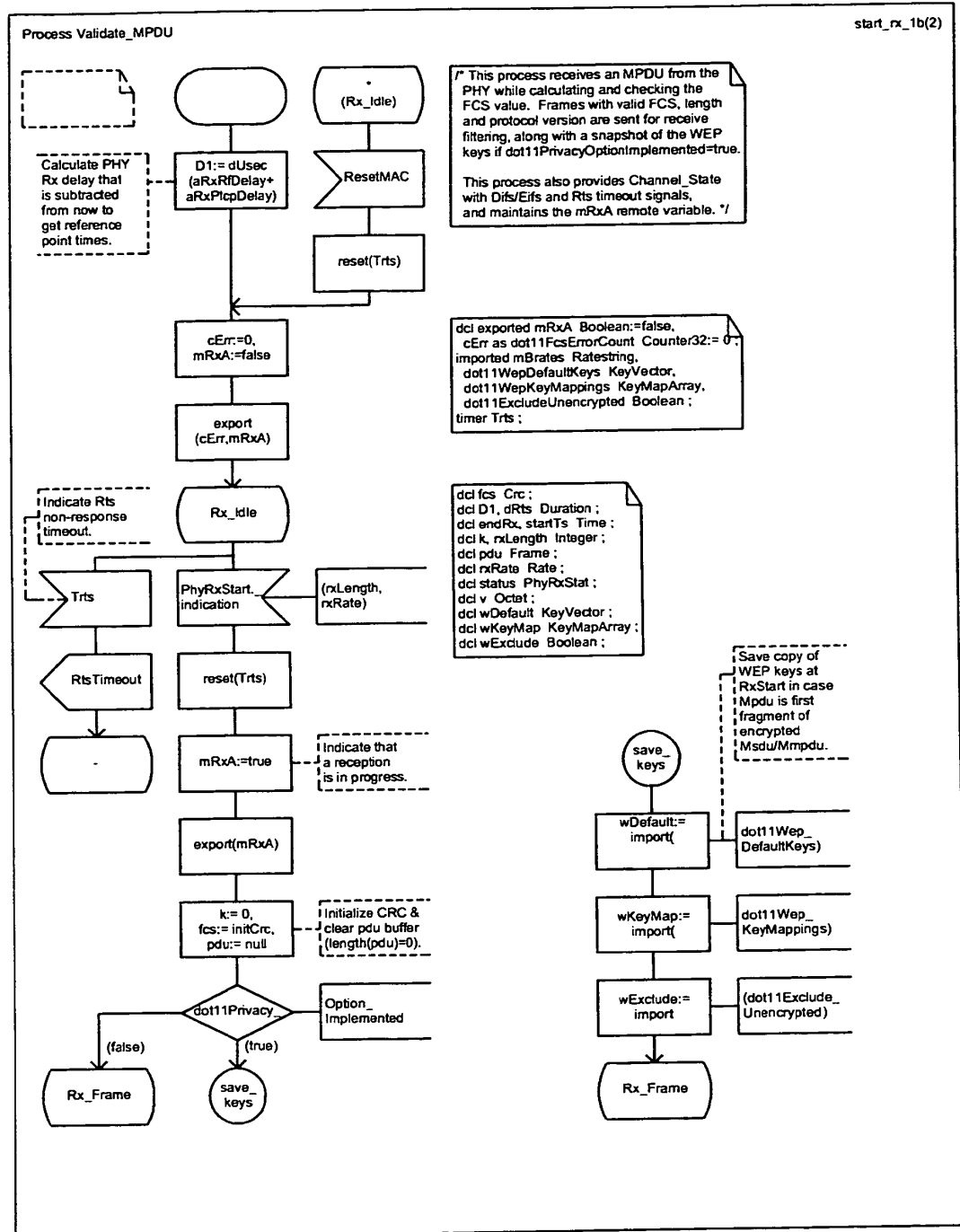


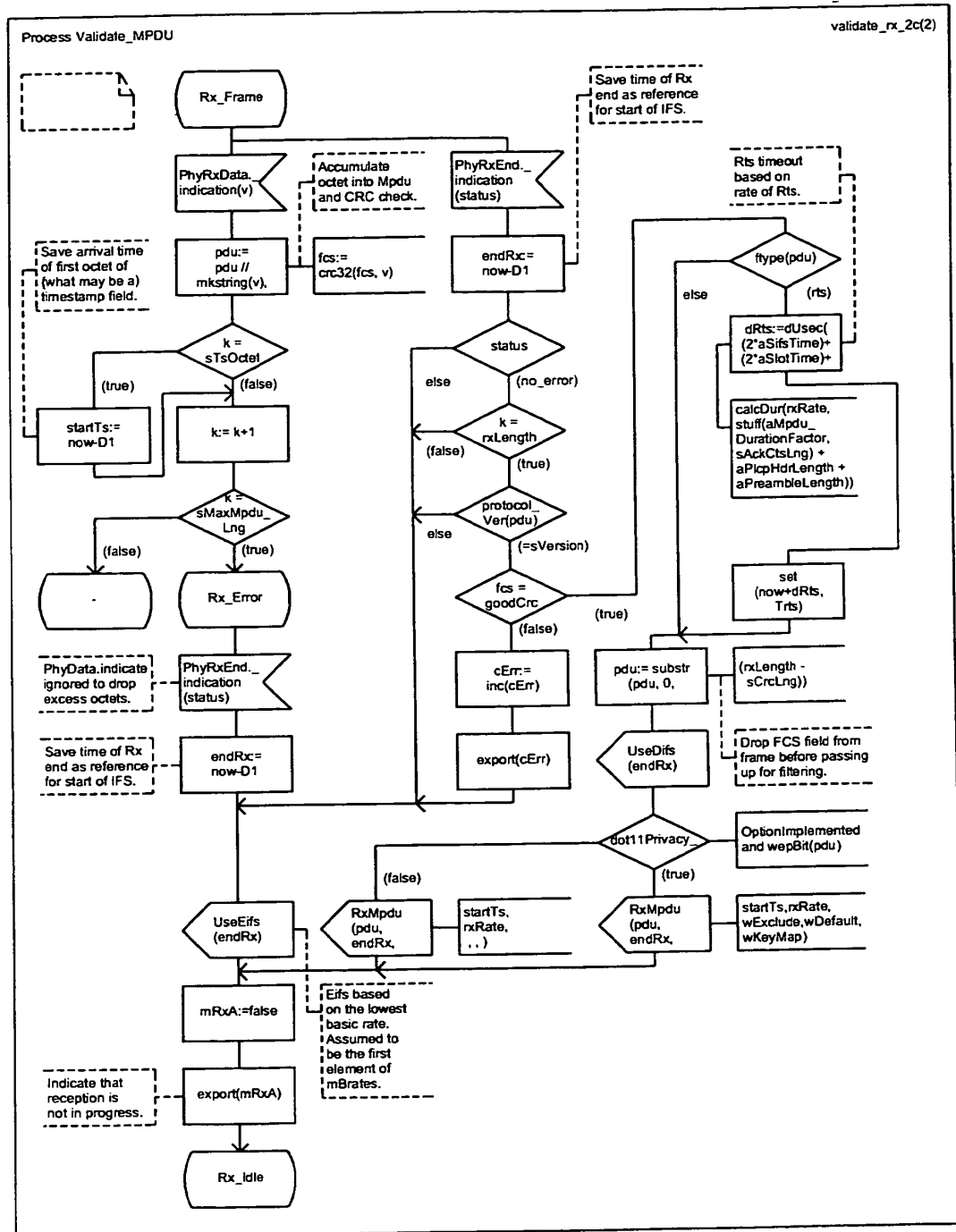


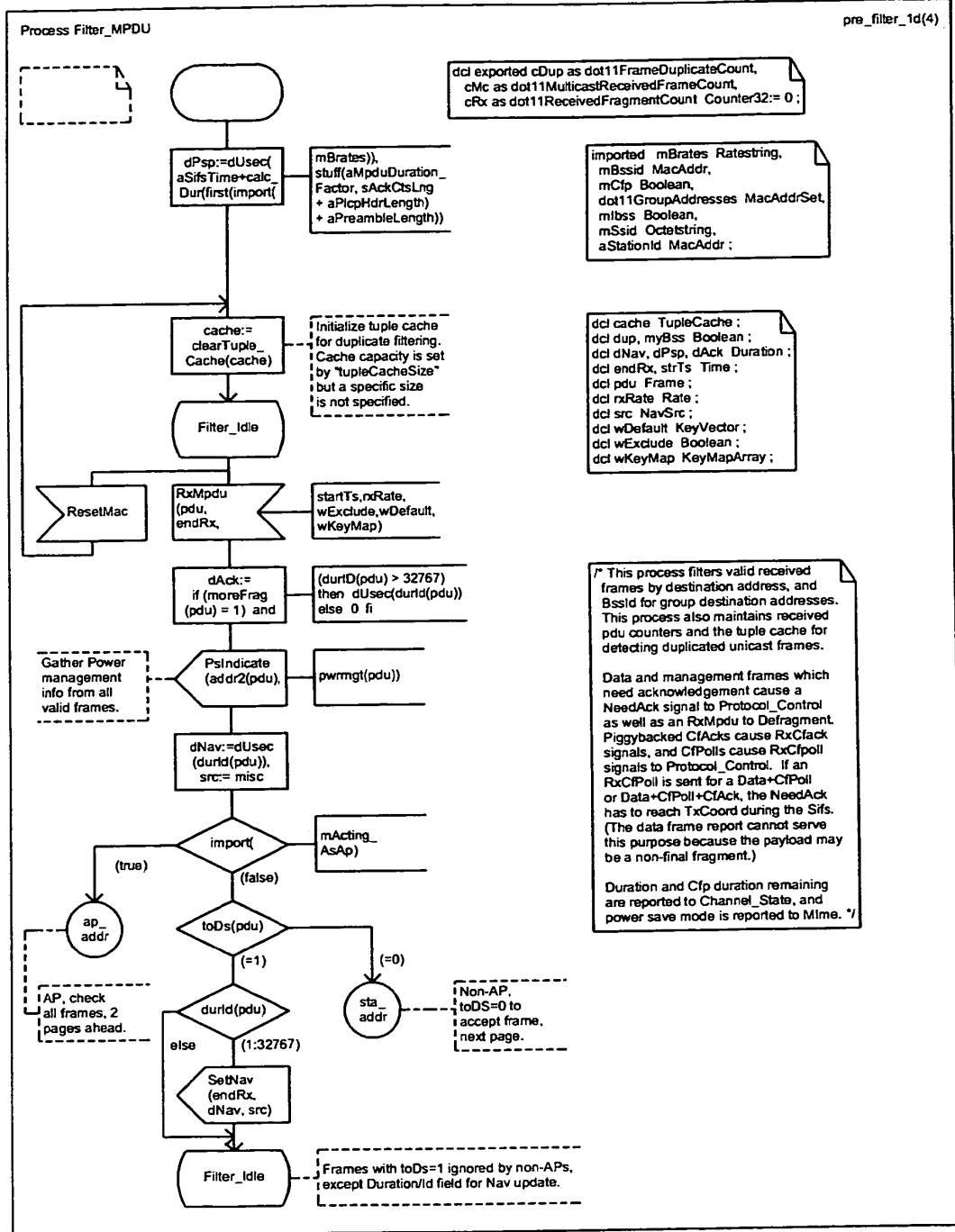


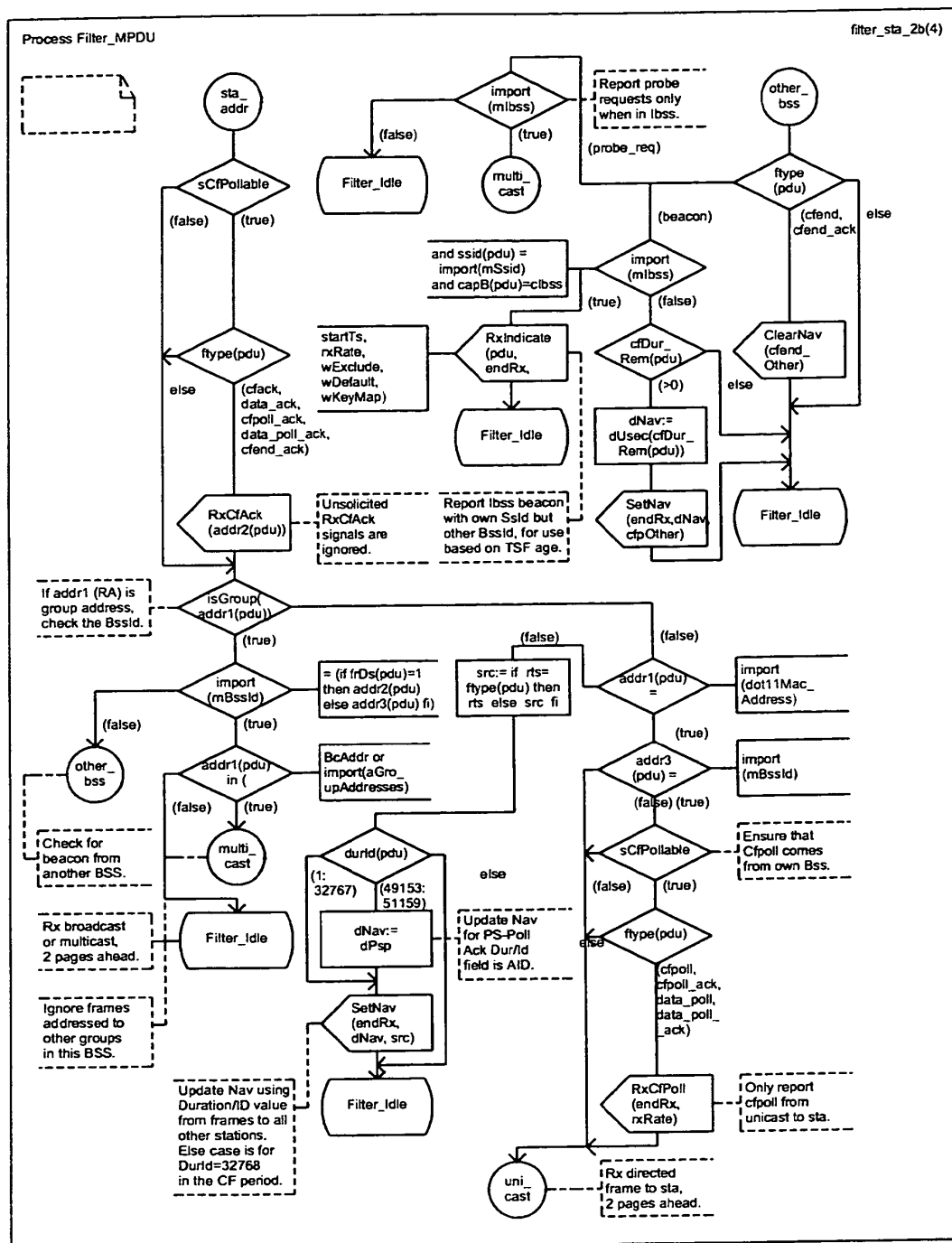


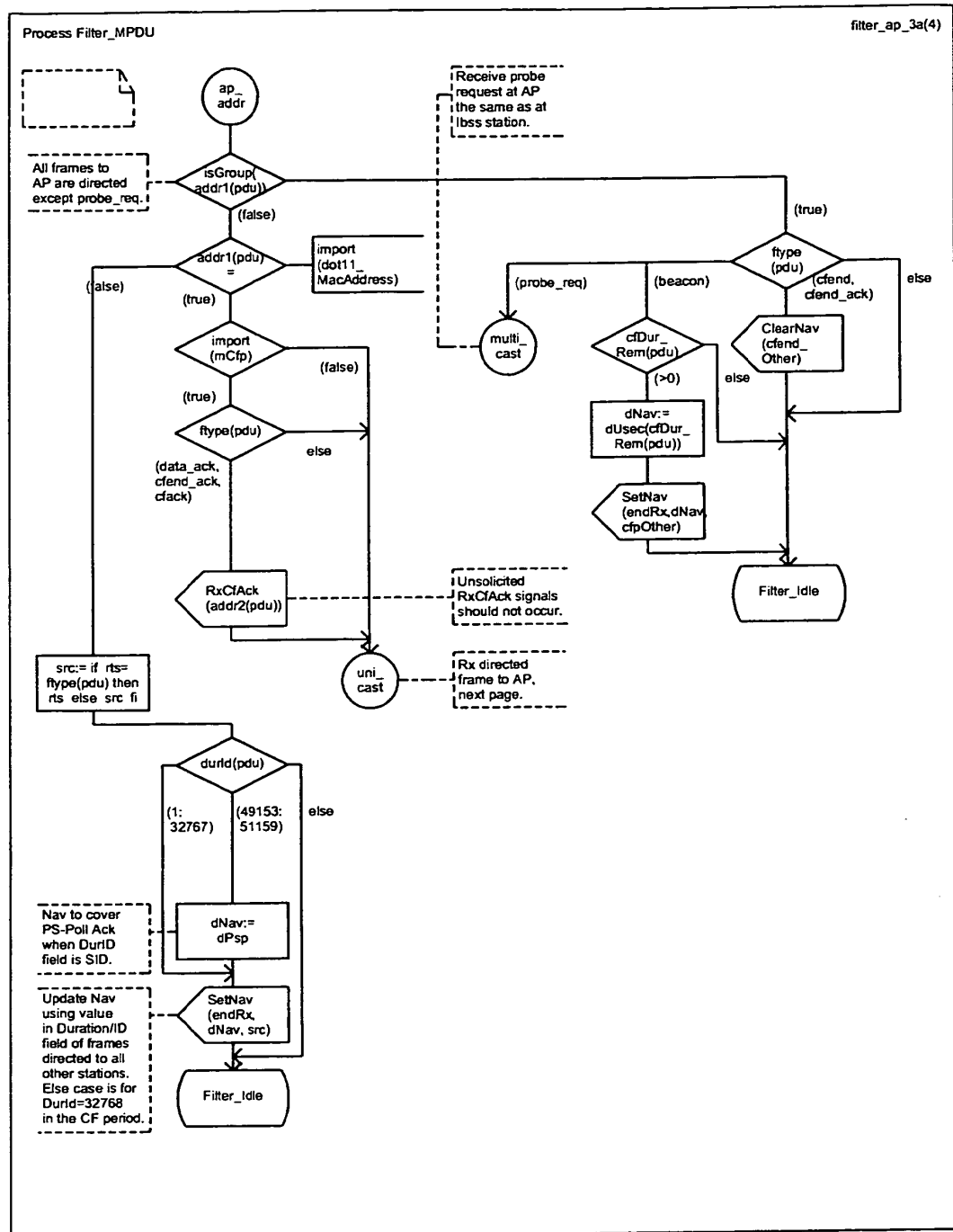


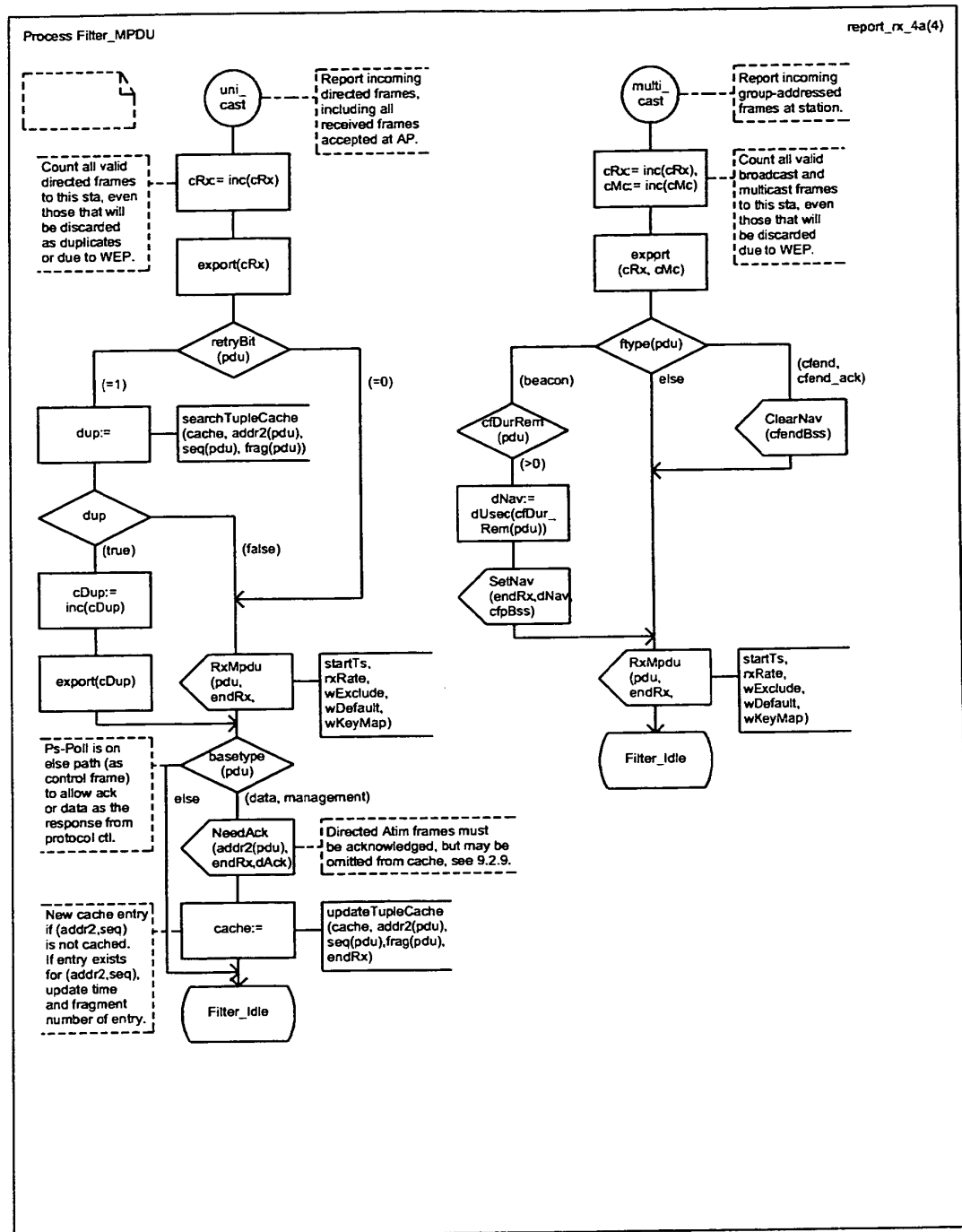


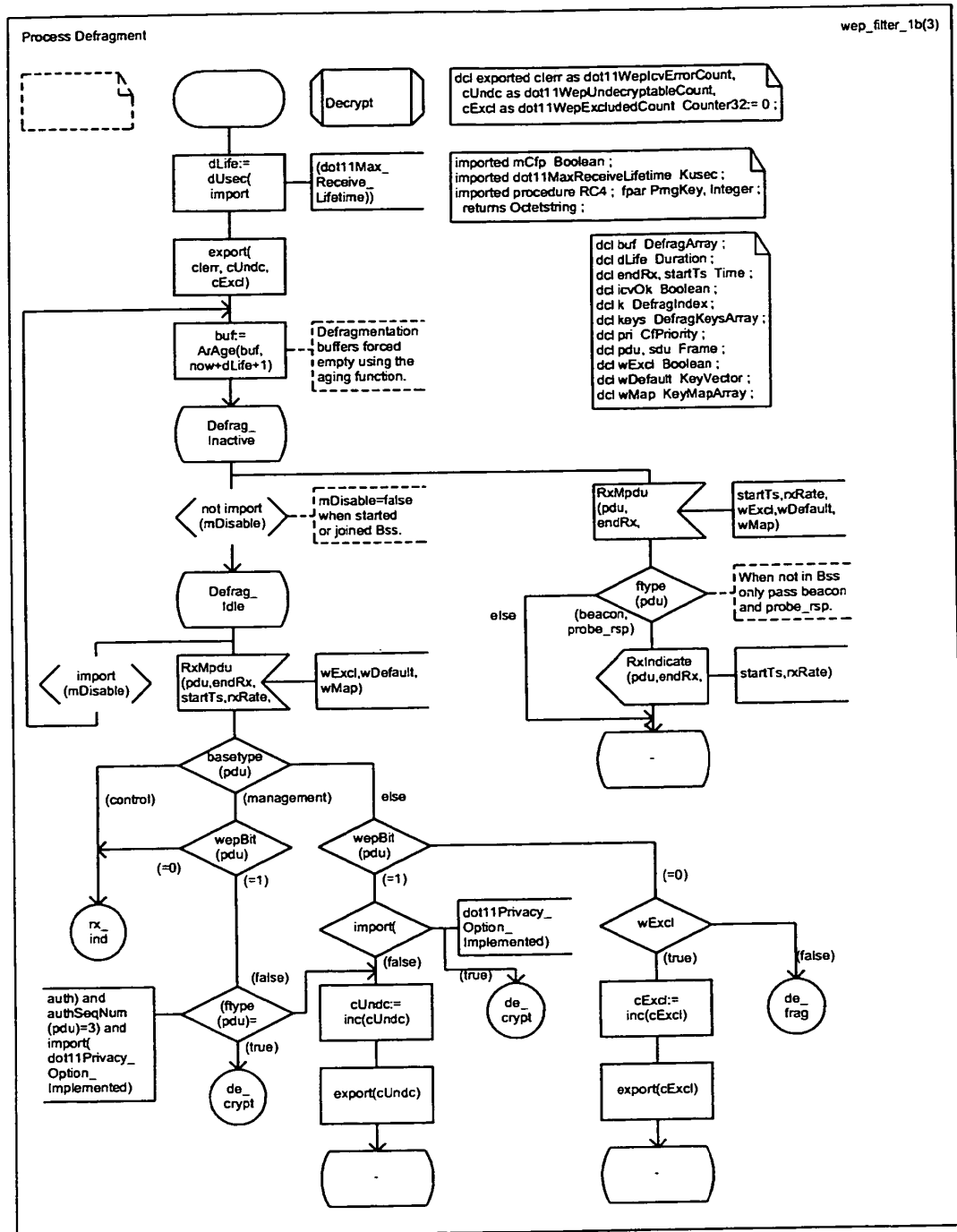


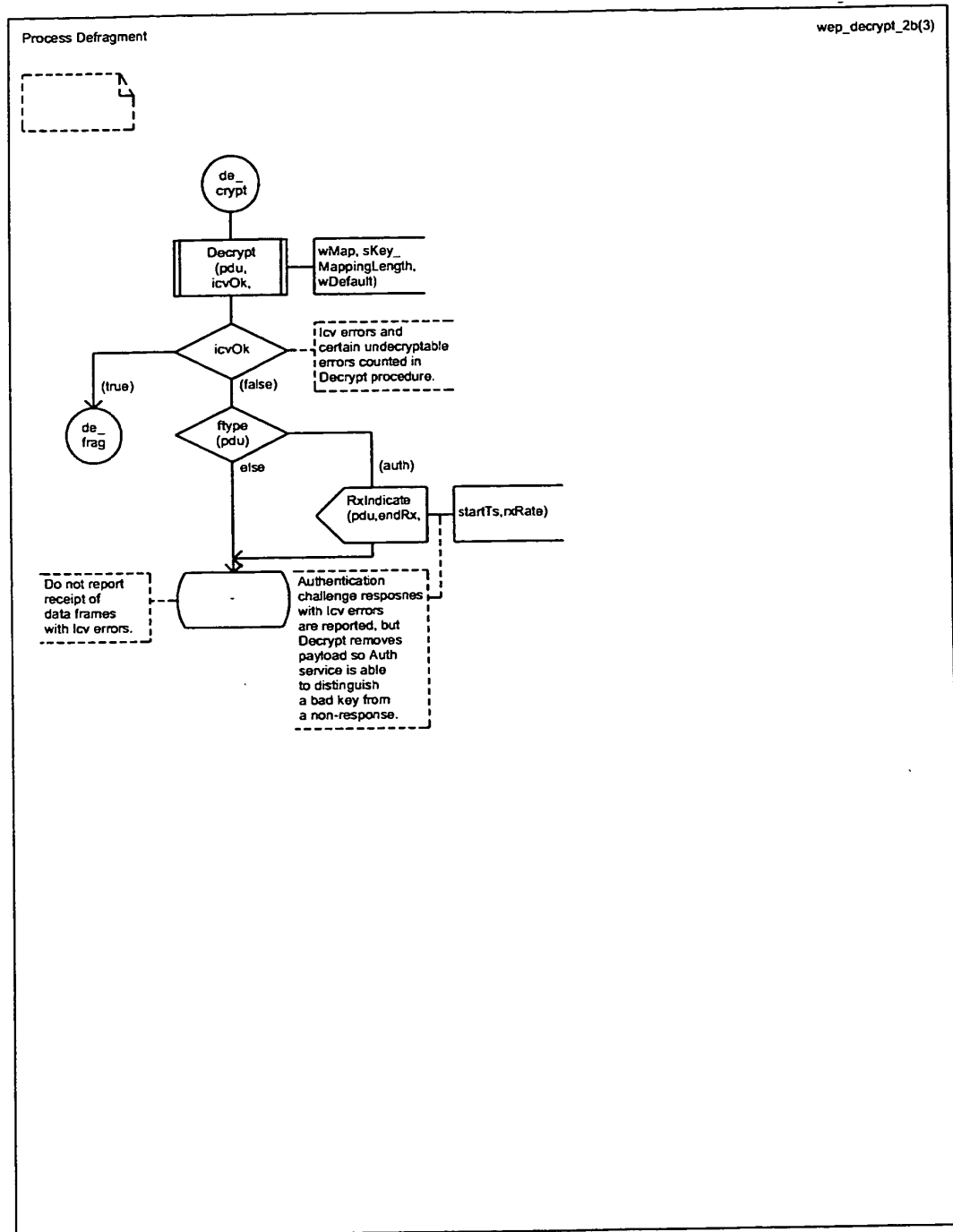


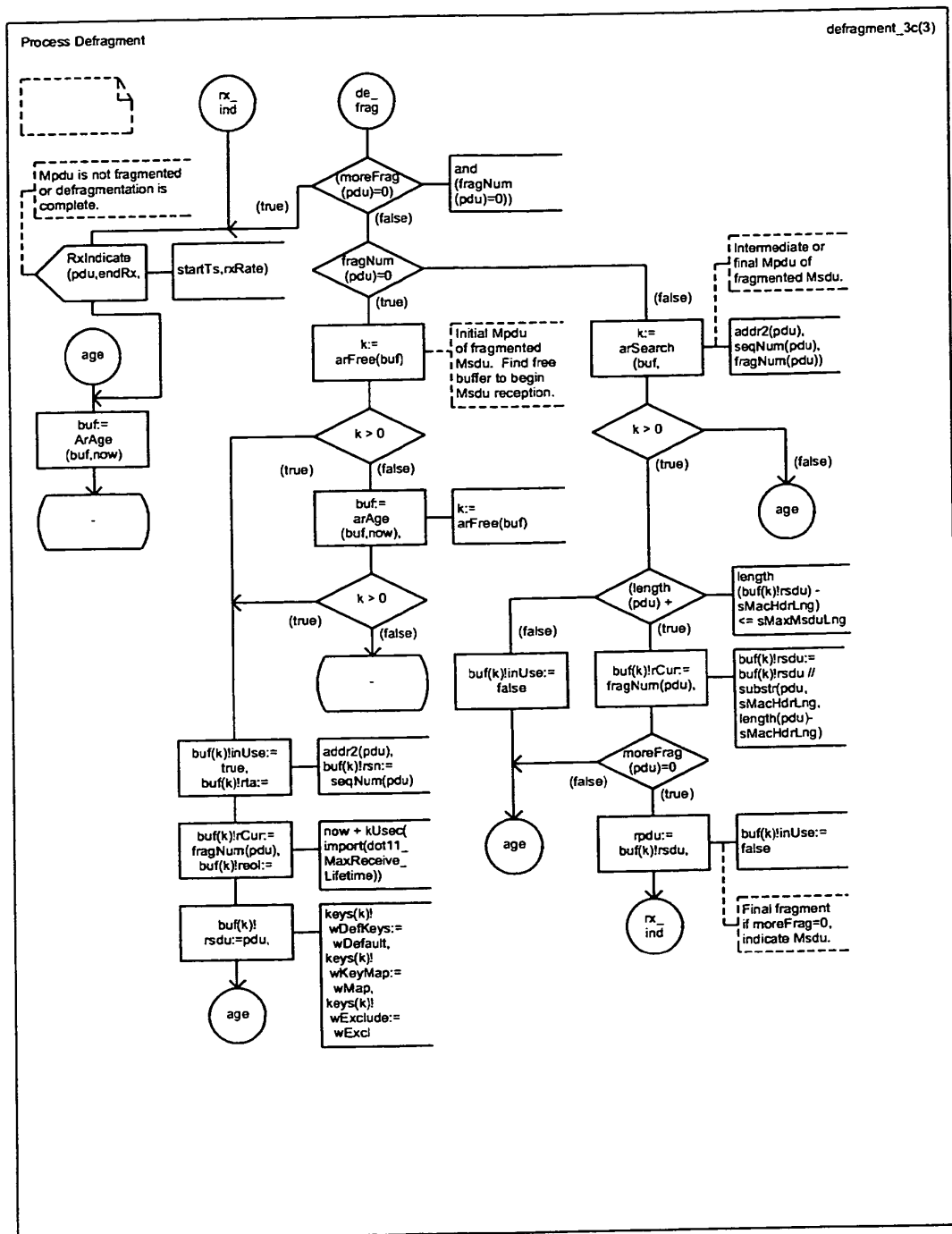














Annex D

(normative)

ASN.1 encoding of the MAC and PHY MIB

```
-- *****
-- * IEEE 802.11 Management Information Base
-- *****
IEEE802dot11-MIB DEFINITIONS ::= BEGIN
    IMPORTS
        MODULE-IDENTITY, OBJECT-TYPE,
        NOTIFICATION-TYPE, Integer32, Counter32 FROM SNMPv2-SMI
        DisplayString, MacAddress, RowStatus,
        TruthValue FROM SNMPv2-TC
        MODULE-COMPLIANCE, OBJECT-GROUP,
        NOTIFICATION-GROUP FROM SNMPv2-CONF
        ifIndex FROM RFC1213-MIB;

-- *****
-- * MODULE IDENTITY
-- *****
ieee802dot11 MODULE-IDENTITY
    LAST-UPDATED "9807080000Z"
    ORGANIZATION "IEEE 802.11"
    CONTACT-INFO
        "WG E-mail: stds-802-11@ieee.org

        Chair: Vic Hayes
        Postal: Lucent Technologies, Inc.
              Zadelstede 1-10
              Nieuwegein, Netherlands
              3431 JZ
        Tel: +31 30 609 7528
        Fax: +31 30 231 6233
        E-mail: vichayes@lucent.com

        Editor: Bob O'Hara
        Postal: Informed Technology, Inc.
              1750 Nantucket Circle, Suite 138
              Santa Clara, CA 95054 USA
        Tel: +1 408 986 9596
        Fax: +1 408 727 2654
        E-mail: bob@informed-technology.com"

    DESCRIPTION
        "The MIB module for IEEE 802.11 entities.
         iso(1).member-body(2).us(840).ieee802dot11(10036)"
        ::= { 1 2 840 10036 }

-- *****
-- * Major sections
-- *****
-- Station Management (SMT) Attributes
--   DEFINED AS "The SMT object class provides the necessary support at the
--   station to manage the processes in the station such that the
--   station may work cooperatively as a part of an IEEE 802.11 network.";
```



```

dot11smt OBJECT IDENTIFIER ::= {ieee802dot11 1}

-- dot11smt GROUPS
-- dot11StationConfigTable ::= {dot11smt 1}
-- dot11AuthenticationAlgorithmsTable ::= {dot11smt 2}
-- dot11WEPDefaultKeysTable ::= {dot11smt 3}
-- dot11WEPKeyMappingsTable ::= {dot11smt 4}
-- dot11PrivacyTable ::= {dot11smt 5}
-- dot11SMNotification ::= {dot11smt 6}

-- MAC Attributes
-- DEFINED AS "The MAC object class provides the necessary support
-- for the access control, generation, and verification of frame check
-- sequences, and proper delivery of valid data to upper layers.";

dot11mac OBJECT IDENTIFIER ::= {ieee802dot11 2}

-- MAC GROUPS
-- reference IEEE Std 802.1F-1993
-- dot11OperationTable ::= {dot11mac 1}
-- dot11CountersTable ::= {dot11mac 2}
-- dot11GroupAddressesTable ::= {dot11mac 3}

-- Resource Type ID
dot11res OBJECT IDENTIFIER ::= {ieee802dot11 3}
dot11resAttribute OBJECT IDENTIFIER ::= {dot11res 1}

-- PHY Attributes
-- DEFINED AS "The PHY object class provides the necessary support
-- for required PHY operational information that may vary from PHY
-- to PHY and from STA to STA to be communicated to upper layers."

dot11phy OBJECT IDENTIFIER ::= {ieee802dot11 4}

-- phy GROUPS
-- dot11PhyOperationTable ::= {dot11phy 1}
-- dot11PhyAntennaTable ::= {dot11phy 2}
-- dot11PhyTxPowerTable ::= {dot11phy 3}
-- dot11PhyFHSSTable ::= {dot11phy 4}
-- dot11PhyDSSSTable ::= {dot11phy 5}
-- dot11PhyIRTable ::= {dot11phy 6}
-- dot11RegDomainsSupportedTable ::= {dot11phy 7}
-- dot11AntennasListTable ::= {dot11phy 8}
-- dot11SupportedDataRatesTxTable ::= {dot11phy 9}
-- dot11SupportedDataRatesRxTable ::= {dot11phy 10}

-- *****
-- * Textual conventions from 802 definitions
-- *****
WEPKeyType ::= OCTET STRING (SIZE (5))

-- *****
-- * MIB attribute OBJECT-TYPE definitions follow
-- *****

-- *****
-- * SMT Station Config Table
-- *****
dot11StationConfigTable OBJECT-TYPE

```

```

SYNTAX SEQUENCE OF Dot11StationConfigEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
    "Station Configuration attributes. In tabular form to
    allow for multiple instances on an agent."
 ::= { dot11sm 1 }

dot11StationConfigEntry OBJECT-TYPE
SYNTAX Dot11StationConfigEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
    "An entry in the dot11StationConfigTable. It is
    possible for there to be multiple IEEE 802.11 interfaces
    on one agent, each with its unique MAC address. The
    relationship between an IEEE 802.11 interface and an
    interface in the context of the Internet-standard MIB is
    one-to-one. As such, the value of an ifIndex object
    instance can be directly used to identify corresponding
    instances of the objects defined herein.

    ifIndex - Each 802.11 interface is represented by an
    ifEntry. Interface tables in this MIB module are indexed
    by ifIndex."

INDEX {ifIndex}
 ::= { dot11StationConfigTable 1 }

Dot11StationConfigEntry ::=
SEQUENCE {
    dot11StationID
    dot11MediumOccupancyLimit
    dot11CFPPollable
    dot11CFPPeriod
    dot11CFPMAXDuration
    dot11AuthenticationResponseTimeOut
    dot11PrivacyOptionImplemented
    dot11PowerManagementMode
    dot11DesiredSSID
    dot11DesiredBSSType
    dot11OperationalRateSet
    dot11BeaconPeriod
    dot11DTIMPeriod
    dot11AssociationResponseTimeOut
    dot11DisassociateReason
    dot11DisassociateStation
    dot11DeauthenticateReason
    dot11DeauthenticateStation
    dot11AuthenticateFailStatus
    dot11AuthenticateFailStation
    MacAddress,
    INTEGER,
    TruthValue,
    INTEGER,
    INTEGER,
    INTEGER,
    TruthValue,
    INTEGER,
    OCTET STRING,
    INTEGER,
    OCTET STRING,
    INTEGER,
    INTEGER,
    INTEGER,
    INTEGER,
    MacAddress,
    INTEGER,
    MacAddress,
    INTEGER,
    MacAddress }

dot11StationID OBJECT-TYPE
SYNTAX MacAddress
MAX-ACCESS read-write
STATUS deprecated
DESCRIPTION
    "The purpose of dot11StationID is to allow a manager to identify

```

a station for its own purposes. This attribute provides for that eventuality while keeping the true MAC address independent. Its syntax is MacAddress. The default value is the station's assigned, unique MAC address."

::= { dot11StationConfigEntry 1 }

dot11MediumOccupancyLimit OBJECT-TYPE

SYNTAX INTEGER (0..1000)

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This attribute shall indicate the maximum amount of time, in TU, that a point coordinator may control the usage of the wireless medium without relinquishing control for long enough to allow at least one instance of DCF access to the medium. The default value of this attribute shall be 100, and the maximum value shall be 1000."

::= { dot11StationConfigEntry 2 }

dot11CFPollable OBJECT-TYPE

SYNTAX TruthValue

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"When this attribute is true, it shall indicate that the STA is able to respond to a CF-Poll with a data frame within a SIFS time. This attribute shall be false if the STA is not able to respond to a CF-Poll with a data frame within a SIFS time."

::= { dot11StationConfigEntry 3 }

dot11CFPPeriod OBJECT-TYPE

SYNTAX INTEGER (0..255)

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The attribute shall describe the number of DTIM intervals between the start of CPPs. It is modified by MLME-START.request primitive."

::= { dot11StationConfigEntry 4 }

dot11CFPPMaxDuration OBJECT-TYPE

SYNTAX INTEGER (0..65535)

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The attribute shall describe the maximum duration of the CPP in TU that may be generated by the PCF. It is modified by MLME-START.request primitive."

::= { dot11StationConfigEntry 5 }

dot11AuthenticationResponseTimeOut OBJECT-TYPE

SYNTAX INTEGER (1..4294967295)

MAX-ACCESS read-write

STATUS current

DESCRIPTION
 "This attribute shall specify the number of TUs that a responding STA should wait for the next frame in the authentication sequence."

::= { dot11StationConfigEntry 6 }

dot11PrivacyOptionImplemented OBJECT-TYPE
 SYNTAX TruthValue
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This attribute, when true, shall indicate that the IEEE 802.11 WEP option is implemented. The default value of this attribute shall be false."

::= { dot11StationConfigEntry 7 }

dot11PowerManagementMode OBJECT-TYPE
 SYNTAX INTEGER { active(1), powersave(2) }
 MAX-ACCESS read-write
 STATUS current
 DESCRIPTION
 "This attribute shall specify the power management mode of the STA. When set to active, it shall indicate that the station is not in power-save mode. When set to powersave, it shall indicate that the station is in power-save mode. The power management mode is transmitted in all frames according to the rules in 7.1.3.1.7."

::= { dot11StationConfigEntry 8 }

dot11DesiredSSID OBJECT-TYPE
 SYNTAX OCTET STRING (SIZE(0..32))
 MAX-ACCESS read-write
 STATUS current
 DESCRIPTION
 "This attribute reflects the Service Set ID used in the DesiredSSID parameter of the most recent MLME_Scan.request. This value may be modified by an external management entity and used by the local SME to make decisions about the Scanning process."

::= { dot11StationConfigEntry 9 }

dot11DesiredBSSType OBJECT-TYPE
 SYNTAX INTEGER { infrastructure(1), independent(2), any(3) }
 MAX-ACCESS read-write
 STATUS current
 DESCRIPTION
 "This attribute shall specify the type of BSS the station shall use when scanning for a BSS with which to synchronize. This value is used to filter Probe Response frames and Beacons. When set to infrastructure, the station shall only synchronize with a BSS whose Capability Information field has the ESS subfield set to 1. When set to independent, the station shall only synchronize with a BSS whose Capability Information field has the IBSS subfield set to 1. When set to any, the station may synchronize to either type of

```
        BSS."
 ::= { dot11StationConfigEntry 10 }

dot11OperationalRateSet OBJECT-TYPE
    SYNTAX OCTET STRING (SIZE(1..126))
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall specify the set of data rates
        at which the station may transmit data. Each octet
        contains a value representing a rate. Each rate
        shall be within the range from 2 to 127,
        corresponding to data rates in increments of
        500 kb/s from 1 Mbit/s to 63.5 Mbit/s, and shall be
        supported (as indicated in the supported rates
        table) for receiving data. This value is reported in
        transmitted Beacon, Probe Request, Probe Response,
        Association Request, Association Response,
        Reassociation Request, and Reassociation Response
        frames, and is used to determine whether a BSS
        with which the station desires to synchronize is
        suitable. It is also used when starting a BSS,
        as specified in 10.3."
 ::= { dot11StationConfigEntry 11 }

dot11BeaconPeriod OBJECT-TYPE
    SYNTAX INTEGER (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall specify the number of TUs that a
        station shall use for scheduling Beacon transmissions.
        This value is transmitted in Beacon and Probe Response
        frames."
 ::= { dot11StationConfigEntry 12 }

dot11DTIMPeriod OBJECT-TYPE
    SYNTAX INTEGER (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall specify the number of beacon
        intervals that shall elapse between transmission of
        Beacons frames containing a TIM element whose DTIM
        Count field is 0. This value is transmitted in
        the DTIM Period field of Beacon frames."
 ::= { dot11StationConfigEntry 13 }

dot11AssociationResponseTimeout OBJECT-TYPE
    SYNTAX INTEGER (1..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall specify the number of TUs that a
        requesting STA should wait for a response to a
        transmitted association-request MMPDU."
 ::= { dot11StationConfigEntry 14 }

dot11DisassociateReason OBJECT-TYPE
```

```
SYNTAX INTEGER(0..65535)
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This attribute holds the most recently transmitted
    Reason Code in a Disassociation frame. If no
    Disassociation frame has been transmitted,
    the value of this attribute shall be 0."

REFERENCE "ISO/IEC 8802-11:1999, 7.3.1.7"
::= { dot11StationConfigEntry 15 }

dot11DisassociateStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute holds the MAC address from the
        Address 1 field of the most recently transmitted
        Disassociation frame. If no Disassociation frame has
        been transmitted, the value of this attribute
        shall be 0."
    ::= { dot11StationConfigEntry 16 }

dot11DeauthenticateReason OBJECT-TYPE
    SYNTAX INTEGER(0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute holds the most recently
        transmitted Reason Code in a Deauthentication frame.
        If no Deauthentication frame has been transmitted, the
        value of this attribute shall be 0."

REFERENCE "ISO/IEC 8802-11:1999, 7.3.1.7"
::= { dot11StationConfigEntry 17 }

dot11DeauthenticateStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute holds the MAC address from the Address 1
        field of the most recently transmitted Deauthentication frame.
        If no Deauthentication frame has been transmitted,
        the value of this attribute shall be 0."
    ::= { dot11StationConfigEntry 18 }

dot11AuthenticateFailStatus OBJECT-TYPE
    SYNTAX INTEGER(0..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute holds the most recently
        transmitted Status Code in a failed Authentication frame.
        If no failed Authentication frame has been transmitted, the
        value of this attribute shall be 0."

REFERENCE "ISO/IEC 8802-11:1999, 7.3.1.9"
```

```

 ::= { dot11StationConfigEntry 19 }

dot11AuthenticateFailStation OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute holds the MAC address from the
        Address 1 field of the most recently transmitted
        failed Authentication frame. If no failed Authentication
        frame has been transmitted, the value of this attribute
        shall be 0."
 ::= { dot11StationConfigEntry 20 }

-- *****
-- *      End of dot11StationConfig TABLE
-- *****

-- *****
-- *      AuthenticationAlgorithms TABLE
-- *****

dot11AuthenticationAlgorithmsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AuthenticationAlgorithmsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This (conceptual) table of attributes shall be a set of
        all the authentication algorithms supported by the
        stations. The following are the default values and the
        associated algorithm:
            Value = 1: Open System
            Value = 2: Shared Key"
        REFERENCE "ISO/IEC 8802-11:1999, 7.3.1.1"
 ::= { dot11smt 2 }

dot11AuthenticationAlgorithmsEntry OBJECT-TYPE
    SYNTAX Dot11AuthenticationAlgorithmsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the Authentication
        Algorithms Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

    INDEX { ifIndex,
            dot11AuthenticationAlgorithmsIndex }
 ::= { dot11AuthenticationAlgorithmsTable 1 }

Dot11AuthenticationAlgorithmsEntry ::= SEQUENCE {
    dot11AuthenticationAlgorithmsIndex      Integer32,
    dot11AuthenticationAlgorithm            INTEGER,
    dot11AuthenticationAlgorithmsEnable     TruthValue }

dot11AuthenticationAlgorithmsIndex OBJECT-TYPE
    SYNTAX Integer32

```

```

MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
    "The auxiliary variable used to identify instances
    of the columnar objects in the Authentication Algorithms Table."
 ::= { dot11AuthenticationAlgorithmsEntry 1 }

dot11AuthenticationAlgorithm OBJECT-TYPE
    SYNTAX INTEGER { openSystem (1), sharedKey (2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute shall be a set of all the authentication
        algorithms supported by the STAs. The following are the
        default values and the associated algorithm.
        Value = 1: Open System
        Value = 2: Shared Key"

    ::= { dot11AuthenticationAlgorithmsEntry 2 }

dot11AuthenticationAlgorithmsEnable OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute, when true at a station,
        shall enable the acceptance of the authentication
        algorithm described in the corresponding table
        entry in authentication frames received by the
        station that have odd authentication sequence numbers.
        The default value of this attribute shall be 1 for
        the Open System table entry and 2 for all other table entries."

    ::= { dot11AuthenticationAlgorithmsEntry 3 }

-- *****
-- *      End of AuthenticationAlgorithms  TABLE
-- *****

-- *****
-- *      WEPDefaultKeys  TABLE
-- *****

dot11WEPDefaultKeysTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WEPDefaultKeysEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for WEP default keys. This table shall
        contain the four WEP default secret key values
        corresponding to the four possible KeyID values. The WEP
        default secret keys are logically WRITE-ONLY. Attempts to
        read the entries in this table shall return unsuccessful
        status and values of null or zero. The default value of
        each WEP default key shall be null."

    REFERENCE "ISO/IEC 8802-11:1999, 8.3.2"
    ::= { dot11smt 3 }

dot11WEPDefaultKeysEntry OBJECT-TYPE

```



```
SYNTAX Dot11WEPDefaultKeysEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
    "An Entry (conceptual row) in the WEP Default Keys Table.

    ifIndex - Each 802.11 interface is represented by an
    ifEntry. Interface tables in this MIB module are indexed
    by ifIndex."

INDEX {ifIndex, dot11WEPDefaultKeyIndex}
 ::= { dot11WEPDefaultKeysTable 1 }

Dot11WEPDefaultKeysEntry ::= SEQUENCE {
    dot11WEPDefaultKeyIndex    INTEGER,
    dot11WEPDefaultKeyValue    WEPKeytype}

dot11WEPDefaultKeyIndex OBJECT-TYPE
    SYNTAX INTEGER (1..4)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances
        of the columnar objects in the WEP Default Keys Table.
        The value of this variable is equal to the WEPDefaultKeyID + 1"
    ::= { dot11WEPDefaultKeysEntry 1 }

dot11WEPDefaultKeyValue OBJECT-TYPE
    SYNTAX WEPKeytype
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "A WEP default secret key value."
    ::= { dot11WEPDefaultKeysEntry 2 }

-- *****
-- *      End of WEPDefaultKeys  TABLE
-- *****

-- *****
-- *      WEPKeyMappings  TABLE
-- *****
dot11WEPKeyMappingsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11WEPKeyMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for WEP Key Mappings. The MIB supports
        the ability to share a separate WEP key for each RA/TA
        pair. The Key Mappings Table contains zero or one entry
        for each MAC address and contains two fields for each
        entry: WEPon and the corresponding WEP key. The WEP key
        mappings are logically WRITE-ONLY. Attempts to read the
        entries in this table shall return unsuccessful status and
        values of null or zero. The default value for all WEPon
        fields is false."
    REFERENCE "ISO/IEC 8802-11:1999, 8.3.2"
    ::= { dot11smt 4 }
```

```

dot11WEPKeyMappingsEntry OBJECT-TYPE
    SYNTAX Dot11WEPKeyMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the WEP Key Mappings Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

    INDEX {ifIndex, dot11WEPKeyMappingIndex}
    ::= { dot11WEPKeyMappingsTable 1 }

Dot11WEPKeyMappingsEntry ::= SEQUENCE {
    dot11WEPKeyMappingIndex      Integer32,
    dot11WEPKeyMappingAddress    MacAddress,
    dot11WEPKeyMappingWEPOn     TruthValue,
    dot11WEPKeyMappingValue      WEPKeytype,
    dot11WEPKeyMappingStatus     RowStatus }

dot11WEPKeyMappingIndex OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances
        of the columnar objects in the WEP Key Mappings Table."
    ::= { dot11WEPKeyMappingsEntry 1 }

dot11WEPKeyMappingAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The MAC address of the STA for which the values from this
        key mapping entry are to be used."
    ::= { dot11WEPKeyMappingsEntry 2 }

dot11WEPKeyMappingWEPOn OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "Boolean as to whether WEP is to be used when communicating
        with the dot11WEPKeyMappingAddress STA."
    ::= { dot11WEPKeyMappingsEntry 3 }

dot11WEPKeyMappingValue OBJECT-TYPE
    SYNTAX WEPKeytype
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "A WEP secret key value."
    ::= { dot11WEPKeyMappingsEntry 4 }

dot11WEPKeyMappingStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create

```

```

        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and
            deleting instances of the columnar objects in the WEP key
            mapping Table."

        DEFVAL {active}
        ::= { dot11WEPKeyMappingsEntry 5 }

-- *****
-- *      End of WEPKeyMappings TABLE
-- *****

-- *****
-- *      dot11PrivacyTable TABLE
-- *****
dot11PrivacyTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PrivacyEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group containing attributes concerned with IEEE 802.11
        Privacy. Created as a table to allow multiple
        instantiations on an agent."

    ::= { dot11smt 5 }

dot11PrivacyEntry OBJECT-TYPE
    SYNTAX Dot11PrivacyEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PrivacyTable Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PrivacyTable 1 }

Dot11PrivacyEntry ::= SEQUENCE {
    dot11PrivacyInvoked          TruthValue,
    dot11WEPDefaultKeyID         INTEGER,
    dot11WEPKeyMappingLength     INTEGER,
    dot11ExcludeUnencrypted      TruthValue,
    dot11WEPICVErrorCount        Counter32,
    dot11WEPExcludedCount        Counter32}

dot11PrivacyInvoked OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When this attribute is true, it shall indicate that the IEEE
        802.11 WEP mechanism is used for transmitting frames of type
        Data. The default value of this attribute shall be false."
    ::= { dot11PrivacyEntry 1 }

dot11WEPDefaultKeyID OBJECT-TYPE

```

```

SYNTAX INTEGER (0..3)
MAX-ACCESS read-write
STATUS current
DESCRIPTION
    "This attribute shall indicate the use of the first,
    second, third, or fourth element of the WEPDefaultKeys
    array when set to values of zero, one, two, or three. The
    default value of this attribute shall be 0."
REFERENCE "ISO/IEC 8802-11:1999, 8.3.2"
 ::= { dot11PrivacyEntry 2 }

dot11WEPKeyMappingLength OBJECT-TYPE
    SYNTAX INTEGER (10..4294967295)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The maximum number of tuples that dot11WEPKeyMappings can hold."
    REFERENCE "ISO/IEC 8802-11:1999, 8.3.2"
 ::= { dot11PrivacyEntry 3 }

dot11ExcludeUnencrypted OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When this attribute is true, the STA shall not indicate at
        the MAC service interface received MSDUs that have the WEP
        subfield of the Frame Control field equal to zero. When this
        attribute is false, the STA may accept MSDUs that have the WEP
        subfield of the Frame Control field equal to zero. The default
        value of this attribute shall be false."

 ::= { dot11PrivacyEntry 4 }

dot11WEPICVErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This counter shall increment when a frame is received with the
        WEP subfield of the Frame Control field set to one and the value
        of the ICV as received in the frame does not match the ICV value
        that is calculated for the contents of the received frame."
 ::= { dot11PrivacyEntry 5 }

dot11WEPExcludedCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This counter shall increment when a frame is received with the
        WEP subfield of the Frame Control field set to zero and the value
        of dot11ExcludeUnencrypted causes that frame to be discarded."
 ::= { dot11PrivacyEntry 6 }

-- *****
-- *      End of dot11Privacy TABLE
-- *****

```

```
-- *****
-- *      SMT notification Objects
-- *****
dot11SMTnotification OBJECT IDENTIFIER ::= { dot11smt 6 }

dot11Disassociate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11DisassociateReason,
dot11DisassociateStation }
    STATUS current
    DESCRIPTION
        "The disassociate notification shall be sent when the STA
        sends a Disassociation frame. The value of the notification
        shall include the MAC address of the MAC to which the
        Disassociation frame was sent and the reason for
        the disassociation.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

    ::= { dot11SMTnotification 0 1 }

dot11Deauthenticate NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11DeauthenticateReason,
dot11DeauthenticateStation }
    STATUS current
    DESCRIPTION
        "The deauthenticate notification shall be sent when the STA
        sends a Deauthentication frame. The value of the notification
        shall include the MAC address of the MAC to which the
        Deauthentication frame was sent and the reason for the
        deauthentication.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

    ::= { dot11SMTnotification 0 2 }

dot11AuthenticateFail NOTIFICATION-TYPE
    OBJECTS { ifIndex, dot11AuthenticateFailStatus,
dot11AuthenticateFailStation }
    STATUS current
    DESCRIPTION
        "The authenticate failure notification shall be sent
        when the STA sends an Authentication frame with a
        status code other than 'successful.' The value of
        the notification shall include the MAC address of the
        MAC to which the Authentication frame was sent and the
        reason for the authentication failure.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

    ::= { dot11SMTnotification 0 3 }
```

```
-- *****
-- *      End of SMT notification Objects
-- *****

-- *****
-- *      MAC Attribute Templates
-- *****

-- *****
-- *      dot11OperationTable  TABLE
-- *****
dot11OperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11OperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group contains MAC attributes pertaining to the operation
        of the MAC. This has been implemented as a table in order
        to allow for multiple instantiations on an agent."

    ::= { dot11mac 1 }

dot11OperationEntry OBJECT-TYPE
    SYNTAX Dot11OperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11OperationEntry Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11OperationTable 1 }

Dot11OperationEntry ::= SEQUENCE {
    dot11MACAddress          MacAddress,
    dot11RTSThreshold        INTEGER,
    dot11ShortRetryLimit     INTEGER,
    dot11LongRetryLimit      INTEGER,
    dot11FragmentationThreshold  INTEGER,
    dot11MaxTransmitMSDULifetime  INTEGER,
    dot11MaxReceiveLifetime    INTEGER,
    dot11ManufacturerID      DisplayString,
    dot11ProductID           DisplayString}

dot11MACAddress OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "Unique MAC Address assigned to the STA."
    ::= { dot11OperationEntry 1 }

dot11RTSThreshold OBJECT-TYPE
    SYNTAX INTEGER (0..2347)
    MAX-ACCESS read-write
    STATUS current
```

DESCRIPTION

"This attribute shall indicate the number of octets in an MPDU, below which an RTS/CTS handshake shall not be performed. An RTS/CTS handshake shall be performed at the beginning of any frame exchange sequence where the MPDU is of type Data or Management, the MPDU has an individual address in the Address1 field, and the length of the MPDU is greater than this threshold. (For additional details, refer to Table 21 in 9.7.) Setting this attribute to be larger than the maximum MSDU size shall have the effect of turning off the RTS/CTS handshake for frames of Data or Management type transmitted by this STA. Setting this attribute to zero shall have the effect of turning on the RTS/CTS handshake for all frames of Data or Management type transmitted by this STA. The default value of this attribute shall be 2347."

::= { dot11OperationEntry 2 }

dot11ShortRetryLimit OBJECT-TYPE
SYNTAX INTEGER (1..255)
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"This attribute shall indicate the maximum number of transmission attempts of a frame, the length of which is less than or equal to dot11RTSThreshold, that shall be made before a failure condition is indicated. The default value of this attribute shall be 7."

::= { dot11OperationEntry 3 }

dot11LongRetryLimit OBJECT-TYPE
SYNTAX INTEGER (1..255)
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"This attribute shall indicate the maximum number of transmission attempts of a frame, the length of which is greater than dot11RTSThreshold, that shall be made before a failure condition is indicated. The default value of this attribute shall be 4."

::= { dot11OperationEntry 4 }

dot11FragmentationThreshold OBJECT-TYPE
SYNTAX INTEGER (256..2346)
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"This attribute shall specify the current maximum size, in octets, of the MPDU that may be delivered to the PHY. An MSDU shall be broken into fragments if its size exceeds the value of this attribute after adding MAC headers and trailers. An MSDU or MMPDU shall be fragmented when the resulting frame has an individual address in the Address1 field, and the length of the frame is larger than this threshold. The default value

for this attribute shall be the lesser of 2346 or the
aMPDUMaxLength of the attached PHY and shall never exceed the
lesser of 2346 or the aMPDUMaxLength of the attached PHY. The
value of this attribute shall never be less than 256."

::= { dot11OperationEntry 5 }

dot11MaxTransmitMSDULifetime OBJECT-TYPE
SYNTAX INTEGER (1..4294967295)
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"The MaxTransmitMSDULifetime shall be the elapsed time in TU,
after the initial transmission of an MSDU, after which further
attempts to transmit the MSDU shall be terminated. The default
value of this attribute shall be 512."

::= { dot11OperationEntry 6 }

dot11MaxReceiveLifetime OBJECT-TYPE
SYNTAX INTEGER (1..4294967295)
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"The MaxReceiveLifetime shall be the elapsed time in TU,
after the initial reception of a fragmented MMPDU or MSDU,
after which further attempts to reassemble the MMPDU or
MSDU shall be terminated. The default value shall be 512."

::= { dot11OperationEntry 7 }

dot11ManufacturerID OBJECT-TYPE
SYNTAX DisplayString (SIZE(0..128))
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The ManufacturerID shall include, at a minimum, the name
of the manufacturer. It may include additional
information at the manufacturer's discretion. The default
value of this attribute shall be null."

::= { dot11OperationEntry 8 }

dot11ProductID OBJECT-TYPE
SYNTAX DisplayString (SIZE(0..128))
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The ProductID shall include, at a minimum, an identifier
that is unique to the manufacturer. It may include
additional information at the manufacturer's discretion.
The default value of this attribute shall be null."

::= { dot11OperationEntry 9 }

-- *****
-- * End of dot11OperationEntry TABLE


```
-- *****
-- *****
-- *      dot11Counters TABLE
-- *****
dot11CountersTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11CountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "Group containing attributes that are MAC counters.
        Implemented as a table to allow for multiple
        instantiations on an agent."

    ::= { dot11mac 2 }

dot11CountersEntry OBJECT-TYPE
    SYNTAX Dot11CountersEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "An entry in the dot11CountersEntry Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11CountersTable 1 }

Dot11CountersEntry ::= SEQUENCE {
    dot11TransmittedFragmentCount Counter32,
    dot11MulticastTransmittedFrameCount Counter32,
    dot11FailedCount Counter32,
    dot11RetryCount Counter32,
    dot11MultipleRetryCount Counter32,
    dot11FrameDuplicateCount Counter32,
    dot11RTSSuccessCount Counter32,
    dot11RTSFailureCount Counter32,
    dot11LACKFailureCount Counter32,
    dot11ReceivedFragmentCount Counter32,
    dot11MulticastReceivedFrameCount Counter32,
    dot11FCSErrorCount Counter32,
    dot11TransmittedFrameCount Counter32,
    dot11WEPUndecryptableCount Counter32 }

dot11TransmittedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall be incremented for an acknowledged
        MPDU with an individual address in the address 1 field
        or an MPDU with a multicast address in the address 1 field
        of type Data or Management."

    ::= { dot11CountersEntry 1 }
```

dot11MulticastTransmittedFrameCount OBJECT-TYPE

SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This counter shall increment only when the multicast bit is set in the destination MAC address of a successfully transmitted MSDU. When operating as a STA in an ESS, where these frames are directed to the AP, this implies having received an acknowledgment to all associated MPDUs. "

::= { dot11CountersEntry 2 }

dot11FailedCount OBJECT-TYPE

SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This counter shall increment when an MSDU is not transmitted successfully due to the number of transmit attempts exceeding either the dot11ShortRetryLimit or dot11LongRetryLimit. "

::= { dot11CountersEntry 3 }

dot11RetryCount OBJECT-TYPE

SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This counter shall increment when an MSDU is successfully transmitted after one or more retransmissions."

::= { dot11CountersEntry 4 }

dot11MultipleRetryCount OBJECT-TYPE

SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This counter shall increment when an MSDU is successfully transmitted after more than one retransmission."

::= { dot11CountersEntry 5 }

dot11FrameDuplicateCount OBJECT-TYPE

SYNTAX Counter32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This counter shall increment when a frame is received that the Sequence Control field indicates is a duplicate."

::= { dot11CountersEntry 6 }

```
dot11RTSSuccessCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment when a CTS is received in
        response to an RTS."

 ::= { dot11CountersEntry 7 }

dot11RTSFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment when a CTS is not received in
        response to an RTS."

 ::= { dot11CountersEntry 8 }

dot11ACKFailureCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment when an ACK is not received
        when expected."

 ::= { dot11CountersEntry 9 }

dot11ReceivedFragmentCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall be incremented for each successfully
        received MPDU of type Data or Management."

 ::= { dot11CountersEntry 10 }

dot11MulticastReceivedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment when a MSDU is received
        with the multicast bit set in the destination
        MAC address."

 ::= { dot11CountersEntry 11 }

dot11FCSErrorCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
```

```

STATUS current
DESCRIPTION

"This counter shall increment when an FCS error is
detected in a received MPDU."

 ::= { dot11CountersEntry 12 }

dot11TransmittedFrameCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment for each successfully transmitted MSDU."

 ::= { dot11CountersEntry 13 }

dot11WEPUndecryptableCount OBJECT-TYPE
    SYNTAX Counter32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This counter shall increment when a frame is received with
        the WEP subfield of the Frame Control field set to one and the
        WEPOn value for the key mapped to the TA's MAC address
        indicates that the frame should not have been encrypted or
        that frame is discarded due to the receiving STA not
        implementing the privacy option."

 ::= { dot11CountersEntry 14 }

-- *****
-- *      End of dot11CountersEntry  TABLE
-- *****

-- *****
-- *      GroupAddresses  TABLE
-- *****

dot11GroupAddressesTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11GroupAddressesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "A conceptual table containing a set of MAC addresses
        identifying the multicast addresses for which this STA
        will receive frames. The default value of this attribute
        shall be null."

 ::= { dot11mac 3 }

dot11GroupAddressesEntry OBJECT-TYPE
    SYNTAX Dot11GroupAddressesEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "An Entry (conceptual row) in the Group Addresses Table.
```

```

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
INDEX {ifIndex, dot11GroupAddressesIndex}

 ::= { dot11GroupAddressesTable 1 }

Dot11GroupAddressesEntry ::= SEQUENCE {
    dot11GroupAddressesIndex Integer32,
    dot11Address              MacAddress,
    dot11GroupAddressesStatus RowStatus}

dot11GroupAddressesIndex OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "The auxiliary variable used to identify instances
        of the columnar objects in the Group Addresses Table."

 ::= { dot11GroupAddressesEntry 1 }

dot11Address OBJECT-TYPE
    SYNTAX MacAddress
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION

        "MAC address identifying a multicast addresses
        from which this STA will receive frames."
 ::= { dot11GroupAddressesEntry 2 }

dot11GroupAddressesStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION

        "The status column used for creating, modifying, and
        deleting instances of the columnar objects in the Group
        Addresses Table."

    DEFVAL {active}
 ::= { dot11GroupAddressesEntry 3 }
-- *****
-- *      End of GroupAddress TABLE
-- *****

-- *****
-- *      Resource Type Attribute Templates
-- *****

dot11ResourceTypeIDName OBJECT-TYPE
    SYNTAX DisplayString (SIZE(4))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

```

"Contains the name of the Resource Type ID managed object.
The attribute is read-only and always contains the value
RTID. This attribute value shall not be used as a naming
attribute for any other managed object class."

REFERENCE "IEEE Std 802.1F-1993, A.7"
DEFVAL {"RTID"}
 ::= { dot11resAttribute 1 }

-- *****
-- * dot11ResourceInfo TABLE
-- *****
dot11ResourceInfoTable OBJECT-TYPE
SYNTAX SEQUENCE OF Dot11ResourceInfoEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION

"Provides a means of indicating, in data readable from a
managed object, information that identifies the source of
the implementation."

REFERENCE "IEEE Std 802.1F-1993, A.7"
 ::= { dot11resAttribute 2 }

dot11ResourceInfoEntry OBJECT-TYPE
SYNTAX Dot11ResourceInfoEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION

"An entry in the dot11ResourceInfo Table.

ifIndex - Each 802.11 interface is represented by an
ifEntry. Interface tables in this MIB module are indexed
by ifIndex."
INDEX {ifIndex}

 ::= { dot11ResourceInfoTable 1 }

Dot11ResourceInfoEntry ::= SEQUENCE {
dot11manufacturerOUI OCTET STRING,
dot11manufacturerName DisplayString,
dot11manufacturerProductName DisplayString,
dot11manufacturerProductVersion DisplayString}

dot11manufacturerOUI OBJECT-TYPE
SYNTAX OCTET STRING (SIZE(3))
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"Takes the value of an organizationally unique identifier."

 ::= { dot11ResourceInfoEntry 1 }

dot11manufacturerName OBJECT-TYPE
SYNTAX DisplayString (SIZE(0..128))
MAX-ACCESS read-only

```
STATUS current
DESCRIPTION

"A printable string used to identify the manufacturer of the
resource. Maximum string length is 128 octets."
 ::= { dot11ResourceInfoEntry 2 }

dot11manufacturerProductName OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..128))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "A printable string used to identify the manufacturer's product
        name of the resource. Maximum string length is 128 octets."
    ::= { dot11ResourceInfoEntry 3 }

dot11manufacturerProductVersion OBJECT-TYPE
    SYNTAX DisplayString (SIZE(0..128))
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "Printable string used to identify the manufacturer's product
        version of the resource. Maximum string length is 128 octets."
    ::= { dot11ResourceInfoEntry 4 }

-- *****
-- *      End of dot11ResourceInfo  TABLE
-- *****

-- *****
-- *      PHY Attribute Templates
-- *****

-- *****
-- *      dot11PhyOperation  TABLE
-- *****
dot11PhyOperationTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "PHY level attributes concerned with
        operation. Implemented as a table indexed on
        ifIndex to allow for multiple instantiations on an
        Agent."

    ::= { dot11phy 1 }

dot11PhyOperationEntry OBJECT-TYPE
    SYNTAX Dot11PhyOperationEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "An entry in the dot11PhyOperation Table.
```

```

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyOperationTable 1 }

Dot11PhyOperationEntry ::= SEQUENCE {
    dot11PHYType          INTEGER,
    dot11CurrentRegDomain Integer32,
    dot11TempType         INTEGER
}

dot11PHYType OBJECT-TYPE
    SYNTAX INTEGER {fhss(1), dsss(2), irbaseband(3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This is an 8-bit integer value that identifies the PHY type
        supported by the attached PLCP and PMD. Currently defined
        values and their corresponding PHY types are:

        FHSS 2.4 GHz = 01 , DSSS 2.4 GHz = 02, IR Baseband = 03"

    ::= { dot11PhyOperationEntry 1 }

dot11CurrentRegDomain OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION

        "The current regulatory domain this instance of the PMD is
        supporting. This object corresponds to one of the
        RegDomains listed in dot11RegDomainsSupported."

    ::= { dot11PhyOperationEntry 2 }

dot11TempType OBJECT-TYPE
    SYNTAX INTEGER {tempType1(1), tempType2(2) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "There are different operating temperature requirements
        dependent on the anticipated environmental conditions. This
        attribute describes the current PHY's operating temperature
        range capability. Currently defined values and their
        corresponding temperature ranges are:

        Type 1 = X'01'-Commercial range of 0 to 40 degrees C,

        Type 2 = X'02'-Industrial range of -30 to 70 degrees C."

    ::= { dot11PhyOperationEntry 3 }

-- *****
-- *      End of dot11PhyOperation TABLE
-- *****

```



```
-- *****
-- *   dot11PhyAntenna  TABLE
-- *****
dot11PhyAntennaTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyAntennaEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "Group of attributes for PhyAntenna. Implemented as a
        table indexed on ifIndex to allow for multiple instances on
        an agent."

    ::= { dot11phy 2 }

dot11PhyAntennaEntry OBJECT-TYPE
    SYNTAX Dot11PhyAntennaEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "An entry in the dot11PhyAntenna Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyAntennaTable 1 }

Dot11PhyAntennaEntry ::= SEQUENCE {
    dot11CurrentTxAntenna      Integer32,
    dot11DiversitySupport     INTEGER,
    dot11CurrentRxAntenna     Integer32 }

dot11CurrentTxAntenna OBJECT-TYPE
    SYNTAX Integer32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION

        "The current antenna being used to transmit. This value
        is one of the values appearing in dot11SupportedTxAntenna.
        This may be used by a management agent to control which
        antenna is used for transmission."

    ::= { dot11PhyAntennaEntry 1 }

dot11DiversitySupport OBJECT-TYPE
    SYNTAX INTEGER {fixedlist(1), notsupported(2), dynamic(3)}
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION

        "This implementation's support for diversity, encoded as:

        X'01'-diversity is available and is performed over the fixed
        list of antennas defined in dot11DiversitySelectionRx.

        X'02'-diversity is not supported."
```

```

X'03'-diversity is supported and control of diversity is also
available, in which case the attribute
dot11DiversitySelectionRx can be dynamically modified by the
LME."
 ::= { dot11PhyAntennaEntry 2 }

dot11CurrentRxAntenna OBJECT-TYPE
    SYNTAX Integer32 (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION

        "The current antenna being used to receive, if the
        dot11 DiversitySupport indicates that diversity is not
        supported. The selected antenna shall be one of
        the antennae marked for receive in the dot11AntennasListTable. "

    ::= { dot11PhyAntennaEntry 3 }

-- *****
-- *      End of dot11PhyAntenna  TABLE
-- *****

-- *****
-- *      dot11PhyTxPower  TABLE
-- *****

dot11PhyTxPowerTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyTxPowerEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "Group of attributes for dot11PhyTxPowerTable. Implemented
        as a table indexed on STA ID to allow for multiple
        instances on an Agent."

    ::= { dot11phy 3 }

dot11PhyTxPowerEntry OBJECT-TYPE
    SYNTAX Dot11PhyTxPowerEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

        "An entry in the dot11PhyTxPower Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
    ::= { dot11PhyTxPowerTable 1 }

Dot11PhyTxPowerEntry ::= SEQUENCE {
    dot11NumberSupportedPowerLevels  INTEGER,
    dot11TxPowerLevel1                INTEGER,
    dot11TxPowerLevel2                INTEGER,
    dot11TxPowerLevel3                INTEGER,
    dot11TxPowerLevel4                INTEGER,
    dot11TxPowerLevel5                INTEGER,

```

```
dot11TxPowerLevel6          INTEGER,
dot11TxPowerLevel7          INTEGER,
dot11TxPowerLevel8          INTEGER,
dot11CurrentTxPowerLevel    INTEGER}

dot11NumberSupportedPowerLevels OBJECT-TYPE
    SYNTAX INTEGER (1..8)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The number of power levels supported by the PMD.
        This attribute can have a value of 1 to 8."
    ::= { dot11PhyTxPowerEntry 1 }

dot11TxPowerLevel1 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL1 in mW.
        This is also the default power level."
    ::= { dot11PhyTxPowerEntry 2 }

dot11TxPowerLevel2 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL2 in mW."
    ::= { dot11PhyTxPowerEntry 3 }

dot11TxPowerLevel3 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL3 in mW."
    ::= { dot11PhyTxPowerEntry 4 }

dot11TxPowerLevel4 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL4 in mW."
    ::= { dot11PhyTxPowerEntry 5 }

dot11TxPowerLevel5 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL5 in mW."
    ::= { dot11PhyTxPowerEntry 6 }

dot11TxPowerLevel6 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
```

```

        DESCRIPTION
            "The transmit output power for LEVEL6 in mW."
        ::= { dot11PhyTxPowerEntry 7 }

dot11TxPowerLevel7 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL7 in mW."
    ::= { dot11PhyTxPowerEntry 8 }

dot11TxPowerLevel8 OBJECT-TYPE
    SYNTAX INTEGER (0..10000)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The transmit output power for LEVEL8 in mW."
    ::= { dot11PhyTxPowerEntry 9 }

dot11CurrentTxPowerLevel OBJECT-TYPE
    SYNTAX INTEGER (1..8)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The TxPowerLevel N currently being used to transmit data.
        Some PHYs also use this value to determine the receiver
        sensitivity requirements for CCA."

    ::= { dot11PhyTxPowerEntry 10 }

-- *****
-- *      End of dot11PhyTxPower TABLE
-- *****

-- *****
-- *      dot11PhyFHSS TABLE
-- *****

dot11PhyFHSSTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyFHSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group of attributes for dot11PhyFHSSTable. Implemented as a
        table indexed on STA ID to allow for multiple instances on
        an Agent."

    ::= { dot11phy 4 }

dot11PhyFHSSEntry OBJECT-TYPE
    SYNTAX Dot11PhyFHSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyFHSS Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."

```

```
INDEX {ifIndex}
 ::= { dot11PhyFHSSTable 1 }

Dot11PhyFHSSEntry ::= SEQUENCE {
    dot11HopTime                INTEGER,
    dot11CurrentChannelNumber    INTEGER,
    dot11MaxDwellTime            INTEGER,
    dot11CurrentDwellTime        INTEGER,
    dot11CurrentSet              INTEGER,
    dot11CurrentPattern          INTEGER,
    dot11CurrentIndex            INTEGER}

dot11HopTime OBJECT-TYPE
    SYNTAX INTEGER (224)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The time in microseconds for the PMD to change from
        channel 2 to channel 80"
    ::= { dot11PhyFHSSEntry 1 }

dot11CurrentChannelNumber OBJECT-TYPE
    SYNTAX INTEGER (0..99)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current channel number of the frequency output by the RF
        synthesizer"
    ::= { dot11PhyFHSSEntry 2 }

dot11MaxDwellTime OBJECT-TYPE
    SYNTAX INTEGER (1..65535)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The maximum time in TU that the transmitter
        is permitted to operate on a single channel."
    ::= { dot11PhyFHSSEntry 3 }

dot11CurrentDwellTime OBJECT-TYPE
    SYNTAX INTEGER (1..65535)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current time in TU that the transmitter shall operate
        on a single channel, as set by the MAC. Default is 19 TU."
    ::= { dot11PhyFHSSEntry 4 }

dot11CurrentSet OBJECT-TYPE
    SYNTAX INTEGER (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current set of patterns the PHY
        LME is using to determine the hopping sequence. "
    ::= { dot11PhyFHSSEntry 5 }

dot11CurrentPattern OBJECT-TYPE
    SYNTAX INTEGER (0..255)
```

```

MAX-ACCESS read-write
STATUS current
DESCRIPTION
    "The current pattern the PHY LME is
    using to determine the hop sequence."
 ::= { dot11PhyFHSSEntry 6 }

dot11CurrentIndex OBJECT-TYPE
    SYNTAX INTEGER (1..255)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current index value the PHY LME is using to determine
        the CurrentChannelNumber."

 ::= { dot11PhyFHSSEntry 7 }

-- *****
-- *      End of dot11PhyFHSS  TABLE
-- *****

-- *****
-- *      dot11PhyDSSSEntry  TABLE
-- *****
dot11PhyDSSSTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyDSSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Entry of attributes for dot11PhyDSSSEntry.  Implemented as a
        table indexed on ifIndex allow for multiple instances on
        an Agent."

 ::= { dot11phy 5 }

dot11PhyDSSSEntry OBJECT-TYPE
    SYNTAX Dot11PhyDSSSEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11PhyDSSSEntry Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry.  Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex}
 ::= { dot11PhyDSSSTable 1 }

Dot11PhyDSSSEntry ::= SEQUENCE {
    dot11CurrentChannel    INTEGER,
    dot11CCAModeSupported  INTEGER,
    dot11CurrentCCAMode    INTEGER,
    dot11EDThreshold       Integer32}

dot11CurrentChannel OBJECT-TYPE
    SYNTAX INTEGER (1..14)
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION

```

```

    "The current operating frequency channel of the DSSS
    PHY. Valid channel numbers are as defined in 15.4.6.2"
 ::= { dot11PhyDSSSEntry 1 }

dot11CCAModeSupported OBJECT-TYPE
    SYNTAX INTEGER (1..7)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "dot11CCAModeSupported is a bit-significant value, representing all of the
        CCA modes supported by the PHY. Valid values are:

            energy detect only (ED_ONLY) = 01,
            carrier sense only (CS_ONLY) = 02,
            carrier sense and energy detect (ED_and_CS)= 04

        or the logical sum of any of these values."
 ::= { dot11PhyDSSSEntry 2 }

dot11CurrentCCAMode OBJECT-TYPE
    SYNTAX INTEGER { edonly(1), csonly(2), edandcs(4) }
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current CCA method in operation. Valid values are:

            energy detect only (edonly) = 01,
            carrier sense only (csonly) = 02,
            carrier sense and energy detect (edandcs)= 04."
 ::= { dot11PhyDSSSEntry 3 }

dot11EDThreshold OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The current Energy Detect Threshold being used by the DSSS PHY."
 ::= { dot11PhyDSSSEntry 4 }

-- *****
-- *      End of dot11PhyDSSSEntry  TABLE
-- *****

-- *****
-- *      dot11PhyIR  TABLE
-- *****

dot11PhyIRTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PhyIREntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Group of attributes for dot11PhyIRTable. Implemented as a
        table indexed on ifIndex to allow for multiple instances on
        an Agent."

 ::= { dot11phy 6 }

dot11PhyIREntry OBJECT-TYPE
    SYNTAX Dot11PhyIREntry
    MAX-ACCESS not-accessible
```

```

STATUS current
DESCRIPTION
    "An entry in the dot11PhyIR Table.

    ifIndex - Each 802.11 interface is represented by an
    ifEntry. Interface tables in this MIB module are indexed
    by ifIndex."
INDEX {ifIndex}
 ::= { dot11PhyIRTable 1 }

Dot11PhyIREntry ::= SEQUENCE {
    dot11CCAWatchdogTimerMax      Integer32,
    dot11CCAWatchdogCountMax     Integer32,
    dot11CCAWatchdogTimerMin     Integer32,
    dot11CCAWatchdogCountMin     Integer32}

dot11CCAWatchdogTimerMax OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This parameter, together with CCAWatchdogCountMax,
        determines when energy detected in the channel can be
        ignored."

    ::= { dot11PhyIREntry 1 }

dot11CCAWatchdogCountMax OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This parameter, together with CCAWatchdogTimerMax,
        determines when energy detected in the channel can be
        ignored."

    ::= { dot11PhyIREntry 2 }

dot11CCAWatchdogTimerMin OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The minimum value to which CCAWatchdogTimerMax can be
        set."

    ::= { dot11PhyIREntry 3 }

dot11CCAWatchdogCountMin OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "The minimum value to which CCAWatchdogCount can be set."
    ::= { dot11PhyIREntry 4 }

-- *****
-- *      End of dot11PhyIR TABLE
-- *****

```



```
-- *****
-- *      dot11RegDomainsSupported TABLE
-- *****
dot11RegDomainsSupportedTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11RegDomainsSupportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "There are different operational requirements dependent on
        the regulatory domain. This attribute list describes the
        regulatory domains the PLCP and PMD support in this
        implementation. Currently defined values and their
        corresponding Regulatory Domains are:

        FCC (USA) = X'10', DOC (Canada) = X'20', ETSI (most of
        Europe) = X'30', Spain = X'31', France = X'32', MKK
        (Japan) = X'40' "
```

```
 ::= { dot11phy 7 }
```

```
dot11RegDomainsSupportEntry OBJECT-TYPE
    SYNTAX Dot11RegDomainsSupportEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11RegDomainsSupport Table.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex, dot11RegDomainsSupportIndex}
    ::= { dot11RegDomainsSupportedTable 1 }
```

```
Dot11RegDomainsSupportEntry ::= SEQUENCE {
    dot11RegDomainsSupportIndex Integer32,
    dot11RegDomainsSupportValue INTEGER }
```

```
dot11RegDomainsSupportIndex OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The auxiliary variable used to identify instances
        of the columnar objects in the RegDomainsSupport Table."
    ::= { dot11RegDomainsSupportEntry 1 }
```

```
dot11RegDomainsSupportValue OBJECT-TYPE
    SYNTAX INTEGER {fcc(16), doc(32), etsi(48), spain(49), france
    (50), mkk(64) }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "There are different operational requirements dependent on
        the regulatory domain. This attribute list describes the
        regulatory domains the PLCP and PMD support in this
        implementation. Currently defined values and their
        corresponding Regulatory Domains are:
```

```

        FCC (USA) = X'10', DOC (Canada) = X'20', ETSI (most of
        Europe) = X'30', Spain = X'31', France = X'32', MKK
        (Japan) = X'40' "
 ::= { dot11RegDomainsSupportEntry 2 }

-- *****
-- *      End of dot11RegDomainsSupported TABLE
-- *****

-- *****
-- *      dot11AntennasList TABLE
-- *****
dot11AntennasListTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11AntennasListEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "This table represents the list of antennae. An
        antenna can be marked to be capable of transmitting,
        receiving, and/or for participation in receive diversity. Each
        entry in this table represents a single antenna with
        its properties. The maximum number of antennae that can
        be contained in this table is 255."
 ::= { dot11phy 8 }

dot11AntennasListEntry OBJECT-TYPE
    SYNTAX Dot11AntennasListEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry in the dot11AntennasListTable,
        representing the properties of a single antenna.

        ifIndex - Each 802.11 interface is represented by an
        ifEntry. Interface tables in this MIB module are indexed
        by ifIndex."
    INDEX {ifIndex, dot11AntennaListIndex}
 ::= { dot11AntennasListTable 1 }

Dot11AntennasListEntry ::= SEQUENCE {
    dot11AntennaListIndex      Integer32,
    dot11SupportedTxAntenna    TruthValue,
    dot11SupportedRxAntenna    TruthValue,
    dot11DiversitySelectionRx  TruthValue }

dot11AntennaListIndex OBJECT-TYPE
    SYNTAX Integer32 (1..255)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The unique index of an antenna which is
        used to identify the columnar objects in
        the dot11AntennasList Table."
 ::= { dot11AntennasListEntry 1 }

dot11SupportedTxAntenna OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current

```

```
DESCRIPTION
    "When true, this object indicates that the
    antenna represented by dot11AntennaIndex
    can be used as a transmit antenna."

 ::= { dot11AntennasListEntry 2 }

dot11SupportedRxAntenna OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When true, this object indicates that the
        antenna represented by the dot11AntennaIndex
        can be used as a receive antenna."

 ::= { dot11AntennasListEntry 3 }

dot11DiversitySelectionRx OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "When true, this object indicates that the
        antenna represented by dot11AntennaIndex can
        be used for receive diversity. This object
        may only be true if the antenna can be used
        as a receive antenna, as indicated by
        dot11SupportedRxAntenna."

 ::= { dot11AntennasListEntry 4 }

-- *****
-- *      End of dot11AntennasList  TABLE
-- *****

-- *****
-- *      SupportedDataRatesTx  TABLE
-- *****
dot11SupportedDataRatesTxTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SupportedDataRatesTxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "The Transmit bit rates supported by the PLCP and PMD,
        represented by a count from X'02-X'7f, corresponding to data
        rates in increments of 500Kb/s from 1 Mbit/s to 63.5 Mbit/s subject
        to limitations of each individual PHY."

 ::= { dot11phy 9 }

dot11SupportedDataRatesTxEntry OBJECT-TYPE
    SYNTAX Dot11SupportedDataRatesTxEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the dot11SupportedDataRatesTx
```

Table.

ifIndex - Each 802.11 interface is represented by an ifEntry. Interface tables in this MIB module are indexed by ifIndex."

INDEX {ifIndex, dot11SupportedDataRatesTxIndex}

::= { dot11SupportedDataRatesTxTable 1 }

Dot11SupportedDataRatesTxEntry ::= SEQUENCE {
dot11SupportedDataRatesTxIndex Integer32,
dot11SupportedDataRatesTxValue Integer32}

dot11SupportedDataRatesTxIndex OBJECT-TYPE

SYNTAX Integer32 (1..8)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"Index object which identifies which data rate to access.
Range is 1..8."

::= { dot11SupportedDataRatesTxEntry 1 }

dot11SupportedDataRatesTxValue OBJECT-TYPE

SYNTAX Integer32 (2..127)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The Transmit bit rates supported by the PLCP and PMD,
represented by a count from X'02-X'7f, corresponding to data
rates in increments of 500Kb/s from 1 Mbit/s to 63.5 Mbit/s subject
to limitations of each individual PHY."

::= { dot11SupportedDataRatesTxEntry 2 }

-- *****
-- * End of dot11SupportedDataRatesTx TABLE
-- *****

-- *****
-- * SupportedDataRatesRx TABLE
-- *****

dot11SupportedDataRatesRxTable OBJECT-TYPE

SYNTAX SEQUENCE OF Dot11SupportedDataRatesRxEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"The receive bit rates supported by the PLCP and PMD,
represented by a count from X'002-X'7f, corresponding to data
rates in increments of 500Kb/s from 1 Mbit/s to 63.5 Mbit/s."

::= { dot11phy 10 }

dot11SupportedDataRatesRxEntry OBJECT-TYPE

SYNTAX Dot11SupportedDataRatesRxEntry

MAX-ACCESS not-accessible

```
STATUS current
DESCRIPTION

"An Entry (conceptual row) in the
dot11SupportedDataRatesRx Table.

    ifIndex - Each 802.11 interface is represented by an
    ifEntry. Interface tables in this MIB module are indexed
    by ifIndex."

INDEX {ifIndex, dot11SupportedDataRatesRxIndex}

 ::= { dot11SupportedDataRatesRxTable 1 }

Dot11SupportedDataRatesRxEntry ::= SEQUENCE {
    dot11SupportedDataRatesRxIndex Integer32,
    dot11SupportedDataRatesRxValue Integer32}

dot11SupportedDataRatesRxIndex OBJECT-TYPE
    SYNTAX Integer32 (1..8)
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Index object which identifies which data rate to access.
        Range is 1..8."
    ::= { dot11SupportedDataRatesRxEntry 1 }

dot11SupportedDataRatesRxValue OBJECT-TYPE
    SYNTAX Integer32 (2..127)
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "The receive bit rates supported by the PLCP and PMD,
        represented by a count from X'02-X'7f, corresponding to data
        rates in increments of 500 Kb/s from 1 Mbit/s to 63.5 Mbit/s."
    ::= { dot11SupportedDataRatesRxEntry 2 }

-- *****
-- * End of dot11SupportedDataRatesRx TABLE
-- *****

-- *****
-- * conformance information
-- *****

dot11Conformance OBJECT IDENTIFIER ::= { ieee802dot11 5 }
dot11Groups OBJECT IDENTIFIER ::= { dot11Conformance 1 }
dot11Compliances OBJECT IDENTIFIER ::= { dot11Conformance 2 }

-- *****
-- * compliance statements
-- *****
dot11Compliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMPv2 entities
        that implement the IEEE 802.11 MIB."

MODULE -- this module
MANDATORY-GROUPS {
```

```

        dot11SMTbase2,
        dot11MACbase, dot11CountersGroup,
        dot11SmtAuthenticationAlgorithms,
        dot11ResourceTypeID, dot11PhyOperationComplianceGroup }

GROUP dot11PhyDSSSComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object
        dot11PHYType has the value of dsss. This group is
        mutually exclusive with the groups dot11PhyIRComplianceGroup and
        dot11PhyFHSSComplianceGroup."

GROUP dot11PhyIRComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object
        dot11PHYType has the value of irbaseband. This group is
        mutually exclusive with the groups dot11PhyDSSSComplianceGroup and
        dot11PhyFHSSComplianceGroup."

GROUP dot11PhyFHSSComplianceGroup
    DESCRIPTION
        "Implementation of this group is required when object
        dot11PHYType has the value of fhss. This group is
        mutually exclusive with the groups dot11PhyDSSSComplianceGroup and
        dot11PhyIRComplianceGroup."

-- OPTIONAL-GROUPS { dot11SMTprivacy, dot11MACStatistics,
--   dot11PhyAntennaComplianceGroup, dot11PhyTxPowerComplianceGroup,
--   dot11PhyRegDomainsSupportGroup,
--   dot11PhyAntennasListGroup, dot11PhyRateGroup }
--

::= { dot11Compliances 1 }

-- *****
-- *   Groups - units of conformance
-- *****
dot11SMTbase OBJECT-GROUP
    OBJECTS { dot11StationID, dot11MediumOccupancyLimit,
        dot11CFPPollable,
        dot11CFPPPeriod,
        dot11CFPPMaxDuration,
        dot11AuthenticationResponseTimeOut,
        dot11PrivacyOptionImplemented,
        dot11PowerManagementMode,
        dot11DesiredSSID, dot11DesiredBSSType,
        dot11OperationalRateSet,
        dot11BeaconPeriod, dot11DTIMPeriod,
        dot11AssociationResponseTimeOut
    }
    STATUS deprecated
    DESCRIPTION
        "The SMT object class provides the necessary support at the
        STA to manage the processes in the STA such that the STA may
        work cooperatively as a part of an IEEE 802.11 network."
    ::= {dot11Groups 1 }

```

```
dot11SMTPprivacy OBJECT-GROUP
  OBJECTS { dot11PrivacyInvoked,
            dot11WEPKeyMappingLength, dot11ExcludeUnencrypted,
            dot11WEPICVErrorCount , dot11WEPExcludedCount ,
            dot11WEPDefaultKeyID,
            dot11WEPDefaultKeyValue,
            dot11WEPKeyMappingWEPon,
            dot11WEPKeyMappingValue , dot11WEPKeyMappingAddress,
            dot11WEPKeyMappingStatus }

  STATUS current
  DESCRIPTION
    "The SMTPPrivacy package is a set of attributes that shall be
    present if WEP is implemented in the STA."
  ::= {dot11Groups 2 }

dot11MACbase OBJECT-GROUP

  OBJECTS { dot11MACAddress, dot11Address,
            dot11GroupAddressesStatus,
            dot11RTSThreshold, dot11ShortRetryLimit,
            dot11LongRetryLimit, dot11FragmentationThreshold,
            dot11MaxTransmitMSDULifetime,
            dot11MaxReceiveLifetime, dot11ManufacturerID,
            dot11ProductID

            }

  STATUS current
  DESCRIPTION
    "The MAC object class provides the necessary support for the
    access control, generation, and verification of frame check
    sequences, and proper delivery of valid data to upper
    layers."
  ::= {dot11Groups 3 }

dot11MACStatistics OBJECT-GROUP

  OBJECTS { dot11RetryCount, dot11MultipleRetryCount,
            dot11RTSSuccessCount, dot11RTSFailureCount,
            dot11ACKFailureCount, dot11FrameDuplicateCount }

  STATUS current
  DESCRIPTION
    "The MACStatistics package provides extended statistical
    information on the operation of the MAC. This
    package is completely optional."
  ::= {dot11Groups 4 }

dot11ResourceTypeID OBJECT-GROUP
  OBJECTS { dot11ResourceTypeIDName, dot11manufacturerOUI,
            dot11manufacturerName, dot11manufacturerProductName,
            dot11manufacturerProductVersion }
  STATUS current
  DESCRIPTION
    "Attributes used to identify a STA, its manufacturer,
    and various product names and versions."
  ::= {dot11Groups 5 }
```

```

dot11SmtAuthenticationAlgorithms OBJECT-GROUP
    OBJECTS { dot11AuthenticationAlgorithm,
               dot11AuthenticationAlgorithmsEnable }
    STATUS current
    DESCRIPTION
        "Authentication Algorithm Table."
    ::= { dot11Groups 6 }

dot11PhyOperationComplianceGroup OBJECT-GROUP
    OBJECTS { dot11PHYType, dot11CurrentRegDomain, dot11TempType }
    STATUS current
    DESCRIPTION
        "PHY layer operations attributes."
    ::= { dot11Groups 7 }

dot11PhyAntennaComplianceGroup OBJECT-GROUP
    OBJECTS { dot11CurrentTxAntenna, dot11DiversitySupport,
               dot11CurrentRxAntenna }
    STATUS current
    DESCRIPTION
        "Attributes for Data Rates for IEEE 802.11."
    ::= { dot11Groups 8 }

dot11PhyTxPowerComplianceGroup OBJECT-GROUP
    OBJECTS { dot11NumberSupportedPowerLevels, dot11TxPowerLevel1,
               dot11TxPowerLevel2, dot11TxPowerLevel3, dot11TxPowerLevel4,
               dot11TxPowerLevel5, dot11TxPowerLevel6, dot11TxPowerLevel7,
               dot11TxPowerLevel8, dot11CurrentTxPowerLevel }
    STATUS current
    DESCRIPTION
        "Attributes for Control and Management of transmit power."
    ::= { dot11Groups 9 }

dot11PhyFHSSComplianceGroup OBJECT-GROUP
    OBJECTS { dot11HopTime, dot11CurrentChannelNumber, dot11MaxDwellTime,
               dot11CurrentDwellTime, dot11CurrentSet, dot11CurrentPattern,
               dot11CurrentIndex }
    STATUS current
    DESCRIPTION
        "Attributes that configure the Frequency Hopping for IEEE
        802.11."
    ::= { dot11Groups 10 }

dot11PhyDSSSComplianceGroup OBJECT-GROUP
    OBJECTS { dot11CurrentChannel, dot11CCAModeSupported,
               dot11CurrentCCAMode, dot11EDThreshold }
    STATUS current
    DESCRIPTION
        "Attributes that configure the DSSS for IEEE 802.11."
    ::= { dot11Groups 11 }

dot11PhyIRComplianceGroup OBJECT-GROUP
    OBJECTS { dot11CCAWatchdogTimerMax, dot11CCAWatchdogCountMax,
               dot11CCAWatchdogTimerMin, dot11CCAWatchdogCountMin }

```



```

    STATUS current
    DESCRIPTION
        "Attributes that configure the baseband IR for IEEE 802.11."
    ::= { dot11Groups 12 }

dot11PhyRegDomainsSupportGroup OBJECT-GROUP
    OBJECTS { dot11RegDomainsSupportValue }
    STATUS current
    DESCRIPTION
        "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 13 }

dot11PhyAntennasListGroup OBJECT-GROUP
    OBJECTS { dot11SupportedTxAntenna,
               dot11SupportedRxAntenna, dot11DiversitySelectionRx }
    STATUS current
    DESCRIPTION
        "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 14 }

dot11PhyRateGroup OBJECT-GROUP
    OBJECTS { dot11SupportedDataRatesTxValue,
               dot11SupportedDataRatesRxValue
    }
    STATUS current
    DESCRIPTION
        "Attributes for Data Rates for IEEE 802.11."
    ::= { dot11Groups 15 }

dot11CountersGroup OBJECT-GROUP
    OBJECTS {
        dot11TransmittedFragmentCount ,
        dot11MulticastTransmittedFrameCount ,
        dot11FailedCount, dot11ReceivedFragmentCount,
        dot11MulticastReceivedFrameCount ,
        dot11FCSErrorCount,
        dot11WEPUndecryptableCount,
        dot11TransmittedFrameCount }

    STATUS current
    DESCRIPTION
        "Attributes from the dot11CountersGroup that are not described
        in the dot11MACStatistics group. These objects are
        mandatory."
    ::= { dot11Groups 16 }

dot11NotificationGroup NOTIFICATION-GROUP
    NOTIFICATIONS { dot11Disassociate,
                     dot11Deauthenticate,
                     dot11AuthenticateFail }
    STATUS current
    DESCRIPTION
        "IEEE 802.11 notifications"
    ::= { dot11Groups 17 }

dot11SMBase2 OBJECT-GROUP
```

```

OBJECTS { dot11MediumOccupancyLimit,
          dot11CFPollable,
          dot11CFPeriod,
          dot11CFMaxDuration,
          dot11AuthenticationResponseTimeOut,
          dot11PrivacyOptionImplemented,
          dot11PowerManagementMode,
          dot11DesiredSSID, dot11DesiredBSSType,
          dot11OperationalRateSet,
          dot11BeaconPeriod, dot11DTIMPeriod,
          dot11AssociationResponseTimeOut,
          dot11DisassociateReason,
          dot11DisassociateStation,
          dot11DeauthenticateReason,
          dot11DeauthenticateStation,
          dot11AuthenticateFailStatus,
          dot11AuthenticateFailStation
        }
STATUS current
DESCRIPTION
    "The SMTbase2 object class provides the necessary support at the
    STA to manage the processes in the STA such that the STA may
    work cooperatively as a part of an IEEE 802.11 network."
 ::= {dot11Groups 18 }

-- *****
-- *      End of 80211 MIB
-- *****
END

```

Annex E

(informative)

Bibliography

E.1 General

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[B8] Olsen, Anders, Ove Faergemand, Birger Moller-Pedersen, Rick Reed, and T. R. W. Smith, *Systems Engineering Using SDL-92*. Amsterdam, the Netherlands: Elsevier Science B.V., 1994.¹¹

⁸An introductory text on SDL, also useful as a language reference (for SDL-88).

⁹A recently published book, which appears to be the most comprehensive single-volume introduction and reference for SDL-92, including its object-oriented extensions.

¹⁰This provides a summary of the changes from SDL-88 to SDL-92.

¹¹A detailed guide to using SDL-92, including a thorough explanation of abstract data type mechanism and SDL combined with ASN.1 (ITU-T Recommendation Z.105).

ISO/IEC 8802-11:1999(E)
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Toward a Smaller Java

By Michael Barr, Embedded.com

Jun 14 2002 (9:06 AM)

URL: <http://www.embedded.com/showArticle.jhtml?articleID=9900680>

Sun's K Virtual Machine gives embedded developers a virtual kick in the pants. KVM makes it possible to run Java programs on any 16-bit processor with 128KB of memory.

Sun's unveiling of the K Virtual Machine (KVM) at JavaOne 1999 was not particularly noted by most of the attendees, who are largely in the business of writing software for desktop and server applications. However, the significance of this announcement to the developers of software for embedded systems cannot be underestimated.

Prior to its announcement of KVM, Sun had steadfastly held to the "write once, run anywhere" principle still much associated with Java. Make software portable to any computing platform, Java's proponents said, and its value will increase manyfold. True enough. But that argument overlooks the simple fact that the majority of the world's computing platforms are inside a heterogeneous mix of products with more limited resources than general-purpose computers.**[1]**

Embedded systems typically have only the minimum CPU horsepower, ROM, RAM, and display capabilities necessary to get the job done. Even cell phones, PDAs, and set-top boxes-high-end embedded systems by almost any standards, and platforms frequently described as "ideal for Java"-are far more resource constrained than desktops. Trying to run a Java program written for a desktop computer on one of these systems is a fool's errand.

The problem with the "write once, run anywhere" mantra is that it doesn't acknowledge the reality of resource constraints or offer would-be Java programmers any other option. Java 2 Micro Edition (J2ME) and the K Virtual Machine do both.

J is for Java

Although platform independence has often been hailed as Java's greatest strength, it is equally important to note that it is easier to produce bug-free software in Java than in C or C++. Java was designed from the ground up to produce code that is simpler to write and easier to maintain. And, though they based their language on the syntax of C, the creators of Java eliminated many of that language's most troublesome features. These features sometimes make C/C++ programs hard to understand and maintain, and frequently lead to undetected programming errors. Here are just a few of the improvements:

- All of Java's primitive data types have a fixed size. For example, an int is always 32 bits in Java, no matter what processor lies underneath.
- Automatic run-time bounds-checking prevents the program from writing or reading past the end of an array.
- All test conditions must return a Boolean result. Common C/C++ programming mistakes,

such as while (x = 3), are thus detected at compile time, eliminating an entire class of bugs.

In addition, Java is an object-oriented language, which allows software developers to encapsulate new data types and the functions that manipulate them into logical units called classes. Encapsulation, polymorphism, and inheritance (the three pillars of object-oriented programming) are all available and are used extensively in the built-in class libraries. Java simplifies inheritance by eliminating multiple inheritance and replacing it with interfaces. It also adds new features that are not available in C++, most notably:

- Automatic garbage collection simplifies dynamic memory management and eliminates memory leaks.
- Built-in language support makes multithreaded applications written in Java more portable than those written in other languages, by providing a consistent thread and synchronization API across all operating systems.

Virtual reality

The virtual machine concept is not unique to Java; it arises from the marriage of two simpler ideas. First, that the work of computer programmers everywhere would be much easier if a single processor architecture was used in every system. And, second, that simulation of one processor by another is always possible and, given sufficient computing power, often reasonable.

The creators of Java designed both a new language and a mythical processor on which all of the programs written in that language would run. Since this processor did not actually exist, they termed it the Java Virtual Machine. The written specification of this "processor" (called The Java Virtual Machine Specification and available in book form[2]) describes a full set of machine-language instructions and their behaviors and reads much like the Programmer's Guide for a real processor. The instruction set recognized by the virtual machine is called the Java bytecodes.[3]

Since the Java processor did not actually exist in hardware (at the time, anyway) it was necessary to simulate it in software. Toward that end, sun developed the first Java Virtual Machine (JVM). The first JVM was a bytecode interpreter, which translates each Java bytecode into one or more of the opcodes of the underlying physical processor, at runtime. An interpreter like this retranslates a bytecode each time it is fetched from memory. Obviously, this slows down the execution of the Java program (think of it as requiring additional processing power). Consider the impact of reinterpretation on a simple for() loop and its inner statements.

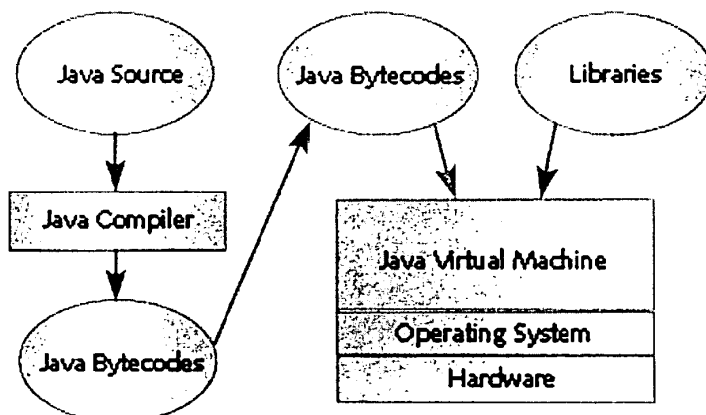


Figure 1: The Java development and execution infrastructure

The overall development and execution infrastructure for a Java program is shown in Figure 1. A program written in the Java programming language is compiled into a set of bytecodes. Those bytecodes are then loaded and executed by a JVM. If the program makes calls to other Java classes, the bytecodes for those classes will likewise be loaded, dynamically linked, and executed. Some of these libraries (java.lang, java.math, java.io, and so on) are intended to be a built-in part of any standard Java execution environment, much as the C standard library is a part of the ANSI C standard.

The principal advantage of the virtual machine concept is portability. Programs written in Java can be executed on any processor for which a simulator (JVM) exists. If the behavior of the virtual machine is defined well enough to ensure consistency across all platforms, applications will produce the same result in each such computing environment.

Getting personal

Of course, portability is about more than just the JVM. A mechanism for executing Java bytecodes on any processor is one-half of application portability; a common set of class libraries is the other.

Java's class libraries are not unlike C's standard libraries. If you've ever used strcmp() or strlen() in a program, you were relying on the standard C library to be linked with your application. Similarly, if you want to manipulate strings in Java, you will need a class library called java.lang to be made part of your runtime environment.

In order to promote and encourage application portability, Sun initially defined several standard runtime platforms (groups of class libraries). Sun referred to these standard platforms as Java Application Environments. The following application environments were defined:

- Standard Java-the full set of class libraries included in Sun's JDK. These classes are appropriate for desktop workstations and servers and may expect significant hardware and operating system resources.
- EnterpriseJava-a superset of the above class libraries, for use in "enterprise" servers and systems.
- PersonalJava-a (not-quite proper) subset of the Standard Java class libraries more appropriate to set-top boxes, PDAs, network computers, and other "networked embedded systems" with a fairly large amount of processing power and memory.

Divergent libraries were necessary because of the enormous growth of the "standard" libraries as Java was initially embraced and adapted by the Internet and enterprise programming communities. See Table 1.

Table 1: Growth of Java's standard libraries

JDK version	Year released	Packages	Classes	Interfaces
1	1996	8	172	40
1.1	1997	23	391	113
1.2	1998	62	1,287	305

The intention of these three standard application environments was to allow Java application developers to easily specify the types of platforms on which their program would run. For example, a program written for use in a PersonalJava-compatible PDA could also be run on a PersonalJava-

compatible set-top box.

Embedded Java

Of course, one of the big problems with using Java in embedded systems is size, a requirement which is at direct odds with virtual machines and large standard libraries.

Sun's original JVM-and one they still license for use in all manner of systems-consumes 512KB of ROM. Included in that figure are the basic elements of bytecode execution: bytecode interpreter, garbage collector, dynamic class loader, and bytecode verifier. Not included are the underlying operating system, your application's bytecodes, and any supporting native code. Even the Java class libraries-required to achieve true portability-are not included in this sizable memory requirement. If you set out to use Sun's JVM and want to include a set of class libraries conforming to the PersonalJava API, you'd soon wind up with a system requirement of about 2MB of ROM.

Several vendors make more embeddable JVMs (smaller and faster, with more deterministic garbage collection, and so on), but you still generally need at least 1MB of ROM to achieve compatibility with the PersonalJava API.

If you're willing to discard portability altogether, you can reduce the ROM requirements significantly. The trade-off between portability and ROM usage can be made in one or both of two places: the JVM or the class libraries. The first Sun-supported approach was to shrink the libraries. That was what they termed the EmbeddedJava API.

Not a true application environment, like the three mentioned earlier, EmbeddedJava simply duplicates the list of class libraries from PersonalJava but makes every library class, method, and data member optional. In other words, if your particular application doesn't require java.net (no networking), don't include those classes in your build. This will obviously reduce application portability (for example, you can no longer run a network time synchronization program), but if that matters less to you than ROM space, you have that option.

The idea is that you write your application to the PersonalJava API, compile it to bytecodes, then run it through additional development steps called filtering and code compaction. A command-line tool called JavaFilter reads your application's bytecodes and produces a list of all the methods and data members of the class libraries on which it depends. Another tool, called JavaCodeCompact, then produces a minimal ROM image for that application by culling elements of the full set of class libraries that aren't used.

An application written for one EmbeddedJava platform may or may not run on another EmbeddedJava platform. That will depend on the library dependencies of the particular application and the precise set of libraries present in ROM on the new system. In most cases, they won't match up properly.

K is for kilobytes

EmbeddedJava was definitely a step in the right direction for developers working in constrained environments. And it was the first evidence that the folks at Sun were beginning to understand that Java wouldn't be very successful in the embedded systems market without some concessions on the portability front. However, EmbeddedJava didn't go far enough.

To truly minimize the ROM requirements for a Java execution environment, developers need to be able to fiddle with the JVM itself, to reduce features in exchange for memory.

The K Virtual Machine (KVM) provides that necessary flexibility. Built from the ground up with efficiency, minimizing RAM and ROM usage, and modularity in mind, KVM is a remarkable piece of software. It is provided in source code form, through Sun's Community Source Licensing Program, [4] and can be customized in many ways.

With KVM, it is possible to run Java applications on 16-bit processors running at just 25MHz and in systems with as little as 128KB of ROM to spare. This is a significant step forward for embedded Java. Sun's support for this approach officially opens the door to its many competitors in the embedded market to provide their own smaller JVMs.

Under the microscope

Shortly after the announcement of KVM, which I'll have more to say about later, came the release of Java 2 Micro Edition (J2ME). Three Java editions—the new name for the standard APIs, starting in Java 2—were created to promote the upward compatibility of applications written in Java. J2ME offers a way to recapture some of the benefits of "write once, run anywhere" that were lost in the fragmented set of platforms that the introduction of EmbeddedJava heralded.

With every platform having a potentially unique set of library features in ROM, the rules for EmbeddedJava meant that almost no application code would be portable. J2ME promises some of the same size reduction with a corresponding increase in portability.

The key is subsetting. If the platform that an application was written for contains a subset of the library features on desktop and server systems, then it can be run on those too. And if, for example, the very same library subset is present on two different manufacturer's cell phones, then an application written for either could be run on both.

The three Java editions are called "Enterprise" (J2EE), "Standard" (J2SE), and "Micro" (J2ME). The approximate goal is to have each library set be a subset of the previous. However, J2ME is not quite a true subset of J2SE. Just as PersonalJava added a few additions and twists to the StandardJava API, so does J2ME. These are mostly in the areas of more limited and diverse display capabilities and user input methods, and greater timer granularity.

Configurations and profiles

Within the J2ME libraries, there are several types of subsets. The first category of these are termed configurations. The currently defined configurations are Connected Device Configuration (CDC) and Connected Limited Device Configuration (CLDC).

CDC is a set of libraries meant for use in devices that plug into the wall, are always on, and have semi-permanent connections to the Internet.

CLDC, which is a proper subset of CDC, is the library set that will be of most interest to the embedded community. CLDC focuses on small devices that are battery-powered and have slow and spotty connections to the Internet, if they have such connections at all. In other words, typical embedded devices with limited resources.



Figure 2: Figure 2 The library sets of Java's editions

Figure 2 shows how the libraries of the two J2ME configurations are related to the libraries of the other Java editions. The CDC and CLDC classes are not a proper subset of the J2SE classes.

For maximum portability of applications, the designers of an embedded system that would run Java applications should select either CDC or CLDC as their library configuration.

Building on the configuration's library framework are one or more optional profiles. These are extensions of the standard libraries specific to a particular class of embedded system. For example, the Mobile Information Device Profile (MIDP) adds class libraries specific to mobile devices like cell phones and PDAs. Any embedded system with a CLDC configuration and MIDP profile in ROM could run applications written for any other platform with those same libraries.

This allows a more reasonable, trade-off--centered approach toward portability. It is certainly much more likely that the owner of a cell phone from one manufacturer would want to run a Java utility, application, or game written for another brand of cell phone, than that the owner of a logic analyzer would want to run Java code originally written for use on a microwave oven. To gain such portability, cell phone manufacturers might be willing to add a few libraries (and a corresponding amount of ROM) that microwave oven manufacturers would not.

J2ME's configurations and profiles are defined by technical partnerships involving Sun and its customers, under the guidelines of the Java Community Process.[5]

Spotless

KVM was first envisioned as a Java virtual machine for Palm handhelds, and it is in that environment that embedded developers can best experiment with and appreciate it and the J2ME libraries.

The MIDP for Palm OS website (java.sun.com/products/midp4palm/) is the place to start. The code and tools you'll find there help Palm OS users run Java applications that are available for other MIDP-compliant devices, such as mobile phones and pagers.

The full CLDC and KVM distribution, which targets the Windows, Solaris, and Linux platforms, is available at java.sun.com/products/cldc/. This code has been designed for easy portability. A helpful and well-written "KVM Porting Guide" is included. And all of the CLDC library code is written in Java and supplied in bytecode form, which KVM can execute once you get it up and running on your target platform.

The first thing to know about KVM is that it's written entirely in ANSI C. It is done this way to make it easy to target any 16- or 32-bit processor for which a C cross compiler exists. Other than implementing a couple of platform-specific functions in C, there's not much to the porting process.

But wait! How can KVM execute platform-independent Java bytecodes on your specific processor without some platform-specific assembly code? Easily! All the authors of KVM had to do was code the equivalent of each Java bytecode in C:

```
switch (bytecode)
{
case 0x01:
...;
case 0x02:
...;
```

```
...
};
```

Your compiler does the rest for them automatically-by turning each C snippet into one or more native opcodes. This may not produce the most efficient translation from each bytecode to the native opcode(s) of your specific processor, but it does make the KVM code extremely portable.

The only platform-dependent functions you'll write to port KVM are concerned with allocating big chunks of memory for heap expansion, deallocating the same, returning the current system time, and handling user interface issues. There are also some (optional) hooks for doing platform-specific stuff during VM startup and exit.

As provided, the source code has been tested on Solaris (using GCC or Sun DevPro C 4.2), Windows (Visual C++ 6.0), Linux (GCC), and Palm OS (CodeWarrior Release 6 for Palm). Makefiles and platform-dependent code for each of these platforms are provided for you.

In the next section, I will refer only to the Palm OS port, which I experimented with myself. I began with the code for KVM 1.0.3 and used Metrowerks CodeWarrior, running on a Windows 2000 development host, to tweak the Palm OS port to my liking.

Size matters

The size of the KVM executable is heavily influenced by the Java language features selected when it is compiled. Configuration options include:

- Floating-point support can be enabled or disabled.
- Internal debug logging and tracing code can be included or excluded.
- The maximum heap size can be set.
- A runtime bytecode caching technique ("fast bytecodes"), which improves performance 15% to 20% can be turned on, at the cost of several kilobytes of extra code.
- Either big- or little-endian data mode can be selected.
- Class prelinking/preloading can be turned on or off.
- Some behaviors of the garbage collector can be tweaked.
- Optional non-CLDC classes, like graphics libraries, can be included or excluded.

Included in the KVM download are pre-built KVM.prc and KVMutil.prc files, which are required for download to a Palm OS device before Java applications can be run there. Somewhat to my surprise, these default files together took up almost 400KB of memory on my Palm V. But that seems to be the maximum, with all options and CLDC libraries included. (The MIDP libraries are not included in this figure.)

I was able to quickly build a much smaller standalone KVM for the Palm (about 60KB), simply by turning off floating-point support, enabling prelinking/preloading, disabling "fast bytecodes," and "ROMizing." The latter means going through an automated, EmbeddedJava-style pruning of the class libraries at build time, to include in memory only those classes, methods, and data members that are actually used by the applications you want to run.

Typical Java applications for the Palm-like games and calculators-load more slowly (one to two seconds) but otherwise execute as responsively as native Palm apps. (It appears the KVM restarts each time a new application is run.) In addition, most of the Java apps I played with were pretty small-about 5KB to 15KB each.

Write once, run anywhere?

Overall, I am impressed by the J2ME concept and the KVM implementation. Some initial concerns about garbage collection were addressed in release 1.0.3. And, though the new collector is not deterministic, it is far more responsive and respectable than its predecessor.

One remaining complaint concerns the threading model, which has yet to be improved in any update. Under KVM, each Java thread executes a fixed number of bytecodes before being preempted by the scheduler. This overly simplistic round-robin approach needs to be replaced by a priority-based preemptive scheduler to make KVM more than just a platform for experimentation.

Additionally, the virtual machine enhancements suggested in the Real-Time Specification for Java [6] would greatly enhance the value of KVM to real-time developers. Some of the proposals address determinism, others garbage collection and thread scheduling. Perhaps now that KVM's source code is out there, a helpful individual or group will come along and make these changes for the benefit of all.

In summary, KVM represents something close to a JVM embedded programmers could live with. There are still some issues of efficiency and determinism to deal with, but those are not of universal concern. By putting the trade-offs of size vs. portability in the hands of the developers- and in the process, minimizing insistence on portability at all cost-Sun has given us a very nice way to run Java programs on simpler processors with far less memory than ever before. And J2ME's configurations and profiles provide a flexible roadmap for achieving a desired level of portability at a more reasonable cost.

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Endnotes

1. "If you round off the fractions, embedded systems consume 100% of the worldwide production of microprocessors." -Jim Turley, processor industry analyst (*ESP*, May 1999)

[Back](#)

2. Lindholm, Tim and Frank Yellin. *The Java Virtual Machine Specification*. New York: Addison-Wesley, 1999.

[Back](#)

3. The term bytecode derives from the fact that each instruction is just one byte wide.

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4. The long and short of Sun's Community Source Licensing Program is that developers can have full access to the source code for the libraries and virtual machine while they are doing research or creating a product. They can even make changes to that code that suit their system's needs. However, before they start shipping a product that includes that software, they need to enter into a licensing agreement with Sun. For more information, read

www.sun.com/software/communitysource/faq.html.

[Back](#)

5. www.jcp.org

[Back](#)

6. www.rti.org

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Handling Samples Correlation in the Horus System

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Abstract— We present an autoregressive model for modelling samples autocorrelation from the same access point in WLAN location determination systems. Our work is in the context of the *Horus* system, which is a *probabilistic* WLAN location determination system. We show that the autocorrelation between consecutive samples from the same access point can be as high as 0.9. Using our model, we describe a technique to use multiple signal strength samples from each access point, taking the high autocorrelation into account, to achieve better accuracy. Implementation of the technique in the *Horus* system shows that the average system accuracy is increased by more than 50%. Our results show that assuming independence of samples from the same access point can lead to degraded performance as the number of samples used in the estimation algorithm is increased, due to the wrong independence assumption. We also discuss how to incorporate the new technique with other algorithms for enhancing the performance of WLAN location determination systems.

I. INTRODUCTION

Horus is an RF-based location determination system [1]–[4]. It is currently implemented in the context of 802.11 wireless LANs [5]. The system uses the signal strength returned from the access points to infer the user location. Since the wireless cards measure the signal strength information of the received packets as part of their standard operation, this makes the *Horus* system a purely software solution on top of the wireless network infrastructure. A large class of applications [6], including location-sensitive content delivery, direction finding, asset tracking, and emergency notification, can be built on top of the *Horus* system.

WLAN location determination is an active research area [1]–[4], [7]–[14]. WLAN location determination systems usually work in two phases: *offline* training phase and *online* location determination phase. During the offline phase, the signal strength received from the access points at selected locations in the area of interest

is tabulated, resulting in a so-called *radio map*. During the location determination phase, the signal strength samples received from the access points are used to “search” the radio map to estimate the user location.

Radio-map based techniques can be categorized into two broad categories: deterministic techniques and probabilistic techniques. *Deterministic techniques* [7]–[9] use deterministic inference algorithms to estimate the user location. For example, in the *Radar* system [7], [8] the authors use nearest neighborhood techniques to infer the user location. On the other hand, *probabilistic techniques* [1]–[3], [10]–[14] store information about the signal strength distributions from the access points in the radio map and use probabilistic inference algorithms to estimate the user location. For example, the *Nibble* system [10], [11] uses a Bayesian Network approach to estimate the user location.

The *Horus* system lies in the category of probabilistic techniques. Its goal is to identify the noisy characteristics of the wireless channel and to develop techniques to handle them. In this paper, we analyze one aspect of the temporal characteristics of the wireless channel: samples correlation from the same access point. We show that consecutive samples can have correlation as high as 0.9. The main challenge is how to use multiple samples to obtain better location estimate technique despite this high correlation value. Our approach is to treat the samples collected from an access point at a given location as a time series [15] and use the time-series analysis techniques to study their characteristics. More specifically, we describe an autoregressive model that captures the correlation of samples from the same access point. Based on the autoregressive model, we present a technique that uses multiple samples from each access point, to enhance the accuracy of the *Horus* system. We present the results of implementing the new technique and compare its accuracy with that of the original *Horus* system. We also discuss how to incorporate the proposed technique

with other techniques for enhancing the performance of WLAN location determination systems.

The rest of the paper is structured as follows: in the next section, we discuss related work. In section III we present an overview of the *Horus* system and briefly introduce autoregressive models. Section IV shows the temporal characteristic of the samples received from an access point and analyzes the autocorrelation of samples. We describe our autoregressive model to capture the signal strength samples correlation and the technique that uses this model to enhance the accuracy of the *Horus* system in Section V. We present the results of implementing the new technique and compare its accuracy to the accuracy of the original technique in Section VI. Finally, Section VII discusses the main findings of the paper and provides concluding remarks.

II. RELATED WORK

In this section, we describe other techniques that use multiple samples to enhance the performance of WLAN location determination systems. We show how the proposed technique relates to them.

A. Signal Strength Space Averaging

The authors of the *Radar* [7], [8] system, a *deterministic* location determination technique, were the first to propose using multiple signal strength samples to obtain better estimation accuracy. Their technique is to average the received samples and use the average value in the k -nearest neighborhood algorithm to determine the best location estimate. Their results indicate that using more samples in the averaging process leads to better accuracy.

The work in this paper is concerned with *probabilistic* location determination techniques in which the process of using multiple samples to obtain a location estimate is more involved. For example, if the system averages n samples, the system needs to calculate the probability of the average value using the distribution of the average of n original distributions. Obtaining this distribution is not trivial if the samples are not independent. We address this issue in Section V.

B. Physical Location Space Averaging

Different systems, e.g. [7], [8], [12]–[14], proposed to use averaging in the *physical-location space*. The system uses a moving time-average of multiple consecutive location estimates to obtain a better location estimate.

Our technique uses multiple samples in the *signal-strength space* to obtain a better location estimate. Moreover our technique can be used in conjunction with

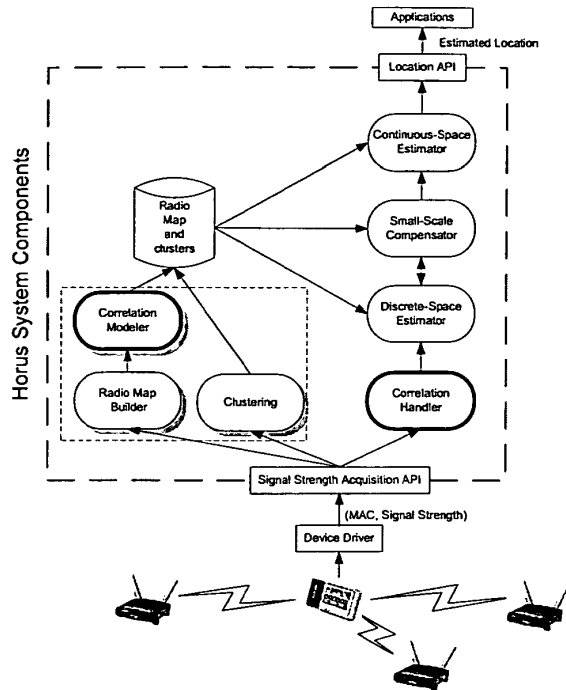


Fig. 1. *Horus* Components: the arrows show information flow in the system. Shaded block represent modules used during the offline phase. In this paper, we describe the correlation modelling and handling components of the *Horus* system (shown in thick lines).

the physical-location space averaging to enhance their accuracy as discussed in Section VII.

The proposed technique is unique in using multiple samples in the signal-strength space to enhance the accuracy of *probabilistic* location determination techniques taking into account the high correlation degree between samples from the same access point.

III. BACKGROUND

A. Overview of the Horus System

In this section, we present a brief overview of the *Horus* system [1]–[4]. Our goal is to provide context for the technique presented in Section V. *Horus* is a probabilistic location determination system. The main goal of the system is to identify the noisy characteristic of the wireless channel and to develop techniques to handle them. Figure 1 shows the components of the *Horus* system. The system uses the signal strength information returned from different access points to infer the user

location and to provide an API for the user applications to use the system functionality.

The system works in two phases:

- 1) *Offline phase*: to build the radio map, cluster radio map locations, and perform other preprocessing tasks for the signal strength models.
- 2) *Online Phase*: to estimate the user location based on the received signal strength from each access point and the radio map prepared in the offline phase.

The radio map stores the distribution of signal strength received from each access point at each location. There are two modes for operation of the *Horus* system: one uses non-parametric distributions and the other uses parametric distributions. In this paper, we will use the parametric distribution mode in which the signal strength distributions are modelled using *Gaussian* distributions.

The *Clustering* module is used to group radio map locations based on the access points covering them. Clustering is used to reduce the computational requirements of the system and, hence, conserve power [1], [3].

The *Discrete Space Estimator* module returns the radio map location that has the maximum probability given the received signal strength vector from different access points. An outline of the algorithm used is given in Algorithm 1 [1], [3], [4].

The *Small-Scale Compensator* module handles the small-scale variation characteristics of the wireless channel [2].

The *Continuous Space Estimator* takes as an input the discrete estimated user location, one of the radio map locations, and returns a more accurate estimate the user location in the continuous space.

In this paper, we describe the *Correlation Modelling* and the *Correlation Handling* modules of the *Horus* system.

B. Time Series Analysis

The technique described in this paper treats the samples received from an access point as a time series and use time-series based techniques to analyze the correlation between the samples. A *time series* [15] is a set of observations generated sequentially in time. If the set is discrete, the time series is said to be discrete, otherwise, it is a continuous time series. We refer to successive equi-spaced samples from a discrete time series s as $s_1, s_2, \dots$. A statistical phenomenon that evolves in time according to probabilistic laws is called a *stochastic process*. The time series to be analyzed may be thought of as a particular realization of the system

Alg. 1 $x = \text{Horus\_GetLocation}(s, \mathbb{X}, RM)$

Input:

s : Measured signal strength vector from k access points ($s = (s_1, \dots, s_k)$).
 $\mathbb{X}$: Radio map locations.
 RM : A radio map based function, where $RM(s_a, a, x)$ returns the probability of receiving signal strength s_a from access point a at location $x \in \mathbb{X}$.

Output:

The location $x \in \mathbb{X}$ that maximizes $P(x/s)$.

```

1: Max  $\leftarrow 0$ 
2: for  $l \in \mathbb{X}$  do
3:    $P \leftarrow \prod_{i=1}^k RM(s_i, i, l)$ 
4:   if  $P > \text{Max}$  then
5:      $x \leftarrow l$ 
6:      $\text{Max} \leftarrow P$ 
7:   end if
8: end for

```

under study. A *stationary* stochastic process is based on the assumption that the process is in a particular state of statistical equilibrium. More formally, a discrete process is strictly stationary if the joint probability of any set of observations must be unaffected by shifting all the times of the observation forward or backward by any integer amount.

Autoregressive models are stochastic models used to analyze stochastic time series. In these models, the current value of the process is expressed as a finite, linear aggregate of previous values of the process and a noise v_t . Therefore, if we denote the values of the process as $s_t, s_{t-1}, s_{t-2}, \dots$, then

$$s_t - \bar{s} = (\phi_1 \cdot s_{t-1} - \bar{s}) + (\phi_2 \cdot s_{t-2} - \bar{s}) + \dots + (\phi_p \cdot s_{t-p} - \bar{s}) + v_t \quad (1)$$

is called an autoregressive process of order p , where $\bar{s}$ is the average of the process.

In this paper, we treat the signal strength samples from an access point as a discrete stationary time series. We model this time series using a first order autoregressive model. To the best of our knowledge, this is the first work to apply time series techniques to the analysis of 802.11 signal strength characteristics.

IV. SIGNAL STRENGTH TEMPORAL CHARACTERISTICS

In this section, we present the temporal characteristics of the signal strength received from an access point

and discuss how they affect the estimation of the user location. For a discussion of spatial characteristics, the reader is referred to [2].

A. Received Signal Strength Variations

Figure 2 shows the normalized histogram of the signal strength received from an access point at a fixed position. The figure shows that the measured signal strength at a fixed position varies over time and the variations can be as large as 10 dBm. This time variation of the channel can be due to changes in the physical environment such as people movement [16].

These variations suggests that depending on a single sample for estimating the user location may lead to inaccurate results if this sample comes from the tail of the distribution. This motivates the need for the techniques that are based on using more than one sample in estimating the user location.

B. Samples Correlation

Figure 3 shows the autocorrelation function of the samples collected from one access point (one sample per second) at a fixed position. The figure shows that the autocorrelation of consecutive samples ($lag = 1$) is as high as 0.9. This high autocorrelation is expected as over a short period of time the signal strength received from an access point at a particular point is relatively stable (modulo the changes in the environment discussed in Section IV-A).

This high autocorrelation value should be considered when using the methods that use multiple samples suggested in the previous section, especially for *probabilistic* location determination techniques. Figure 6 shows the effect of averaging samples on the accuracy of a probabilistic WLAN location determination system that assumes the *independence* of samples¹. The figure shows that although averaging increases accuracy, the wrong independence assumption leads to increasing average distance error *increases* as the number of averaged samples increases. The goal of this paper is to take the high samples correlation into account to further enhance the performance of probabilistic WLAN location determination systems.

V. HANDLING SAMPLES CORRELATION

This section describe an autoregressive model that captures the autocorrelation between samples from the same access point. Following that, we present a technique that uses this model to calculate the distribution of

¹The figure is discussed in more details in Section VI.

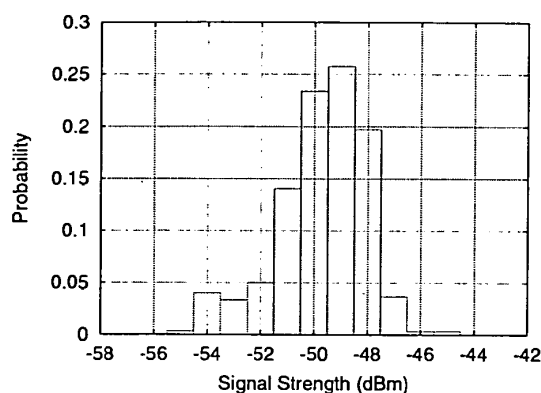


Fig. 2. An example of a normalized histogram of the signal strength of an access point.

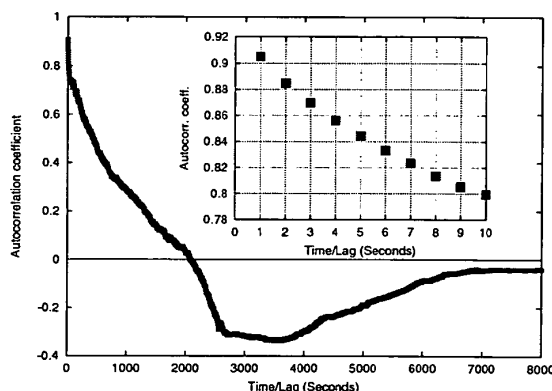


Fig. 3. An example of the autocorrelation between samples from an access point. The sub-figure shows the autocorrelation for the first 10 lags.

the average of n correlated samples. Finally, we modify the *Horus* location determination system to incorporate the new technique.

A. Autoregressive Model

Let s_t be the *stationary* time series representing the samples from an access point where t is the discrete time index. s_t can be represented as a *first order* autoregressive model as:

$$s_t = \alpha \cdot s_{t-1} + (1 - \alpha) \cdot v_t \quad ; 0 \leq \alpha \leq 1 \quad (2)$$

where v_t is a noise process, independent from s_t , and α is a parameter that determines the degree of auto-

correlation of the original samples. Moreover, different samples from v_t are i.i.d.'s².

The model in Equation 2 states that the current signal strength value (s_t) is a linear aggregate of the previous signal strength value (s_{t-1}) and an independent noise value (v_t). The parameter α gives flexibility to the model as it can be used to determine the degree of autocorrelation of the original process. For example, if α is zero, the samples of the process s_t are i.i.d.'s, whereas if α is one the original samples are identical (autocorrelation=1). In the following subsections we describe some properties of the autoregressive model that we will use in the rest of the paper.

1) *Relation Between the Mean of s_t and v_t* : We can see from Equation 2 that $E(s_t) = E(v_t)$. The two processes have the same mean.

2) *Relation Between the Variance of s_t and v_t* : The relation between the variance of the original and noise processes can be obtained as follows:

$$\begin{aligned} Var(s_t) &= Var(\alpha.s_{t-1} + (1-\alpha).v_t) \\ &= \alpha^2.Var(s_{t-1}) + (1-\alpha)^2.Var(v_t) \quad (3) \\ &\quad (s_t \text{ and } v_t \text{ independent}) \end{aligned}$$

Since the samples of s_t are identically distributed (stationary process), $Var(s_t) = Var(s_{t-1}) = Var(s)$. Therefore equation 3 can be rewritten as:

$$(1-\alpha^2)Var(s) = (1-\alpha)^2.Var(v_t) \quad (4)$$

therefore

$$\begin{aligned} \frac{Var(v_t)}{Var(s)} &= \frac{1-\alpha^2}{(1-\alpha)^2} \\ &= \frac{1+\alpha}{1-\alpha} \end{aligned} \quad (5)$$

3) *Relation Between s_t and s_0* : We start from equation 2.

$$\begin{aligned} s_t &= \alpha.s_{t-1} + (1-\alpha)v_t \\ &= \alpha^2.s_{t-2} + \alpha.(1-\alpha)v_{t-1} + (1-\alpha)v_t \\ &= \alpha^3.s_{t-3} + \alpha^2.(1-\alpha)v_{t-2} \\ &\quad + \alpha.(1-\alpha)v_{t-1} + (1-\alpha)v_t \\ &\vdots \\ &= \alpha^t.s_0 + (1-\alpha).\sum_{i=1}^t \alpha^{t-i}.v_i \end{aligned} \quad (6)$$

²This model is equivalent to the one given in Equation 1.

B. Estimating the Value of α

In this section, we show that α value can be approximated using the autocorrelation coefficient with lag one (r_1). r_1 is estimated from a sample of size N as [15]:

$$r_1 = \frac{\sum_{t=1}^{N-1} [s_t - \bar{s}].[s_{t+1} - \bar{s}]}{\sum_{t=1}^N [s_t - \bar{s}]^2} \quad (7)$$

where $\bar{s}$ is the expected value of process s .

For large values of α (close to one), Equation 2 can be approximated as:

$$s_t \approx \alpha.s_{t-1} \quad (8)$$

Substituting Equation 8 in Equation 7 yields:

$$\begin{aligned} r_1 &\approx \frac{\sum_{t=1}^{N-1} [s_t - \bar{s}].[\alpha.s_t - \bar{s}]}{\sum_{t=1}^N [s_t - \bar{s}]^2} \\ &\approx \frac{\sum_{t=1}^{N-1} [s_t - \bar{s}].[\alpha.(s_t - \bar{s}) - (1-\alpha).\bar{s}]}{\sum_{t=1}^N [s_t - \bar{s}]^2} \quad (9) \\ &\approx \frac{\alpha.\sum_{t=1}^{N-1} [s_t - \bar{s}]^2}{\sum_{t=1}^N [s_t - \bar{s}]^2} \quad (\alpha \text{ close to } 1) \end{aligned}$$

For large N , Equation 9 can be rewritten as:

$$r_1 \approx \alpha \quad (10)$$

Therefore for a large value of α and N , as is the case here, α can be estimated using the autocorrelation coefficient with lag one.

C. Distribution of the Average of n Correlated Samples

In this section, we obtain the mean and variance of the samples of a new process whose samples are the average of n samples from the original process.

1) *Mean of the Distribution of the Average of n Samples*: We use $A(n)$ to denote the random variable whose value is the average of n samples (from $t = 0$ to $t = n - 1$) of the original process s_t , $n > 1$. Since

$$A(n) = \frac{1}{n}.\sum_{j=0}^{n-1} s_j \quad (11)$$

therefore, $E(A(n)) = E(s_t)$. The mean of the distribution of the average of n samples is the same as the mean of the distribution of each sample.

2) *Variance of the Distribution of the Average of n Samples*: From equation 6, $A(n)$ can be written as:

$$\begin{aligned} A(n) &= \frac{1}{n} \sum_{j=0}^{n-1} \left\{ \alpha^j \cdot s_0 + (1-\alpha) \cdot \sum_{i=1}^j \alpha^{j-i} \cdot v_i \right\} \\ &= \frac{1}{n} \cdot \left\{ \frac{1-\alpha^n}{1-\alpha} \cdot s_0 + (1-\alpha) \cdot \sum_{j=1}^{n-1} \sum_{i=1}^j \alpha^{j-i} \cdot v_i \right\} \end{aligned} \quad (12)$$

therefore,

$$\begin{aligned} \text{Var}(A(n)) &= \frac{1}{n^2} \cdot \left\{ \left(\frac{1-\alpha^n}{1-\alpha} \right)^2 \cdot \text{Var}(s_0) \right. \\ &\quad \left. + (1-\alpha)^2 \cdot \sum_{j=1}^{n-1} \sum_{i=1}^j \alpha^{2 \cdot (j-i)} \cdot \text{Var}(v_i) \right\} \end{aligned} \quad (13)$$

from equation 5

$$\begin{aligned} \text{Var}(A(n)) &= \frac{\text{Var}(s_0)}{n^2} \cdot \left\{ \left(\frac{1-\alpha^n}{1-\alpha} \right)^2 \right. \\ &\quad \left. + (1-\alpha)^2 \cdot \sum_{j=1}^{n-1} \sum_{i=1}^j \alpha^{2 \cdot (j-i)} \right\} \\ &= \frac{\text{Var}(s_0)}{n^2} \cdot \left\{ \left(\frac{1-\alpha^n}{1-\alpha} \right)^2 \right. \\ &\quad \left. + (1-\alpha)^2 \cdot \sum_{j=1}^{n-1} \frac{1-\alpha^{2 \cdot j}}{1-\alpha^2} \right\} \\ &= \frac{\text{Var}(s_0)}{n^2} \cdot \left\{ \left(\frac{1-\alpha^n}{1-\alpha} \right)^2 + n-1 \right. \\ &\quad \left. - \alpha^2 \cdot \frac{1-\alpha^{2 \cdot (n-1)}}{1-\alpha^2} \right\} \end{aligned} \quad (14)$$

Since s_t is a stationary process, $\text{Var}(s_0) = \text{Var}(s)$ and the final relation between $\text{Var}(A(n))$ and $\text{Var}(s)$ is:

$$\text{Var}(A(n)) = \frac{\text{Var}(s)}{n^2} \cdot \left\{ \left(\frac{1-\alpha^n}{1-\alpha} \right)^2 + n-1 - \alpha^2 \cdot \frac{1-\alpha^{2 \cdot (n-1)}}{1-\alpha^2} \right\} \quad (15)$$

Note that when $\alpha = 0$ (i.e. the samples of s_t are independent), Equation 16 reduces to:

$$\text{Var}(A(n)) = \frac{\text{Var}(s)}{n} \quad (16)$$

Figure 4 shows the ratio between the variance of the averaging process and original process for different values of α and n . The variance of the averaging

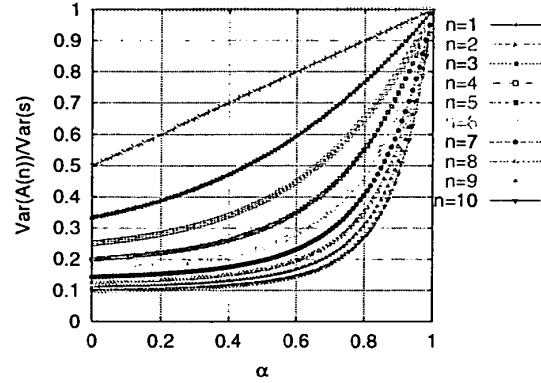


Fig. 4. Ratio between the variances of the averaging process and the original process for different values of α and n

process, $\text{Var}(A(n))$, is always less than or equal to the variance of the original process, $\text{Var}(s)$, being equal in case α equals one or if the signal strength samples are independent. Intuitively, the lower the variance of the signal strength distribution at each location, the better the ability to discriminate between different locations and the better the accuracy.

D. Modified Horus Algorithm

In this section, we use the results of the previous section to obtain the distribution of the average of n correlated samples. We use this value to determine the most probable user location. We assume that the *Horus* system is running in the parametric mode where the signal strength distribution follows a *Gaussian* distribution [3], [12], [13]. Since the individual distribution of each sample follows a *Gaussian* distribution, the probability distribution of the average of n samples follows a *Gaussian* distribution whose mean and variance can be obtained using the results in Section V-C.

The technique works as follows:

- *Offline phase*: the system calculates the parameters of the distribution of the average of n samples for each access point in the radio map.
- *Online phase*: Given n samples from an access point, the algorithm obtains their average and calculate the probability of each radio map location given this value of the average using the distribution of the average of n samples calculated during the offline phase.

Algorithm 2 shows the details of the modified *Horus* algorithm. Note that the value of α is implicitly used

in the online phase as the distribution of the average of n samples depends on the value of α as discussed in Section V-C.

Alg. 2 $x = \text{Corr\_Horus\_GetLocation}(n, S, \mathbb{X}, RM)$

Input:

n : Number of samples from each access point.
 S : Measured signal strength vectors from k access points ($S = (\bar{s}_1, \dots, \bar{s}_k)$). Each $\bar{s}_i, 1 \leq i \leq k$ is a vector containing n samples from access point i .
 $\mathbb{X}$: Radio map locations.
 RM : A radio map based function, where $RM(s_a, a, x)$ returns the probability of the average, of the n samples received from access point a at location $x \in \mathbb{X}$, being s_a .

Output:

The location $x \in \mathbb{X}$ that maximizes $P(x/S)$.

```

1: for  $i = 1..k$  do
2:    $Avg(i) \leftarrow \text{average}(\bar{s}_i)$ 
3: end for
4:  $Max \leftarrow 0$ 
5: for  $l \in \mathbb{X}$  do
6:    $P \leftarrow \prod_{i=1}^k RM(Avg(i), i, l)$ 
7:   if  $P > Max$  then
8:      $x \leftarrow l$ 
9:      $Max \leftarrow P$ 
10:  end if
11: end for

```

VI. EXPERIMENTAL EVALUATION

In this section we present the result of implementing the correlation handling technique in the context of the *Horus* system.

A. Experimental Testbed

We performed our experiment in the south wing of the fourth floor of the Computer Science Department building. The layout of the floor is shown in Figure 5. The wing has a dimension of 224 feet by 85.1 feet. The technique was tested in the Computer Science Department wireless network. The entire wing is covered by 12 access points installed in the third and fourth floors of the building.

For building the radio map, we took the radio map locations on the corridors on a grid with cells placed 5 feet apart (the corridor's width is 5 feet). We have a total of 110 locations along the corridors. On the average,

each location is covered by 4 access points. The value of α , autocorrelation degree, for these access points was approximately 0.9 for all access points.

Using the device driver and the API we developed [17], we collected 300 samples at each location, one sample per second. The cards used were Lucent Orinoco silver NICs supporting up to 11 Mbit/s data rate [18]. To test the performance of the system, we used an independent test set that was collected on different days, time of day, and by different persons than the training set.

B. Results

We start by showing the effect of the wrong independence assumption on the performance of the original *Horus* system. Figure 6 shows the average distance error for different values of n . We can see that averaging can significantly improve performance (average error decreases by about 2 feet from $n = 1$ to $n = 2$). However, as the number of averaged samples increases, the performance degrades. The minimum value at $n = 2$ can be explained by noting that there are two opposing factors affecting the system accuracy:

- 1) as the number of averaged samples (n) increases, the accuracy of the system should increase.
- 2) as n increases, the estimation of the distribution of the average of the n samples becomes worse due to the wrong independence assumption.

At low values of n ($n = 1, 2$) the first factor is the dominating factor and hence the accuracy increases. Starting from $n = 3$, the effect of the bad estimation of the distribution becomes the dominating factor and accuracy degrades.

Figure 7 shows the average distance error for different values of α and n . The figure shows that as the value of α , used in calculating the parameters of the distribution of the average of n samples, approaches the true α value (0.9), the system accuracy increases.

Note that at low values of α averaging more samples leads to worse accuracy, as shown in Figure 7, till we reach a switch-over point at about $\alpha = 0.4$ where averaging more samples starts to give better accuracy. Using the modified technique, the system can achieve an average accuracy of about 2.15 feet, better than the original system by more than 2.4 feet.

VII. DISCUSSION AND CONCLUSIONS

The main contribution of this paper is three fold:
(a) We applied the time series analysis techniques to modelling the behavior of signal strength samples from

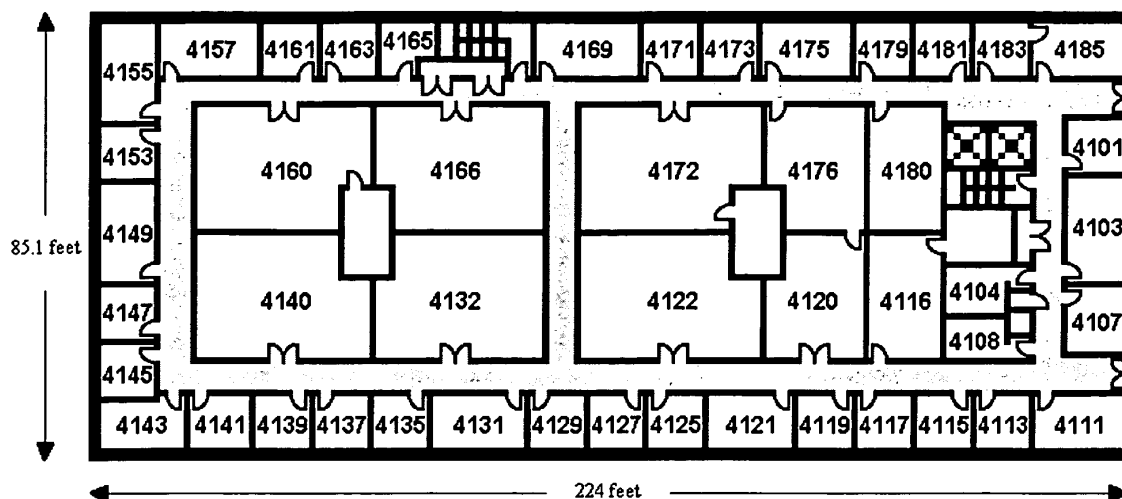


Fig. 5. Plan of the south wing of the 4th floor of the Computer Science Department building where the experiment was conducted. Readings were collected in the corridors (shown in gray).

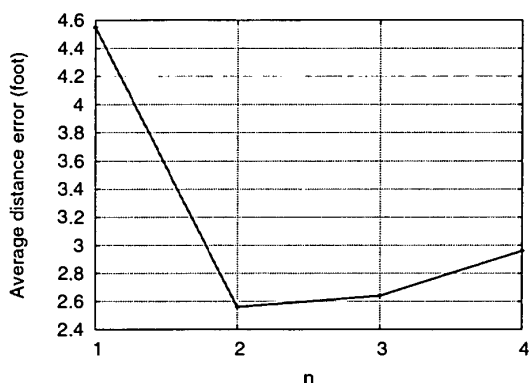


Fig. 6. Effect of the wrong independence assumption on the average distance error. As the number of averaged samples increases, the average system error increases.

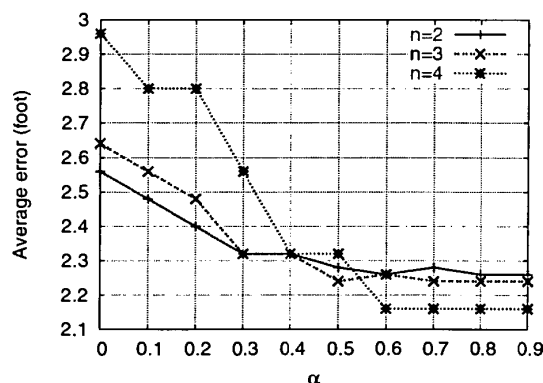


Fig. 7. Average distance error for different values of α and n . As the value of α approaches the true value of 0.9, the system performance increases. The case for $n = 1$ (original *Horus* system performance) is shown in Figure 6 for clarity.

an access point, (b) we presented a technique that uses multiple samples from the same access point, taking high correlation into account, to enhance the accuracy of probabilistic WLAN location determination systems, and (c) we analyzed the performance of the proposed technique by implementing it in the context of the *Horus* system.

We showed that the samples autocorrelation can be as large as 0.9 and therefore it becomes crucial to take this high autocorrelation into account when designing

location determination algorithms that use more than one sample. We described an autoregressive model to capture the autocorrelation between samples from the same access point, showed how to estimate its parameters, and derived some useful properties of the model.

Based on the autoregressive model, we presented a technique that uses the average of n samples from the same access point, taking samples autocorrelation into account, to enhance the accuracy of the *Horus* system.

The results show that the average distance accuracy is enhanced by more than 2.4 feet (50%) using the modified technique. Assuming independence of samples leads to degraded accuracy as the number of averaged samples increases since the estimate distribution of the average of n samples becomes worse with increasing n .

For the proposed technique, as n increases the accuracy of the system is enhanced. However, a side effect of this increased accuracy is that the latency of calculating the location estimate increases with the increase of the number of samples required. In general, we have a trade-off between the accuracy required and the latency of location estimate. The higher the required accuracy, the higher n and the higher the latency to obtain the location estimate. This decision is dependent on the application in use.

Latency can be reduced by presenting the location estimate incrementally using one sample at a time. The system need not to wait till it acquires the n samples all at once. Instead, it can give a more accurate estimate of the location as more samples become available by reporting the estimated location given the partial samples it has. In this mode, the system can be incorporated with a physical-location space moving averaging method to further enhance the accuracy.

The computational overhead of the modified technique is minimal. The system calculates the parameters of the distribution of the average of n samples in the offline phase, which is done only once. The only additional requirement in the online phase is calculating the average which involves n addition operations and one division. This is amortized over the number of locations in the radio map.

We believe that the model and the technique presented in the paper are general and can be applied to other probabilistic WLAN location determination techniques to enhance their accuracy.

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Integrated Link Adaptation and Power Control for Wireless IP Networks

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Abstract: In this paper, we prove that the problem of maximizing data throughput by adaptive modulation and power control while meeting packet error requirements is NP-complete. A heuristic algorithm for integrated link adaptation and power control is thus proposed to achieve specified error rates and to improve overall throughput for real-time applications in wireless IP networks. The algorithm divides terminals into groups according to their signal path gains, and periodically adapts transmissions based on the required error rates, actual error statistics and average transmission power of each terminal group. Transmission power is adjusted by an enhanced Kalman-filter method to ensure successful reception. Simulation results reveal that the algorithm consistently delivers the specified error performance, and attempts to maximize network throughput for a wide range of parameter settings.

1. INTRODUCTION

As telecommuting and Internet access become increasingly popular, customers' demand for broadband network services has been growing significantly. In the very near future, broadband services are also expected to support real-time, multimedia services such as voice, image and video. Wireless access is one of the approaches to providing such services. In particular, the ETSI is in the process of establishing the protocol standards for the Enhanced Data rates for GSM Evolution (EDGE) system as the third generation wireless network for high-speed services.

Using packet-switching technology, and multiple modulation and coding levels, the EDGE system employs a link-adaptation technique to adapt packet transmission to one of six coding levels [E98] (a current proposal has nine modulation and coding levels [E99]), where the highest data rate can exceed 550 Kbits/sec. The main idea of link adaptation is to adapt the modulation and coding levels according to the channel and interference conditions in order to improve data throughput. For example, when the channel and interference conditions are poor, a low modulation level (i.e., few information bits per symbol) and/or heavy coding should be used in a packet transmission to enable correct signal detection. On the other hand, if the channel situations are favorable, high modulation level and/or light coding can be used to increase data rate.

Due to unreliable radio links, it is challenging to ensure quality of service (QoS) in terms of packet error rate (PER) in the wireless networks. For real-time services such as IP voice, music and video, stringent delay requirements severely limits or even precludes retransmission of lost packets. Thus, tight delay requirements often translate into stringent requirements for PER. As a result, in order to support such real-time services, it is important to design the wireless networks such that the required QoS can be delivered to users.

Evidently, link adaptation is helpful in delivering the QoS. Specifically, when the channel condition is poor, transmitters can lower modulation levels to decrease the requirements of signal-to-interference-plus-noise ratio (SINR) for correct signal detection. Lowering SINR requirements increases the probability of successful reception, thus helping to meet the PER objective. However, especially for interference-limited systems with sufficient traffic load, adapting even to the lowest modulation level may not always guarantee meeting the specified PER. In this case, increasing transmission power can improve signal strength and thus the SINR at the receivers. Hence, one can view power control as performing an active role in delivering the expected PER to users, while adaptive modulation plays a passive (or reactive) role. As discussed further below, the complementary roles of power control and link adaptation give us a very efficient approach to providing the required QoS to users. With this understanding, a key design problem for a wireless packet network like the EDGE system is: *how to maximize the overall network throughput over the choice of modulation and coding levels, and transmission power, subject to meeting given PER requirements.* In this paper, we propose and analyze an integrated algorithm of link adaptation and power control for the problem.

Our recent work [LW99] and [LW00] on integrated power control and link adaptation represent our initial attempts in solving the problem. In particular, the proposed algorithm in [LW00] chooses the modulation and power level according to a power-stability criterion (to maintain stable transmission power in a long run). In this work, we find that the use of the stability criterion is actually unnecessary, when the link adaptation and power control operate based on the measured PER at the receivers and their requirements, provided that a feasible setting of modulation and power levels exists to support

the required PER in the network under consideration. This is so because monitoring and controlling the PER performance by the link adaptation and power control implicitly force transmission power to fall within a given dynamic range. Indeed, the algorithm proposed in this paper is based on monitoring the PER performance.

Let us briefly review other work on power control and link adaptation. Power control has been widely studied to combat interference in wireless networks; see e.g., [Z92], [RZ98] and [UY98]. Recently, [L99] proposes a Kalman-filter method for power control in packet-switched time-division-multiple-access (TDMA) networks. An enhanced version of the Kalman-filter method is used to control transmission power here. Much work on link adaptation by adaptive modulation has been done for fading channels; see for example, [GC97] and [AG98]. By considering interference-limited systems, [QC99a] shows that the overall network throughput can be maximized by adaptive modulation and power control. Recently, [C99] and [QC99b] propose new adaptation schemes to improve overall data throughput for non-real-time data services. However, the use of link adaptation to deliver the specified QoS for real-time, multimedia applications is an open issue, which is the topic to be addressed in this paper. Furthermore, we examine how power control, which is not considered in [C99] and [QC99b], is integrated with link adaptation for performance improvement.

The rest of this paper is organized as follows. We first present the operations and power control for the wireless packet networks under consideration in Section 2. In Section 3, we prove that the problem of maximizing network throughput while meeting the given PER requirements is NP-complete. That is, no efficient algorithm for solving the problem exists. Then, a new algorithm for integrated link adaptation and power control based on monitoring PER performance is proposed in Section 4. In Section 5, we study the performance of the proposed algorithm by simulation. Finally, Section 6 presents our conclusion.

2. NETWORK OPERATIONS AND POWER CONTROL

Consider a packet-switched TDMA network with data rates up to several megabits per second, link lengths (or cell radius) typically less than 10 kilometers and operating frequency in the range of 1 to 5 GHz. Assume that the TDMA network supports IP in a way that each data message (e.g., an email) is divided into a number of packets, each of which can be transmitted in one time slot. Similar to other IP networks, when a transmitter (either a mobile terminal or a base station) sends a message, all its packets are transmitted in contiguous time slots. Similar to the EDGE system, the network under consideration allows transmitters to choose one of M combinations of modulation and coding levels for transmission in each time slot, according to the link-adaptation algorithm in use. In

this study, the key effect of using different modulation and coding levels is a change of SINR requirement for correct data reception. Thus, for brevity, we refer to the adaptation of modulation and coding levels simply as adaptive modulation here. Further, although the algorithm for integrated power control and adaptive modulation to be proposed below is applicable to both uplink (from terminal to base station) and downlink (from base station to terminal), our discussion will focus on the uplink transmission here.

The enhanced Kalman-filter method [L00] is used to control transmission power. That is, the transmission power for time slot n is set to be

$$p(n) = \gamma^* \delta(n) \tilde{i}(n) / g(n) \quad (1)$$

where γ^* is the SINR target for the chosen modulation level, $i(n)$ is the interference-plus-noise power (mW) in slot n predicted by the Kalman filter, $\delta(n)$ is an error margin (to be discussed further below), and $g(n)$ is the (estimated) path gain between the terminal that transmits in slot n and its base station.

The error margin $\delta(n)$ is obtained by tracking the accuracy of the interference power predicted by the Kalman filter. More precisely, let Δ (a random variable in dB) be the error of the Kalman-filter prediction and the error for slot n be

$$E(n) = I(n) - \tilde{I}(n) \quad (2)$$

where $I(n)$ and $\tilde{I}(n)$ are the measured and predicted interference-plus-noise power in dBm for slot n , respectively. Based on the $E(n)$'s, we approximate the cumulative probability function (CDF) for Δ . Towards this end, let there be J intervals of prediction error and the range of the j^{th} interval be $(a_j, a_{j+1}]$. For each time slot $n > 0$ and each $j = 1$ to J , compute the following

$$P_n^j = \begin{cases} \phi P_{n-1}^j & \text{if } E(n) > a_{j+1} \\ \phi P_{n-1}^j + 1 - \phi & \text{otherwise} \end{cases} \quad (3)$$

where ϕ is a properly chosen parameter between 0 and 1, and $P_0^j = 1$ for all $j = 1$ to J . Let $\Delta(n)$ be a specified ω^{th} percentile (e.g., for 90th percentile, $\omega = 0.9$) of Δ based on the error statistics up to slot n . We approximate $\Delta(n) \approx a_k$ where k is the smallest from 1 to J such that $P_n^k \geq \omega$. Let $\delta(n)$ and $i(n)$ be the linear-scale equivalent of $\Delta(n)$ and $I(n)$, respectively. The corresponding percentile of the interference-plus-noise power in mW is the product of $i(n)$ (predicted by the Kalman filter) and $\delta(n)$. Accordingly, the transmission power for slot n is determined by (1).

In essence, the term $\delta(n)$ represents an error margin, which depends on the accuracy of the interference prediction by the Kalman filter and the specified confidence probability ω . Nevertheless, the error margin is chosen dynamically and appropriately with a goal of delivering the SINR target γ^* regardless of the actual message length and control delay. See [L00] and [L99] for details of the Kalman method.

3. PROBLEM COMPLEXITY

In this section, we prove that a simple form of the problem of maximizing network throughput subject to meeting a given PER requirement posed in Section 1 is NP-complete [GJ79]. More precisely, let the system have N terminals in N different co-channel sectors concurrently transmitting packets to their base stations (i.e., having N radio links) at each time slot. The modulation level and power for link i at a given slot are denoted by L_i and p_i , respectively. Let there be M modulation levels, indexed by 1 to M , and K discrete levels of transmission power, denoted by real numbers t_i for $i = 1$ to K . As a result, for each i , $L_i \in \{1, 2, \dots, M\}$ and $p_i \in \{t_1, t_2, \dots, t_K\}$. For simplicity, the data rate and the required SINR detection threshold for link i are assumed to be αL_i and βL_i , respectively, where α and β are proportionality constants. Let $\mathbf{L} = (L_1, L_2, \dots, L_N)$ and $\mathbf{p} = (p_1, p_2, \dots, p_N)$. Using this notation, the problem of maximizing the overall throughput λ for each time slot is:

$$\max_{\mathbf{L}, \mathbf{p}} \lambda = \sum_{i=1}^N \alpha L_i \quad (4)$$

$$\text{subject to } \frac{g_{ii} p_i}{\sum_{j \neq i} g_{ij} p_j + \sigma} \geq \beta L_i \text{ for all } i = 1 \text{ to } N \quad (5)$$

where g_{ij} is the path gain from the transmitter of link j to the receiver of link i and σ is the receiver noise power. We note that the above SINR constraints are used to represent the PER requirement for the chosen modulation level. Further, the throughput is maximized for each time slot. For the packet-switching networks under consideration, the values of g_{ij} 's in (5), and thus the optimal $\mathbf{L}$ and $\mathbf{p}$ change from one time slot to another. However, the optimization in (4) is also valid for circuit-switching wireless networks where these quantities are independent of time.

Theorem 1. *The problem of maximizing the overall throughput in (4) subject to the SINR (or equivalently PER) requirement in (5) is NP-complete.*

Proof. The optimization problem (4) is nonlinear due to the products of p_j 's and L_i 's in (5). Let $Q_{ij} = L_i p_j$ for all $i, j = 1$ to N . Thus, $Q_{ij} \in \{t_1, \dots, t_K, 2t_1, \dots, 2t_K, \dots, Mt_1, \dots, Mt_K\}$. Since Q_{ij} 's are finite, real numbers, we can express each Q_{ij} in terms of binary (zero or one) variables X_{ijk} 's as $Q_{ij} = \sum_{k=a_{ij}}^{\bar{a}_{ij}} X_{ijk} 2^k$ where a_{ij} and $\bar{a}_{ij}$ are properly chosen integers according to the accuracy tolerance of the binary representation. Similarly, we express $L_i = \sum_{k=b_i}^{\bar{b}_i} Y_{ik} 2^k$ and $p_i = \sum_{k=c_i}^{\bar{c}_i} Z_{ik} 2^k$. Consequently, (4) becomes a nonlinear zero-one integer programming problem. Now, we apply the technique in [C69] to linearize the problem by introducing new variables to replace the cross-product terms. Then, the proof is completed by using the fact that the resultant, linear integer programming is NP-complete [GJ79, p.245]. $\square$

As the optimization problem is NP-complete, it is unlikely that any efficient algorithm may exist. Thus, we choose to devise a heuristic approach in the following with a primary goal of delivering the specified PER and maximizing the network throughput as a secondary objective.

4. INTEGRATED LINK ADAPTATION AND POWER CONTROL

There are two key factors for efficient link-adaptation schemes. First, to maximize the network throughput, it is desirable to have a link-adaptation technique that adapts quickly to changes of radio conditions. On the other hand, to guarantee the required PER, it is advantageous to adapt the link according to the actual error performance. Since error statistics require a long time to accumulate, link adaptation based on per-user error performance will be too slow in responding to changes of channel conditions. As a compromise, we propose to divide all terminals in each co-channel sector into groups and to perform link adaptation on a per-terminal-group basis according to the error performance of each group. This way, the statistics collection time can be shortened significantly, thus enabling quick link adaptation to improve data throughput while meeting the error requirements.

4.1 Terminal Grouping by Signal Path Gains

The quality of a radio link between a terminal and its associated base station can typically be characterized by three parameters: the signal path gain (including shadow fading), and signal transmission and interference power. In the packet networks under consideration, both transmission and interference power change constantly. In our view, signal path gain is the most intrinsic parameter for link quality. So, we propose to use the signal path gain as a criterion for the terminal grouping. Terminals of the same group are expected to have similar link quality, and cause similar amount of interference to others.

Another supporting reason for using signal path gain as the grouping criterion is that signal and interference path gains are almost uncorrelated. To illustrate our idea, consider the cellular layout and channel assignment of frequency reuse factor of 2 in Figure 1 [WL99], where 2,000 terminals are randomly populated at fixed locations in each cell. With typical radio propagation assumptions (see Section 5 for details), we examined the relationship between the signal path gain (shadowing included) from a terminal to its associated base station and the sum of path gains from the terminal to all other co-channel base stations, which receive interference from the terminal for uplink transmission. The sum of interfering path gains reflects the potential impacts of interference caused by the terminal. It is found that the signal path gain and the sum of interfering path gains have a very small correlation coefficient of 0.018. Such uncorrelated relationship is desirable for our purposes. Otherwise, if it is a strong positive correlation, the link adaptation based on such a

terminal group basis may make unstable changes of modulation level.

One way to perform the terminal grouping is to determine the range of the signal path gain for a given network. Then, the range is divided into several (not necessarily uniform) regions. Terminals with corresponding signal path gain in each region form a group. To speed up the collection of error statistics uniformly, it is desirable to have a roughly equal number of terminals in each group. As a natural candidate, the number of terminal groups can be chosen to be equal to the number of modulation levels in the system such that each group may be transmitting or receiving at a distinct modulation level. Of course, the number of groups should be selected based on the number of active terminals; too few terminals per group will defeat the purpose of terminal grouping in terms of shortening the statistics collection time.

4.2 Adaptation Algorithm by Terminal Grouping

The new algorithm for link adaptation and power control for uplink transmissions is outlined below (while similar operations apply to downlink):

1. For each co-channel sector, its base station continuously collects the error statistics, and computes the PER P_E for every K packet transmissions from terminals of each group. In addition, it keeps track of the average transmission power $\bar{p}$ of the K packet transmissions, regardless of their modulation levels, for each terminal group.
2. This step is taken every time after K packets have been transmitted by terminals of the same group. If P_E is higher than the required value P_R , adjust the modulation level down by one level for the next K packet transmissions by terminals in the group. The purpose is to lower the required SINR for correct reception, thus improving the PER when needed. Further, if $\bar{p}$ is less than a given threshold p_t (e.g., 15 dBm), step up the modulation level by one level for the next K transmissions from the terminal group. The idea there is to utilize unused power to increase data rate, if possible.
3. To achieve the PER requirement, each modulation level is associated with a nominal SINR target. Using the enhanced Kalman-filter power control in Section 2, adjust the transmission power for each time slot to achieve the SINR target for the adapted modulation level.
4. For each terminal, the SINR target is adjusted periodically and relatively slowly (i.e., similar to the CDMA outer-loop power control) to ensure required error performance for individual terminals.

5. PERFORMANCE STUDY

5.1 Simulation Model

We use computer simulation to study the performance of the proposed algorithm for link adaptation and power control based on the terminal grouping, which is referred to as the terminal-grouping method below. The cell layout and interleaved channel assignment (ICA) with a frequency reuse factor of 2 [WL99] in Figure 1 is simulated. Each cell is divided into 4 sectors, each of which is served by a base station antenna at the center of the cell. The beamwidth of each base station antenna is 60° , while terminals have omnidirectional antennas. Each radio link between a terminal and its base station is characterized by a path-loss model with an exponent of 4 and lognormal shadow fading with a standard deviation of 8 dB. Fast fading is not considered in this study. Cell radius is assumed to be 1 Km and the path loss at 100m from the cell center is -70 dB. Thermal noise power at the receiver is fixed and equal to -110 dBm. Each sector is populated with 500 terminals randomly and each of them selects the base station that provides the strongest signal power. For convenience, terminals in all cells are assumed to be synchronized at the slot boundary for transmission. Furthermore, unless stated otherwise, we assume 100% traffic load in this study; that is, there are always terminals ready for transmission in each co-channel sector. Message length is assumed to be Pareto distributed with an average of 10 packets [L99].

The enhanced Kalman-filter method outlined in Section 2 is used to control transmission power for each time slot. For tracking the CDF of the prediction error Δ , ϕ in (3) is set to be 0.999 (approximately equal to tracking the error over a sliding window of 1,000 slots) and the number of error intervals J is 100. For a given PER requirement P_R , the ω^{th} percentile of the prediction error with $\omega = 1 - P_R$ is used in determining the error margin $\delta(n)$ for adjusting power in (1). For example, when $P_R = 0.02$, $\delta(n)$ is the 98th percentile of the prediction error. In any event, transmission power is limited between 0 to 30 dBm. The average power threshold, p_t , for determining stepping up the modulation level in Step 2 of the algorithm is 15 dBm. Two adjustable parameters for the Kalman-filter method, W and η , are set to be 30 and 0.5, respectively. The model also assumes that interference power in one time slot can be measured accurately and used to determine the power for the next slot.

We assume that the system has 6 modulation levels. The SINR detection requirements and the corresponding data throughput for each modulation level are given in Table 1. For example, for a packet transmission using modulation level 1, if the SINR at the receiver is greater than 10 dB, the packet is received successfully and the data throughput is 22.8 Kbps. Naturally, the SINR requirements are also used as the targets γ^* for various modulation levels to control power in (1). For simplicity, slow adjustment of SINR targets for individual terminals in Step 4 of the algorithm is not

considered in the simulation. Parameters in Table 1 are actually adapted from Table 3 and estimated from Figure 20 of [E98]. With 6 modulation levels, all 500 terminals in each sector are divided into 6 groups of equal size according to their signal path gain. Initially, the group with the weakest to the strongest signal path gain uses modulation level 1 to 6 for transmission, respectively. Then, according to the algorithm, the modulation level is re-adapted every $K=1,000$ packets transmitted by each terminal group. For each parameter setting, the simulation model was run for 0.4 million time slots and performance results presented below were obtained for the middle cell in Figure 1.

5.2 Performance Results and Discussions

To set up a basis for comparison, we consider a simple link-adaptation scheme without power control (PC) that chooses the modulation level according to the SINR measurement of the previous time slot. Specifically, the scheme compares the SINR measurement with the detection requirements in Table 1. For example, when the measurement lies between 12 and 16 dB, modulation level 2 is used for transmission in the next time slot. Every sector makes such selection for its transmitting terminal independently. This SINR scheme is referred to as *Case A* in Table 2. Cases B to D are identical to Case A, except that the enhanced Kalman method is now used to control transmission power according to the various PER requirements P_R . To help us understand the algorithm characteristics, Cases E to G correspond to the link-adaptation method by terminal grouping without power control, while Cases H to J represent our proposed algorithm. Table 2 presents the throughput, the PER for packets transmitted at different modulation levels, and the overall PER averaged over all levels for these cases.

First of all, we observe from the table that when power control is not used, Cases A and E to G for both the SINR and terminal-grouping methods cannot control the PER effectively. For the SINR method, it is so because the previous SINR measurements may not accurately predict SINR performance in future time slots because of the burstiness of packet transmission in the wireless packet environment. As a result, the chosen modulation level may not lead to successful packet reception as the radio conditions can change drastically in time. As for Cases E to G, the terminal-grouping method adapts the modulation level according to the requirement P_R . However, the scheme is not effective in delivering the PER performance because the link adaptation takes place only periodically and the radio conditions can vary significantly from one time slot to another during the adaptation period.

As the results for Cases B to D show, the SINR scheme with the enhanced Kalman power control is still not quite effective because SINR measurements may not accurately reflect future link quality. In contrast, according to the specified PER requirement P_R , the proposed algorithm adapts transmissions at appropriate modulation levels, and adjusts transmission power to

meet the SINR detection threshold. Consequently, as shown in Table 2, the PER performance for Cases H to J generally comes very close to the PER target P_R . One can observe that the PER for transmission at modulation level 1 in Case H is noticeably higher than the required 2% PER. This reveals that the radio conditions may not support the very stringent PER performance for a very small fraction of terminals. In any event, the overall PER of 2.7% is very close to the target of 2% in that case. As intuitively expected, when P_R becomes stringent, the throughput is reduced in Cases H to J. For comparison, we also include results for Method D in Table 2 of [LW99] as Case K here. Despite differences in the link adaptation algorithms, the error performance for Case K is very similar to that of Case H. However, the new algorithm proposed here yields about 10% more throughput than that reported in [LW99]. Furthermore, our extensive testing shows that the new algorithm is more robust in delivering desirable performance for a wide range of settings than the previous one.

It is important to point out that the ability to control the PER to meet the specified targets by the proposed algorithm comes at a price of reduced throughput. In fact, this represents an interesting tradeoff between maximizing throughput and controlling PER performance. For example, one can see from Table 2 that the SINR method in Cases A to D yields almost 1/3 more throughput than Cases H to J of the terminal-grouping method. Nevertheless, to meet the PER requirements for specific applications, network designers can use the integrated algorithm for power control and link adaptation to achieve a desirable tradeoff between the PER and throughput.

Finally, we studied the packet error and throughput performance of the proposed algorithm with partial traffic loading. For a given loading, after a terminal completes a message transmission, its associated sector remains idle for a random number of time slots before a next terminal in the sector is allowed to start a new message transmission. The duration of an idle period is geometrically distributed and its average is determined according to the average message length and the traffic loading. We measured the actual PER and throughput of the proposed algorithm for various target (required) PER and traffic load conditions. Although these results are not presented here due to space limitation, they allow us to make several observations. First, we find that the proposed algorithm indeed can deliver the required PER performance as the measured PER comes very close to the target values. Second, it is interesting to note that the throughput increases as traffic load decreases. This is a very desirable feature because the power control in the proposed algorithm will detect reduced interference power when traffic load decreases, thus lowering the transmission power needed to yield the SINR target γ^* in (1). In turn, comparing the average transmission power with a fixed threshold p , by Step 2 of the algorithm in Section 4.2 will likely step up the modulation level for transmission, which results into increased data throughput. Third, for a given traffic

load, the throughput does not always improve as the target PER is increased (relaxed). Evidently, for very stringent PER requirement, the algorithm will force most of the transmissions using the more robust modulation, which yields a low throughput. On the other hand, when the required PER is too high, the algorithm tends to allow too many packets transmitted using high modulation levels, which result into unsuccessful reception and lowered throughput. For a given traffic load, there appears to be an "optimal" target PER that can maximize the network throughput.

6. CONCLUSIONS

The problem of maximizing data throughput by adaptive modulation/coding and power control while meeting requirements of packet error rate has been shown to be NP-complete. A heuristic algorithm for integrated link adaptation and power control has been proposed to achieve specified error rates while improving overall throughput for real-time applications in broadband wireless networks. The algorithm divides terminals into groups according to their signal path gains, and adapts the transmissions based on the required error rates, actual error statistics and the average transmission power of each terminal group. Transmission power is adjusted by an enhanced Kalman-filter method [L00] to ensure correct reception.

The performance of the proposed algorithm has been studied by computer simulation. Our results reveals that the algorithm delivers the required error performance, and attempts to maximize network throughput. It can further improve throughput when interference is reduced for decreased traffic load. Extensive testing shows that the algorithm is very robust and efficient. By having various packet error requirements, the algorithm is applicable to real-time, multi-media services. The new algorithm can also serve as a useful tool for achieving a desirable tradeoff among throughput, packet error rate and coverage in the networks.

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Table 1. SINR Requirement & Throughput.

Modulation Level	SINR Detection Requirement (dB)	Throughput (Kbps)
1	10	22.8
2	12	34.3
3	16	41.25
4	19	51.6
5	23	57.35
6	28	69.2

Fig.1. A 4-Sector Cell Layout and ICA

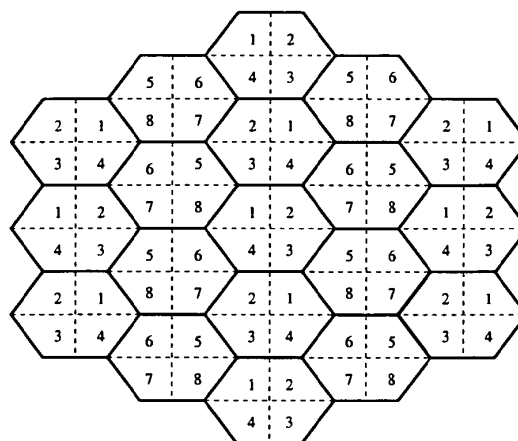


Table 2. Performance Comparison of Link-Adaptation Methods.

Cases	PER for Modulation Levels						Overall PER	Throughput (Kbps)
	1	2	3	4	5	6		
SINR-Based Adaptation Method								
A) Without PC	0.61	0.061	0.092	0.10	0.12	0.10	0.17	44.15
B) Kalman PC ($P_R = 2\%$)	0.59	0.067	0.098	0.10	0.12	0.11	0.16	45.67
C) Kalman PC ($P_R = 5\%$)	0.52	0.050	0.076	0.073	0.090	0.12	0.11	46.87
D) Kalman PC ($P_R = 10\%$)	0.13	0.076	0.088	0.090	0.093	0.083	0.093	39.19
Terminal-Grouping Method for Adaptation								
E) Without PC ($P_R = 2\%$)	0.14	0.012	0.010	0.007	0.018	0.025	0.10	26.88
F) Without PC ($P_R = 5\%$)	0.15	0.026	0.026	0.011	0.017	0.060	0.10	26.88
G) Without PC ($P_R = 10\%$)	0.19	0.045	0.060	0.052	0.026	0.060	0.11	33.34
H) Kalman PC ($P_R = 2\%$)	0.051	0.027	0.023	0.022	0.022	0.018	0.027	35.60
I) Kalman PC ($P_R = 5\%$)	0.061	0.052	0.055	0.050	0.055	0.041	0.053	38.74
J) Kalman PC ($P_R = 10\%$)	0.12	0.097	0.10	0.10	0.10	0.075	0.099	38.79
K) Method D in [LW99]	0.052	0.023	0.031	0.045	0.045	0.028	0.029	32.7

Development and Implementation of a Bluetooth Networking Infrastructure for the a Notebook-University Scenario

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Abstract

In the context of the UbiCampus project, the Notebook-seminar was developed in the Institute of Communications Engineering (Institut für Allgemeine Nachrichtentechnik, IANT) at the University of Hannover. In this seminar the students worked in groups in order to provided a Bluetooth infrastructure for the rooms of the IANT. In this paper the UbiCampus project is described, as well as the most interesting results of the 3 groups that participated in the seminar.

1. Introduction

The first part of this paper is the description of the UbiCampus project and the Notebook Seminar developed in its context

1.1. The UbiCampus Project

The UbiCampus project [1], [2] of the University of Hanover (Universität Hannover, UH) and the medical university Hanover (Medizinische Hochschule Hannover, MHH) is promoted as one of 22 projects in the context of the advertisement Notebook University by the BMBF (Bundesministerium für Bildung und Forschung), with the initiative "Neue Medien in der Bildung" (New Media in Education) [3].

Goal of the UbiCampus project is the development and introduction of mobile multimedia technologies for the interactive presence teaching. The aim is to obtain constructive learning attempts with frequent changes between presentation and independent learning.

In order to do it 4 scenarios are implemented on basis of different interaction samples in the context of pilot attempts.

The 4 scenarios are:

Interaktive Vorlesung (interactive lecture) - lecture introduction to the operating systems at the Notebook
Notebook seminar - autonomous development of a project task

Mobile Projektgruppe(Mobile project group) - pair programming in the context of a software project

Zielgruppenoptimierte Veranstaltung (goal group-optimized meeting) - physics for the medical profession and biomedical technology

These 4 scenarios will be implemented during the course of the project, integrated in the normal learning process in the scope of the pilot attempts and finally evaluated.

A new learning style is proposed, which results from the permanent use of the Notebook. It becomes the central and continuously available medium of the study, which use goes clearly beyond the previous occasional one of the stationary computers. It concerns not only the access to teaching and learning materials, but particularly around the extension on the interaction by direct computer access and simulations. Furthermore the interactive co-operation between the students within a team plays an important role.

1.2. The Notebook-Seminar

One of the 4 scenarios to be implemented in the UbiCampus project is the Notebook-seminar, which has been developed in the Institute of Communications Engineering.

The educational objective was to achieve with an independent work of the project tasks both an intensive insight into the Bluetooth technology and to learn the methods of working in a project. Notebooks are used as typical "engineer instrument" to the procurement, preparation and representation of the information. Assistants attend advising and looking after the project realization.

The first seminar took place in the winter semester 2002-2003. In this seminar a Bluetooth infrastructure for the seminar rooms, the labs and the hall area of the IANT had to be designed. The infrastructure

should allow the mobile end-devices (notebooks, PDA's etc.) different services, such as secure mobile and wireless access to inter- and intranet, or the communication between devices among each other (e.g. Broadcast-Function).

The following demands on the project were set:

- In the seminar rooms the network had to be able to be used with enough capacity by at least 25 people simultaneously.
- The temporal use of the Bluetooth infrastructure had to be known, in order to deduct the available services.
- The network should have a good "Quality of Service" to show for itself.
- The network should have a high security standard to enjoy.

To provide these demands the following tasks were formulated:

- a) Provide a total concept for the networking.
- b) Selection and dimensioning of the network elements.
- c) Provide a security concept.

Each of these tasks was developed for one group, each with 4-5 members. The most interesting results are detailed next. Each student worked with his own notebook, and a Bluetooth USB-dongle was provided for each student.

2. Results

Some of the obtained results are the development of a handover concept, the use of Bluetooth to do location and positioning, or the implementation of a program to measure the signal strength and represent.

2.1. Handover Concept

There are different motivations to induce a handover, such as the movement of the user, the results of the measurement of the radio hop, high traffic load or service measurements. To create a concept of handover in Bluetooth the handover method of the other cellular networks can be adjusted and converted.

If the received signal power is too weak, a handover should be induced. We can define a critic handover limit (i.e. Received Signal Strength Indicator (RSSI) = -5), and if the received signal power reaches or exceeds this limit the handover is induced, but the connexion should be maintained.

The criteria to choose a new Access Point (AP) are:

Accessibility: select the Base Station (BS) from which the signal is strongest. For indoor networks the signal strength depends not only on the distance, but also on the objects that are in the room. The signal strength can be the only criterion of the accessibility. An example is represented in Fig.1.

The signal strength of AP1 in the red area is smaller from the one of AP2 because of the object S. However in the green area is stronger than the one from AP2. In the blue area is the signal strength of AP2 under the critical border.

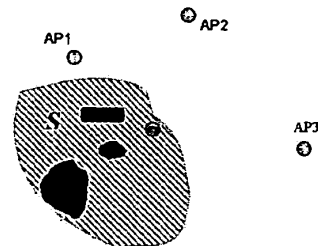


Fig.1: Example of accessibility

Access Point – load: The maximum number of Mobile Stations (MS) that can access at the same time an AP is 7. The effective connecting rate of individual MS is $1Mbit/n$, where n is the number of MS connected to an AP. The more number of MS connected to an AP, the slower is the connection. With the Handover procedure we should select, if possible, an AP with few load.

Distance to the AP: the distance between the BS and the future AP should be as short as possible (more signal strength).

With these 3 criteria a hypothetical decision factor is formulated:

$$h = d \times s \times l$$

Here d is the distance in meter, s is the signal strength in RSSI-RSSI₀ (with RSSI₀ the critic handover limit) and l is the load or number of MS.

Taken into account this decision factor, the algorithm to select a new AP during the handover process is the following:

1. Calculate the actual position of the MS
2. Calculate the decision factor for each AP, and sort the AP according to the obtained valued (The list of AP is obtained at the first connection from the handover agent)
3. Choose the AP with the smallest factor
4. If the selected AP is not accessible, select the next AP. Otherwise completed.

Handover Procedure by Bluetooth: proposed procedure

If the handover conditions are achieved, the MS selects a new AP and sends to the server the measured data and a *Handover Request*.

When the server receives this request writes the data in a table and sends an *Allocation Inquiry* to the preferred AP. If the answer of the AP is positive, the server “breaks” the old connection, creates a new one with the new AP and sends the MS a *Handover Response*. If the answer of the AP is negative, the server search from the table an AP with the lowest decision value and sends an allocation inquiry to it. The process starts again until a new AP is found.

When the MS receives the *Handover Response* from the server according to the connection type there are two possibilities.

With a SCO connection the MS interrupts the transmission with the old AP and creates a new one with the new AP. The MS sends to the server a *Disconnection Acknowledge*, and once the server receives it are transferred the contents of the buffers. After that the server sends a *Ready Response*.

If the connection is ACL, the transmission is broken and the position of the break point is marked. The MS sends to the server a *Disconnection Acknowledge*, and once the server receives it the transmission continues at the marked place. After that the Server sends a *Ready Response*.

If the MS uses LAP, is used the PPP tunnelling, which server is located in the handover-agent. The AP is only responsible for the redirection of the PPP packet. The PPP connection will be retained when the handover occurs.

But if the MS uses PAN, the handover agent has a Routing table, which contains the IP address of the MS of the AP with which is connected AP. After the handover the routing table is updated.

2.2. Location using Bluetooth

The *Received signal Strength Indicator* (RSSI) is defined in order to show whether the received signal strength lies in the golden receiver power rank, so that the transmitter can place their sending achievement. The golden receiver power rank (Fig.2) is defined by two thresholds. The lower threshold level corresponds to the received energy, which has at least 6dB over the actual sensitivity of the receiver, however maximum of -56dBm. The upper threshold level is 20dB over the lower threshold level with an accuracy of ± 6 dB.

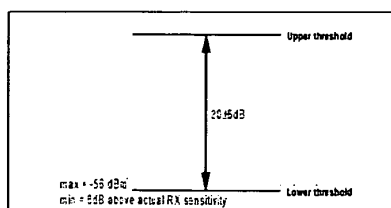


Figure 2: The golden receiver power rank

The RSSI measurement compares the received signal strength with the two thresholds. The command of the HCI-layer *HCI_Read_RSSI* offers the possibility of querying the RSSI. This command returns a positive difference, if the received signal strength lies above the upper threshold of the golden receiver power rank. If it lies under the lower threshold, returns a negative difference. If the received signal strength lies in the golden receiver power rank, a zero is returned.

If we call S the received signal strength, the following equations are determined by the definition of RSSI:

$$S = \text{RSSI} + T_0, \text{ for } \text{RSSI} > 0$$

$$S = \text{RSSI} - T_u, \text{ for } \text{RSSI} < 0$$

$$T_0 = T_u + 20\text{dB}$$

where T_0 designs the upper threshold and T_u the lower threshold of the golden receiver power rank.

In order to determine the distance by means of RSSI it is accepted that there is no obstacle between transmitters and receivers. As a result the following equation is obtained:

$$\text{RSSI}(d) = \text{RSSI}(d_0) + 10\lg(d/d_0), \text{ for } \text{RSSI} > 0$$

$$\text{RSSI}(d) = \text{RSSI}(d_0) + 10\lg(d/d_0), \text{ for } \text{RSSI} < 0$$

From this equation a design for the qualitative relationship between the distance and the RSSI can be provided. The distance where the RSSI is always zero is the golden receiver power rank. Since the RSSI values are constant in this distance, they are not applicable for the computation of the distance. The distance between the transmitter and the receiver can be computed in the ideal case (no obstacle, no reflecting, RSSI not equal 0) with this equation.

To determine the geometrical position of one point, the method of triangulation can be used. Before doing it the positions of several reference points must be determined in a coordinate system, and the distances between the determining goal point to the points of reference must be also measured. But the triangulation method could be a little difficult, and the method of least-square estimation (LSE) will be used.

To define the position of a Bluetooth device (MD) the distances between the MD and a few reference devices (RD) must be measured. The measurement with Bluetooth has however some disadvantages:

First of all, the concept of Bluetooth actually is the replacement of cable between different devices. A Bluetooth equipment has the advantage of low power consumption, which supposes a relative small range

of coverage. This involves the limitation of the measurement to the indoor range.

Secondly Bluetooth does not have an efficient method available for measurement of the signal strength. The Bluetooth specification defines two HCI instructions, *HCI_Read_RSSI* and *HCI_Get_Link_Quality*, which can be used for this purpose. The *HCI_Read_RSSI* instruction returns the difference between the measure of the received signal strength and the delimitations on the golden receiver power rank. The accuracy of the RSSI value depends on the Bluetooth hardware manufacturer. The *HCI_Read_RSSI* instruction always returns zero, which is not used to determine the distance, if the RSSI is in the golden receiver power rank. Unfortunately the golden receiver power rank has a width of 20dB, which is already a large range, where the received signal strength is also optimal for the receivers. For the determination of the distance only the positive and negative RSSI values can be used, which shortened the measuring range again. Since the length and the width of a room is normally under 20m, the RSSI values will not lie in the negative range, and only the positive RSSI values will be possible. The *HCI_Get_Link_Quality* command returns an unsigned 8-bits Integer as indication of the connection quality. However the Bluetooth specification does not supply guidance over the meaning of this number.

Thirdly, we have supposed transmission in free area, which means no obstacle or objects which reflects the radio wave on the transmission path. But in the real indoor environment there are many objects which can affect the transmission of the radio wave, such as walls, window, doors, roof, soils, tables, chairs, etc. Almost in every case the object whose position is to be determined is held by a person in the hand, and the person has also effect on the radio transmission.

Because of these reasons the received signal strength depends not only on the distance between the transmitter and the receiver, and the equation said before is not useful. Instead of it we have to measure the RSSI at different points and use a function approximation.

2.3 Location algorithm

In the room, where the location should be done, N Bluetooth devices are placed as reference station (RS). The number of RS and the position of each of them are stated in such a way that the transmitted power is so strong that the RSSI of those is always positive.

The RSSI of all RS is measured in some cells, which should be uniform distributed. In order to reduce the external effect to the RSSI, it has to be measured

several times and take an average value. The measured RSSI and the associated positions of the cells are stored. After sufficient data are collected, the approximation of the appropriate functions can be accomplished. The distance of each cell to all BS is computed considering the coordinates of the cell as the position of it. The coordinate of the centre of the cell is (x_z, y_z) , and (x_b, y_b) is the coordinate of the RS. The RS is h meter over the cell. The distance d is then:

$$d = \sqrt{(x_z - x_b)^2 + (y_z - y_b)^2 + h^2}$$

To do the approximation three-function type are used, the logarithmic function and polynomial function with 2 and 3-Order. To each function type is determined a function with the method LSE, and the value of R^2 is calculated. R^2 designates the *similarity* degree of the function with the measuring points and is defined as

$$R^2 = 1 - \frac{SSE}{SST}, SSE = \sum (Y_j - \hat{Y}_j)^2, SST = (\sum Y_j^2) - \frac{(\sum Y_j)^2}{n}$$

The function with the largest R^2 -value is used for the later computation of the distance. This procedure must be accomplished once for each RS, so that each RS possesses its own function for the determination of the distance.

Finally the position of the MS is computed by means of the measured RSSI at its position. The MS measures the RSSI from each RS several times and the average value is taken. Then the distances of the MS are computed to the respective RS with the determined function. The coordinate of the position of the MS can be computed then with LSE method.

2.4 Propagations conditions

The prediction of radio propagations is generally difficult. It is still more difficult to predict or compute the radio propagations in buildings with their specific absorptions, reflections and overlays. With the simulations is tried to copy the reality as well as possible so that an approach prediction can be done. A simple simulation in the programming language C++ was written, in order to measure the radio propagation of the Access Points distributed along the institute (14th and 15th floor of the building).

Neither in the data sheets of the dongles, nor in those of the AP, data concerning the kind of antenna used was described, therefore reliable conclusions about the antenna gain and the directional characteristic cannot be reached. Thus as basis for the computation

is supposed an isotropic spherical source, whose power is uniformly distributed in all directions. Other aspect to consider is the data of the devices. In Bluetooth are specified 3 power classes, each of one with a different power transmission and range: class 1 (100mW or 20 dBm, 100 m), class 2 (2,5mW or 4 dBm, 40m) and class 3 (1mW or 0 dBm, 10m). All ranges refer to free area, thus for Line of sight (LOS) connections. These ranges cannot be achieved because of the absorptions caused in buildings due to its construction. The AP used in the Institute of Communications Engineering have 20 dBm of power transmission, while the USB adapters only 4 dBm. The receiver sensitivity of the USB adapters is approx. -80 dBm and the AP more than -85 dBm. In the computation was supposed always a sensitivity of -80 dBm for all devices, which brings an additional safety level for the accessibility to the AP. As the search for a suitable program with which one can simulate wave propagation within buildings was not successful, a C++ simulation program had to be written, which computes the wave propagation and is restricted to the dependence on the walls and free space attenuation.

In the following paragraphs is described the algorithm used in this program. First the plans of the two floors, with dimensions 870 x 450 pixels, were stored in the computer. During the model production of the walls were specified 2 different types, one to represent the normal partition walls, and the other one to represent the thick concrete walls in the area of the elevators and the toilets. The wall types were already considered as a fixed value. Variable specifications were the safety level, the power transmission as well as the receiver sensitivity. The safety level is defined, because during the transfer absorption are considered only the walls. Objects such as cupboards, shelves, people, contribute also to the absorption, however are almost impossible to be simulated in the context of this project. The algorithm for the computation of the field strength is with exception of the reflection and the diffraction, both not considered, equal to the algorithm of the Raytracing software. After the location of the AP, which is marked by one mouse-click on the graphic surface and represents the transmitting antenna, the surface is drawn line by line. For each 3rd pixel the program determines the distance pixel-AP on the basis a mathematical linear equation. It serves as basis for the computation of the free space attenuation (Figure 3)

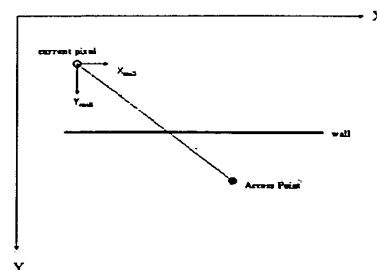


Figure 3: Computation of the field strength

If between the current pixel and the AP are one or more walls, the field strength must be decreased by the appropriate portion of the wall absorption. Whether a certain wall on the way is penetrated along the determined straight lines, determines the following algorithm. The current pixels serves as origin of a new, small coordinate system (x_{small}, y_{small}). For each point on the distance $x_{small} = 0$ to $x_{small} = x_{AP}$ is determined the y-value in accordance with the linear equation. If the point determined is identical to one point of the stored positions of the wall, then no LOS connection exists, and the receipt level must be weakened in the place of the current pixels additionally for free space attenuation around the absorption value of the type of wall concerned. In the developed program could be problems if the upward gradient of the linear equation became too large. Then it could happen that with any x the pertinent y-value was the far below y-value of the wall, and which next y-value was with $x+1$ the far over y-value of the wall. This problem was gone around thereby as the determined y-values are successively put down in an array, and after each new point computation it is queried whether between the current y-value and the preceding possibly the y-value of a wall lies. With this algorithm it is now possible to recognize whether a jet (linear equation) a wall penetrates, or not. Some results are represented in Fig.4.

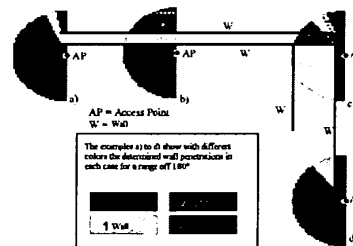


Figure 4: Example of propagation measurement

For unexplainable reasons the algorithm described does not function at high upward gradient values always satisfyingly. Therefore occasionally error samples are with high upward gradients to recognize (Fig.4, example b: Yellow pixels within the red range). After the algorithm functioned became the formula for the free space attenuation added, and the receipt levels graphically represented (see Fig.4).

After the test phase of the algorithm of recognition of the wall penetrations the formula for the free space attenuation was added and a total test with the graphic surface was accomplished. The result is represented in Fig.5. The frequency was 2.4 GHz, the safety level was 2 dB, the transmitted power 0 dB, the receiver sensibility -80 dB, the attenuation of the walls model 15 dB and the attenuation of the walls model 213 dB. The strength of the receipt levels are coloured represented. Red means that a very good receipt level prevails there, while yellow represents a very bad. The blue points represent the used Bluetooth devices.

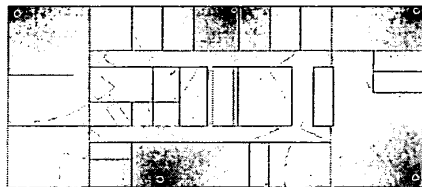


Figure 5: Simulation results

On the basis of practical field strength measurements the Bluetooth infrastructure already existing was examined and the results were compared with the theoretically determined values of the simulation program. At some points theoretically according to the results of the simulation no receipt would have been more possible. However a receipt could be proven in the mentioned places. This effect was to be noticed particularly clearly in the corridors. The receipt of the signals must have come by reflections at the walls and by the smaller absorption of the opened doors, because this effect was not considered in the simulation.

2.5. Security issues

Wireless networks and its problems

The open access to wireless communications networks makes the safety attitudes one of the most significant factors to be examined and understood. Most of the available technologies use nowadays the radio frequency spectrum. This frequency band could be without large expenditure for almost everyone

intercepted and subjected to a large number of disturbances subjected. Because the wireless communication is momentarily already used for business purposes and will be in the near future still much more strongly used, this vulnerable conditions is not acceptable and is need a security concept.

In cable-based networks the cables used to interconnect the devices offer a certain physical protection against manipulations. The cables normally are within a building, which is protected by certain access controls. Within the areas, where the devices are, the cables are freely accessible. A potential aggressor must break in the cables thus into the building and look for them in the appropriate area. In order to arrive at the data, the cable must be intercepted. In mobile, wireless networks the data are simple openly over air transferred and thus in a certain spatial periphery to receive. It can even be that the transmission is receivable outside of a building. The data communication is thus accessible over the air interface very much more easily, than with a network connected with cable. Due to the easy listening receptivity in the wireless surrounding field are necessary an authentication, a coding and an access control with strong cryptography.

Additionally in ad-hoc networks the participants do not know each other when network is constructed, therefore is it not possible to construct the network using common information as for example secret keys. Possibly they use even different safety standards.

General security aspects and its solutions

In nearly all the applications where Bluetooth can be used, private or personal data of the users is administered or used. Therefore it is particularly important that no strange user can log in into a network and/or a computer and access its data. Beside the contamination by so-called "Virus" and the unnoticed falsification the data, an additional danger results if a strange user accesses to the data by imitation of an acquaintance into a network and using a wrong identity obtain unnoticed access and if necessary in further networks too(account abuse). Also without login for potential aggressors can be possible to arrive into the possession of confidential data to falsify. The radio interface could be heard or the data could be manipulated on the way from the sender to the receiver.

Nevertheless, using coded traffic another overview of the activities of the network can be noted by monitoring of the radio interface and if necessary a conclusion can be drawn. With mobile Bluetooth users a transaction log can be provided, which betrays critical habits of a user.

There are several possibilities for the solution of the safety problems. A first attempt for a safe network would be a participant identification using clear characteristics, e.g. the MAC address. These were registered into an Access Control List (ACL). If a client with a strange MAC address tries to access the network, he is rejected. Authentication would be the next step toward a safe net. The authentication could be solved e.g. in terms of software using passwords, and/or on the hardware side by Smart Cards or similar. Further different groups of users for different safety-relevant ranges could be created. So it could be prevented that networks were abused, or data were seen or changed by unauthorized users.

In the case of data transmission in the network it is important the maximum permitted load to code e.g. WEP (Wired Equivalent Privacy). Here is worked with different key lengths, i.e. 64 or 128 bits. Enclosed are 24 bits called the initialization vector (one of the random numbers which are changed by the hardware from packet to packet) and the remainder (40 and/or 104 bits) is defined by the user. Secure end-to-end connections using the IP protocol can be realized by using VPN (Virtual private network).

A very simple characteristic for the safety increase is the delimitation of the range of the Access Points. In Bluetooth this is already given by the standard, which contains a range of approx. 10 m. In the WLAN functionality there is the possibility to switch the functionality off.

Frequency Hopping in Bluetooth is too a safety aspect. Here the frequency is changed 1600 times per second. If a potential aggressor wants to hear the signal, first he must synchronize himself with the signal.

Bluetooth security

Bluetooth signals can be easily heard. For that reason were necessary in the Bluetooth specification special safety mechanisms to avoid the falsification of data during the transmission. In particular the link layer makes available features, with which authentication and coding of data are possible.

Bluetooth contains 3 different security modes for the authentication of devices, which are used depending upon equipment and safety need.

Mode 1: this mode refers to missing safety precautions and is used when there are not implemented critical applications on the appropriate devices. In this mode the devices ignore the safety functions of the link layer, so that the access to databases that do not include sensitive data is released.

Mode 2: this mode offers security on the service level and makes possible the appropriate access

procedures in applications which run in parallel or processes with different safety requirements.

Mode 3: this mode offers security on the safeguard level, by which the link manager provides on a uniform level during the connecting fittings for all applications for safety precautions. This mode is less flexible, however it can be implemented by the security level more easily than mode 2, in which each application has its own safety level.

With the security mode 2 the safety stages can be specified for devices and services separately. For devices there are 2 stages of confidence, trusted and untrustworthy. Trusted devices stand in a firm relationship to each other (paired devices) and have unrestricted access to all services.

Untrustworthy devices are not located in permanent relationship, and/or connection, because they are not trustworthy. There can be cases, in which devices stand to each other in a firm relationship although they are untrustworthy. In these cases the access to services is limited.

The trust level of equipment can be set in such a way that it has only access to a service, and/or a group of services. The requirements for authorizing, authentication and coding are specified depending upon access of the devices independently of each other:

- With services, which require authorizing and authentication, the access will be only permitted to trusted devices; all other devices must authorize it manually.
- Services, which require only an authentication.
- Services, which stand open for all

A safety approach is the employment of a security manager, who is queried during the establishment of a connection. The security manager can make possible for so trustworthy devices, after inquiry of the internal database, services and access of the appropriate safety stage. However this inquiry of the security manager cannot replace existing network-specific safety precautions. During extremely strict requirements, security would have to be supplemented by safety mechanisms on the application layer. A characteristic of the Bluetooth security architecture is that actions are avoided if possible with the access to services. Actions are necessary only if a limited use of services is to be granted to devices, or if trustworthy relations with devices has to be arranged, which permit unrestricted data access.

In order to be able to satisfy different requirements in view of the availability of services without user interferences, the authentication must take place after the definition of the security stage of the requested service. The authentication takes place when a connection requirement for the service is transferred. The following events arise with the access to trustworthy equipment successively:

- The connection requirement is made by L2CAP
- L2CAP requests the access with the security manager
- The security manager queries the service data base
- The security manager queries the equipment data base
- If necessarily the security manager forces the Authentication and coding
- The security manager allows the access
- L2CAP continues with the mechanism of the connection

Thereby the authentication can take place into both directions, so that the client must authenticate itself with the server, or in reverse.

Even if the Bluetooth security architecture is not co-ordinated with the mode 3 (security on the connecting level), it can support nevertheless this mode easily. The security manager can order the link manager that the authentication is forced, before a base band connection is made by the HCI. Before the transition of mode 2 on mode 3 there are however some steps necessary, to avoid that trusted devices do not receive access. The security manager must remove all connecting codes for not trusted devices, which are stored in the radio module. In addition it can use the HCI.

For arriving connections is required the access control of the L2CAP-level and sometimes also the upper multiplex protocols (e.g. RFCOMM). With the reception of the connecting desire the protocol object sets an inquiry with the security manager, both are passed on the multiplex information. The security manager decides, whether the connection may be initiated or not. It answers then the protocol object. If the entrance is granted on the part of the security manager, the procedure is continued for the mechanism of a connection. If the connecting desire is rejected, the connection is terminated.

3. Conclusions

In this paper is exposed the results of the project Notebook Seminar developed at the Institute of Communications Engineering at the University of Hannover in the context of the UbiCampus project. In this seminary the students have worked in groups in order to provided a Bluetooth infrastructure for the rooms of the IANT. The most interesting results were exposed.

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Graph Coloring Algorithms*

Walter Klotz

Abstract

Deterministic graph coloring algorithms of contraction and sequential type are investigated. Sequential algorithms can be extended by backtracking to relatively effective algorithms for the chromatic number of a graph. Incomplete backtracking leads to new heuristics for graph coloring.

Keywords: graph coloring, chromatic number.

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1 Introduction

Graph coloring serves as a model for conflict resolution in problems of the following type. Suppose that in a set V certain pairs of elements are incompatible. The problem is to find a partition of V into a minimal number of subsets of mutually compatible elements. The situation is described by a graph $G = (V, E)$ with vertex set V and edge set E formed by all pairs of incompatible Elements. Partitioning of V into k subsets is equivalent to coloring the vertices of G with k colors.

A (*proper*) *coloring* of the vertices of a graph $G = (V, E)$ is a map $F : V \rightarrow \mathbb{N}$, where adjacent vertices receive distinct colors in $\mathbb{N}$; that is, if $uv \in E$, then $F(u) \neq F(v)$. The *chromatic number* $\chi(G)$ is the minimum number of colors needed for a coloring of G . A graph G is *k-chromatic*, if $\chi(G) = k$, and G is *k-colorable*, if $\chi(G) \leq k$. A *color class* of a coloring F contains all vertices of the same color. The color classes of F form a partition of V into *independent* subsets, i.e. subsets of pairwise non-adjacent vertices.

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The problem of determining the chromatic number $\chi(G)$ is NP-complete. Therefore, no polynomial time algorithm is known for $\chi(G)$. In this paper we investigate several heuristics for graph coloring and a (sequential) backtracking algorithm for the exact value of $\chi(G)$. All heuristics considered are deterministic, they contain no random elements. For a survey of other heuristics see de Werra[7].

2 Contraction Algorithms

Contraction algorithms for graph coloring originate in a theorem of Zykov[8]. For non-adjacent vertices x and y we denote by $G/x, y$ the graph resulting from G by contracting y into x , i.e. y is deleted and the neighborset $N_G(x)$ of x becomes $N_G(x) \cup N_G(y)$. Moreover, $G + xy$ is the graph with the additional edge xy .

Theorem 1.

$$\chi(G) = \min \{ \chi(G/x, y), \chi(G + xy) \} \text{ for non-adjacent vertices } x \text{ and } y.$$

Proof. Let $C(G)$ be the set of (proper) colorings of G and $|F|$ the number of colors used by $F \in C(G)$. Then we have

$$\begin{aligned} \chi(G) &= \min \{ |F| : F \in C(G) \} \\ &= \min \{ \min \{ |F| : F(x) = F(y) \}, \min \{ |F| : F(x) \neq F(y) \} \} \\ &= \min \{ \chi(G/x, y), \chi(G + xy) \}. \end{aligned} \quad \square$$

By multiple application of Theorem 1 graph G becomes the root of a binary tree of graphs, the *Zykov tree*. The construction of the Zykov tree is finished, when no further reduction according to Theorem 1 is possible. So the leaves of the Zykov tree are complete Graphs $G_i = (V_i, E_i)$. Theorem 1 implies $\chi(G) = \min |V_i|$. This is the basis of an algorithm of Corneil and Graham[4] for $\chi(G)$, which searches through the Zykov tree in a depth-first manner. But despite some technical refinements this algorithm is inferior to the sequential backtracking algorithm described in section 3.

The Zykov tree is not uniquely determined. It depends on the order, in which non-adjacent pairs x, y are chosen. Each Zykov tree has exactly one branch which is exclusively generated by contractions. Let G_c be the complete graph at the end of this branch. The number of vertices, $|V(G_c)|$, of this graph is an upper bound for $\chi(G)$. The longer the branch to G_c is, the better will be

this bound. So a good strategy for the selection of a non-adjacent pair x, y to be contracted might be to retain as many non-adjacent pairs of vertices as possible. Equivalently, the resulting graph $G/x, y$ should have as few edges as possible. The difference of the number of edges $|E(G)| - |E(G/x, y)|$ equals the number $cn(x, y)$ of common neighbors of x and y . In the algorithm of Brigham and Dutton[2] non-adjacent vertices with a maximal number of common neighbors are contracted until a complete graph is achieved.

More effective and yielding better results than the algorithm of Brigham and Dutton is the algorithm RLF (Recursive-Largest-First) of Leighton[6], see also Hertz[5]. Here x is a fixed vertex of maximal degree. Non-neighbors y with a maximal number of common neighbors with x are contracted into x until x is adjacent to every other vertex. To increase effectiveness, x is then removed and a new vertex of maximal degree in the residual graph is chosen. Vertex x and all vertices contracted into x constitute a color class. If x has a non-neighbor, but no non-adjacent vertex with a common neighbor, then the graph is unconnected and x is adjacent to all other vertices of its own component. To enforce the RLF-principle consequently, we must continue the construction of the color class of x with a vertex of maximal degree in an other component. This has been taken into account in our implementation of the algorithm. The (worst-case time-)complexity of RLF is $O(|V|^3)$. One factor $|V|$ is due to the determination of a vertex x of maximal degree. Traversing the non-neighbors of x in search for a vertex y with a maximal number of common neighbors with x may cost another $O(|V|^2)$ elementary operations. We propose the following informal code for the RLF-algorithm.

Given a graph $G = (V, E)$ with vertex set $V = V(G)$ and edge set E .

A coloring $F : V \rightarrow \mathbb{N}$ is established and will be returned.

```

colornumber = 0;                                     //number of used colors
while ( $|V(G)| > 0$ ) {
    determine a vertex  $x$  of maximal degree in  $G$ ;
    colornumber = colornumber + 1;
     $F(x) = \text{colornumber}$ ;
     $NN =$  set of non-neighbors of  $x$ ;
    while ( $|NN| > 0$ ) {                                //find  $y \in NN$  to be contracted into  $x$ 
        maxcn = -1; //becomes the maximal number of common neighbors
        ydegree = -1; //becomes degree( $y$ )
        for every vertex  $z \in NN$  {
            cn = number of common neighbors of  $z$  and  $x$ ;
            if ( $cn > \text{maxcn}$  or ( $cn == \text{maxcn}$  and  $\text{degree}(z) < ydegree$ )) {
                 $y = z$ ;
            }
        }
    }
}

```



```

        ydegree = degree(y);
        maxcn = cn;
    }
}
if (maxcn == 0){ //in this case G is unconnected
    y=vertex of maximal degree in NN;
}
F(y) = colornumber;
contract y into x;
update the set NN of non-neighbors of x;
}
G = G - x; //remove x from G
}
return F.

```

3 Sequential Coloring

One of the simplest coloring methods is sequential coloring $SC(O)$ according to a given order $O = [a_0, \dots, a_{n-1}]$ of the vertices:

$F(a_0) = 1$.

If $a_1, \dots, a_{i-1}$ ($i \geq 1$) have already received colors, let $F(a_i)$ be the smallest color not yet used in the neighborhood of a_i .

The LF-algorithm (Largest First) is based on an ordering of the vertices of the graph $G = (V, E)$ according to non-increasing degrees. Its complexity is $O(|V|^2)$.

The algorithm DSATUR (Degree of Saturation) of Brèlaz[1] is a sequential coloring algorithm with a dynamically established order of the vertices. Suppose F is a partial coloring of the vertices of G . The degree of saturation of a vertex x , $deg_s(x)$, is the number of different colors at the vertices adjacent to x . DSATUR starts by assigning color 1 to a vertex of maximal degree. The vertex to be colored next in the sequential coloring procedure of DSATUR is a vertex x with maximal $deg_s(x)$. The complexity of DSATUR is $O(|V|^3)$.

Definition 1. Colorings F_1, F_2 of $G = (V, E)$ are equivalent, if they induce the same partition of the vertex set V into color classes.

Definition 2. A coloring F of the vertices $a_0, \dots, a_{n-1}$ of the graph G is tight with respect to the given order, if

$$F(a_i) \leq \text{colors}(i-1) + 1 \text{ for all } i = 0, 1, \dots, n-1,$$

where $\text{colors}(j)$ denotes the number of different colors at the vertices $a_0, \dots, a_j$, resp. $\text{colors}(-1) = 0$.

A backtracking sequential coloring algorithm, which returns the exact value of $\chi(G)$, was first developed by Brown[3]. Many unnecessary branches of the search tree can be avoided by the following theorem.

Theorem 2. Every coloring $F : V \rightarrow \mathbb{N}$ of the vertices $a_0, \dots, a_{n-1}$ of the graph $G = (V, E)$ is equivalent to a tight coloring with respect to the given order of vertices.

Proof. We change F to an equivalent, tight coloring by renaming colors.

Suppose $F(a_0) = k_1 > 1$. If no vertex has color 1, we change color k_1 to color 1, else we interchange colors k_1 and 1.

Assume that we have already made F tight for all vertices $a_0, \dots, a_{i-1}$, $i \geq 1$. Then exactly the colors $1, 2, \dots, l = \text{colors}(i-1)$ appear at the vertices $a_0, \dots, a_{i-1}$.

Suppose $F(a_i) = k > l+1$. If no vertex has color $l+1$, we change color k to color $l+1$, else we interchange colors k and $l+1$. $\square$

The original algorithm of Brown[3] was improved by Brèlaz[1]. The vertices of the graph are stored in an array A . Initially they are ordered according to non-increasing degrees. The order is dynamically changed. Suppose $A[0], \dots, A[i-1]$ have already been colored. The number of different colors at these vertices is $\text{colors}(i-1) = l_i$. The set of free colors at $x = A[i]$, $U = \text{freeColors}(x)$, is the subset of colors in $\{1, 2, \dots, l_i + 1\}$, which are not present in the neighborhood of x . If an upperbound optColorNumber , $\chi(G) \leq \text{optColorNumber}$, has been established by a coloring F , all colors $\geq \text{optColorNumber}$ can be removed from U . The vertex to be colored next is as in DSATUR a vertex of maximal degree of saturation. It is colored with the smallest color in U . If U is empty, a backtrack is executed.

BSC (Backtracking Sequential Coloring) algorithm for the determination of the chromatic number $\chi(G)$ of the graph $G = (V, E)$.

```

Find an ordering  $A = [a_0, \dots, a_{n-1}]$  of the vertices according to non-increasing
degrees;
start = 0; //starting index
optColorNumber =  $|V| + 1$ ; //optimal number of colors
x = A[0]; //current vertex to be colored
colors(-1) = 0; //colors(j) = number of colors at A[0], ..., A[j]
U = [1]; //Variable for the set(sequence) of free colors
freeColors(x) = U; //set of free colors of x
while (start  $\geq$  0){
    //x is colored in the following for-loop. Backtracking is
    //necessary, if  $U = \emptyset$  or if an improved coloring has been found
    back = false; //boolean variable for backtracking
    for (i = start; i <  $|V|$ ; i++){
        if (i > start){ //for i = start x and U are already available
            find an uncolored vertex x of maximal degree of saturation;
            U = set of free colors of x, which are < optColorNumber;
            sort U non-decreasing;
        }
        if ( $|U| > 0$ ){
            k = U[0]; //selected free color
            F(x) = k; //current coloring
            remove k from U;
            freeColors(x) = U;
            l = colors(i - 1);
            colors(i) = max{k, l};
        }
        else{ //U =  $\emptyset$ , backtrack one position
            start = i - 1;
            back = true;
            break; //leaving the for-loop
        }
    }
    if (back){
        if (start  $\geq$  0){
            x = A[start]; //new starting vertex
            uncolor x;
        }
    }
}

```

```

         $U = \text{freeColors}(x);$ 
    }
}
else{ //in this case the above for-loop has been passed without a break
     $F_{opt} = F;$  //storing the currently optimal coloring
     $optColorNumber = colors(|V| - 1);$ 
     $i = \text{least index with } F(A[i]) = optColorNumber;$ 
     $start = i - 1;$ 
    if ( $start < 0$ ){
        break; //leaving the while-loop
    }
    uncolor all vertices  $A[i]$  with  $i \geq start$ ;
    for ( $i = 0; i \leq start; i++$ ){
         $x = A[i];$ 
         $U = \text{freeColors}(x);$ 
        remove from  $U$  all colors  $\geq optColorNumber$ ;
         $\text{freeColors}(x) = U;$  //the current coloring is to be improved
    } //notice: here we have  $x = A[start]$ ,  $U = \text{freeColors}(x)$ 
}
}
return  $F_{opt}$ .

```

The algorithm can be improved by some refinements. If we start the ordering A of the vertices with a clique on the vertices $A[0], \dots, A[r-1]$, these vertices receive fixed colors $1, \dots, r$. The algorithm can be stopped, if backtracking leads to an index $< r$. A lower bound $lb \leq \chi(G)$ may be established by applying BSC to a dense subgraph. The algorithm may then be finished, if a coloring is found, which uses no more than lb colors. We call a vertex x a *merging vertex* with respect to a free color k of x , if all uncolored neighbors of x are adjacent to a vertex with color k . In this case we may reduce $\text{freeColors}(x)$ to $\{k\}$.

From BSC we gain the heuristic IBSC(k) by restricted backtracking (Incomplete Backtracking Sequential Coloring), where each vertex may only be k -times the new starting vertex after backtracking. For $k \geq 1$ the complexity of IBSC(k) is $O(k|V|^4)$.

4 Runtime Comparisons

We have generated 100 random graphs on 60 vertices for each edge-density 0.1, 0.3, 0.5, 0.7 resp. 0.9. For the algorithms LF, DSATUR, RLF, IBSC(1), IBSC(2), IBSC($|V|$) and BSC we display the average number of colors used and (in brackets) the average running time in ms.

edge-density	0.1		0.3		0.5	
LF	4.86	(0.94)	9.09	(1.32)	13.59	(1.92)
DSATUR	4.18	(1.84)	8.21	(2.89)	12.50	(4.62)
RLF	4.17	(10.13)	7.96	(11.95)	11.94	(12.06)
IBSC(1)	4.00	(2.99)	7.57	(27.38)	11.52	(45.68)
IBSC(2)	3.99	(3.00)	7.39	(43.04)	11.39	(72.17)
IBSC($ V $)	3.99	(3.14)	7.10	(267.76)	11.00	(1107.75)
BSC	3.99	(5.14)	7.02	(485.65)	10.67	(19632.51)

edge-density	0.7		0.9	
LF	19.24	(1.86)	28.52	(2.03)
DSATUR	18.08	(5.82)	27.49	(8.25)
RLF	17.18	(13.05)	27.26	(13.26)
IBSC(1)	16.83	(53.87)	26.23	(43.32)
IBSC(2)	16.66	(83.95)	26.20	(61.63)
IBSC($ V $)	16.08	(1382.24)	25.84	(424.18)
BSC	15.53	(39996.20)	25.80	(1154.61)

The results show that LF, the fastest algorithm on our list, yields poor quality. Its application makes sense only for very large graphs. RLF should be applied only for dense graphs, otherwise too many contractions consume too much time. Incomplete backtracking in a simple form, e.g. IBSC(1), may be a good alternative to RLF or DSATUR.

In some situations the different performances of the algorithms can be made more striking, if the coincidences of the number of colors used with the chromatic number are counted. We applied the algorithms to 100 random graphs on 120 vertices with edge-density 0.1. The number of direct hits of the chromatic number is shown.

LF: 0, DSATUR: 5, RLF: 4, IBSC(1): 16, IBSC(2): 19, IBSC($|V|$): 61.

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Market-based Proportional Resource Sharing for Clusters

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Abstract

Enabling technologies in high speed communication and global process scheduling have pushed clusters of computers into the mainstream as general-purpose high-performance computing systems. More generality, however, implies more sharing and this raises new questions in the area of cluster resource management. In particular, in systems where the aggregate demand for computing resources can exceed the aggregate supply, how to allocate resources amongst competing applications is an important problem. Traditional solutions to this problem have focused mainly on global optimization with respect to system-centric performance metrics, metrics which ignore higher level user intent. In this paper, we propose an alternative market-based approach based on the notion of a computational economy which optimizes for *user value*. Starting with fundamental requirements, we describe an abstract architecture for market-based cluster resource management based on the idea of proportional resource sharing of basic computing resources. Using this architecture, we have implemented a 32-node (64 processors) prototype system that provides a market for time-shared CPU usage for sequential and parallel programs. To begin evaluating our ideas, we are currently in the process of studying how users respond to the system by collecting data on real day-to-day usage of the cluster.

1 Introduction

Enabling technologies in high speed communication [3, 4, 7, 23, 37] and global process scheduling [2] have pushed clusters of computers [1, 6, 8, 27] into the mainstream as general-purpose high-performance computing systems. No longer restricted to strict space-sparing as personal supercomputers, clusters today are capable of supporting multiple parallel and sequential jobs concurrently and delivering high performance as well. More generality in the system, however, implies more sharing and this raises new questions in the area of cluster resource management. In particular, in systems where the aggregate demand for computing resources can exceed the aggregate supply, how to allocate resources amongst competing applications is an important problem.

Traditional solutions to cluster resource management [5, 10, 13, 15, 18, 39] have mainly focused on global optimization with respect to system-centric performance metrics (e.g. mean job completion time, average system utilization). For systems with significant sharing, though, these approaches present two problems. First, global optimizations are not targeted to be consistent with the individual resource valuations of the users. Optimizations are performed as though all applications are equally important¹ while ignoring individual user value of the resources which vary based

¹Some schedulers, such as the Unix priority scheduler, make implicit assumptions about user value and thus do not treat all applications equally. For example, in observing the fraction of a job's CPU scheduling quantum used, priority schedulers attempt to infer whether a job is "interactive" or "compute-bound" and modifies the job's priority in accordance with what it thinks will result in "better" performance.

on the immediacy, importance, and the resource demands of the user's computing needs. Thus, in allocating resources to competing applications, these solutions are unlikely to deliver the greatest value to the users for a given set of resources. Second, traditional solutions lack proper incentives to encourage users to back off the system during periods of high contention. In systems where aggregate demand can exceed aggregate supply, the probability of overcommitting cluster resources is non-negligible. With users pursuing selfish, locally-optimal behavior, this can be a problem during periods of high contention as users have no incentive to perform socially desirable behavior to improve global goodness.

To address these issues, we propose a market-based approach to cluster resource management based on the notion of a computational economy which optimizes for *user value*. In this scheme, clusters are organized as economies of independent sellers and buyers. Cluster nodes act as independent sellers of computing resources and user applications act as buyers who purchase resources based on the personal value delivered to users. Users express value using a currency which can be traded for resources and are charged for resource use based on the rate they are willing to pay and the rate other users are willing to pay on competing applications. Starting with fundamental requirements, we develop the idea of computational economies by presenting an abstract architecture for market-based cluster resource management based on the idea of proportional resource sharing of basic computing resources. We then describe an implementation of this architecture, a 32-node (64 processors) prototype system that provides a market for time-shared CPU usage for sequential and parallel programs. To begin evaluating our ideas, we are currently in the process of studying how users respond to the system by collecting data on real day-to-day usage of the cluster.

The rest of this paper is organized as follows. In Section 2, we present the three fundamental functional requirements for market-based systems. In Section 3, we present an abstract architecture for market-based cluster resource management based on proportional resource sharing. Using this architecture, in Section 4, we describe an implementation of an initial 32-node (64 processors) market-based cluster which provides time-shared CPU usage for sequential and parallel programs. Section 5 discusses related work and in Section 6, we present some conclusions.

2 Three Fundamental Requirements

There are three fundamental functional requirements for market-based resource management on a cluster: (i) a means for users to express value, (ii) policies to translate value into resource allocations, and (iii) mechanisms to enforce resource allocations. Variations in how these requirements are met defines the design space of market-based systems.

2.1 Expressing Value

For a market-based system to optimize for user value, it must first determine what is the personal user value for each application competing for shared resources. Without this knowledge, the system has no meaningful way of inferring which applications are more valuable when deciding how to allocate resources. Thus, the first component needed is a means to concretely express a user's personal value in executing each application on a system. There are two parts to this: the medium of expression used to express value and the entity (or entities) to which value is being assigned.

When running an application, each user has some implicit notion of how important the execution of an application at some instant in time is to them. For example, a user running Netscape is likely to value its execution less than the execution of an important simulation whose results need to be

included in a paper due later the same day. To make this notion of value concrete to the system, there needs to be a mapping from personal user value to some common medium of expression for value. A common solution to this problem is to use a common currency (e.g., US\$). As long as users can form reasonably accurate mappings from personal value to a currency, this solution is adequate.

The second part of expressing value concerns to what entity or entities value is being assigned. For example, when a user says that a simulation is important, perhaps the thing that is valued is the simulation's wall-clock completion time. On the other hand, when a user runs a server, perhaps the user values the average requests per second it can sustain. Ideally, the entities to which the user assigns value would be expressed in the vocabulary of the application in terms the user deals with.

Forming the mapping between application-specific performance metrics and low-level resources can be solved, in some cases quite accurately, for some applications. However, in many cases, this will not be the case. In cases where those mappings cannot be made, users can approximate this in terms of basic computing resources. For example, a user running a scientific simulation might want to speak in terms of grid points evaluated per second, but percentage of the CPU obtained over time may be just as effective. For many applications, we hypothesize that the basic resources critical for performance are well-known.

2.2 Translating Value

Given competing users' values for applications using a shared resource, a market-based system then needs a policy for translating those values into specific resource allocations with appropriate performance guarantees. How the policy goes about doing this involves a critical trade-off between human-computer interaction (HCI) design goals and criteria in the design of economic mechanisms.

On one hand, from the HCI perspective, because the expression of value and the policy to translate value is directly exposed to and observable by users (the policy may not actually be known, but the effects of the policy in terms of resource allocations can certainly be observed), this favors use of a policy that is simple, intuitive, and which users can form a crisp mental model of how the system behaves in response to their choices. On the other hand, from a game theory perspective, a common design goal is for policies to be *incentive compatible*, meaning that in deciding how to assign a value to an application the optimum utility-maximizing behavior is to reveal one's true value; thus users need not be concerned with other users' behavior [14]. Different policies in real systems will reflect different trade-offs between these two perspectives.

Another issue associated with the translation of value to resource allocations is the nature of the resource allocations themselves. This relates to the point made earlier regarding what are the entities to which value is being assigned. When value is translated to resource allocations, those allocations should reflect a performance guarantee, hard or statistical, that can be ultimately meaningful to the user after zero or more layers of translation. For example, assigning value to a fraction of a resource that an application obtains over time is well-defined and meaningful. This would be a case with zero layers of translation. As another example, suppose a video application wanted to run 30 frames per second and the maximum achievable frame rate was directly proportional to CPU utilization, then providing a mechanism to control the CPU very precisely (e.g., using a stride scheduler) would be a reasonable way to provide meaningful resource allocations, after one level of translation.

2.3 Enforcing Value

Finally, once value has been translated into resource allocations with performance guarantees, operating system mechanisms are needed to enforce those allocations so that users get the resources they are paying for. That is, we need appropriate quality of service (QoS) mechanisms on the resources to which value is being assigned (and users are being charged!).

Numerous papers have been published on novel quality of service mechanisms for CPU time, networking, physical memory, I/O, spin-locks, etc. Unfortunately, despite a plethora of mechanisms, relatively little work has been done in the area of policies which can make effective use of these mechanisms in real user environments. There are a number of possible reasons for this: no incentives to prevent unrestricted, socially unacceptable use of the mechanisms (i.e., what's to discourage a user from turning the service knob to the maximum setting?), lack of inclusion in popular operating systems, etc.

Perhaps the most likely reason is that on personal computers and workstations, there simply is not a compelling need to have quality of service mechanisms to control resource usage of competing applications. (On the networking side, the absence of QoS is no doubt partly due to difficulty in implementing and deploying end-to-end QoS.) On single node systems, more often than not, typical applications being run execute reasonably well in the presence of competition. On the other hand, on a cluster system, whose intended use is high performance computing, the situation is quite the opposite. Very demanding applications are common and the effects of and frequency in which non-negligible contention occurs for shared resources are significant.

3 Architecture

To address the issues raised in Section 2, in this section, we define an abstract architecture for market-based resource management on clusters. We take specific positions on certain key issues (e.g., the entities to which value is being assigned). These positions are based largely on our goal of defining an architecture which can be used to realize real systems with end-to-end properties that can be measured in real settings with users running a wide range of applications. This goal stands in contrast to much of the previous work on market-based systems which was highly theoretical in nature and focused on fairly narrow slices of the problem (e.g., extensive game theoretic analyses of policies to translate value to allocations). The architecture consists of five layers (Figure 1): *resources*, computational resources such as CPU, physical memory, and disk; *resource managers*, operating system entities which enforce resource allocations; *the economic front end*, the entity which translates user value into resource allocations; *access modules*, the means by which users assign value and run applications on the system; and *users and applications*, the entities which use the system and ultimately drive the design decisions in all other layers.

3.1 Resources

Resources are the computational resources that are controlled by the resource managers and allocated to applications to deliver value to users. Basic time-shared resources such as CPU time, I/O bandwidth, and networking bandwidth and shared-spaced resources such as physical memory and disk space are typical examples. More unconventional examples include spin-locks on SMPs and time-shared access to special-purpose devices, such as a wall-of-monitors.

In the context of the computational economy, we focus primarily on resources that exhibit scarcity and which have significant application-level performance implications. In other words, we focus

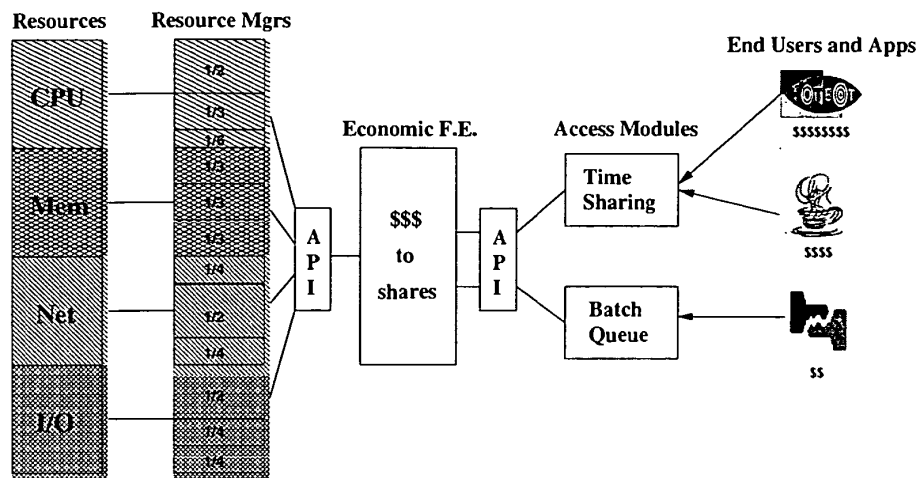


Figure 1: **Abstract end-to-end system architecture.** End users, running a wide range of applications, assign values to their applications and run them on the cluster using the appropriate access module. Access modules run jobs on the cluster and obtain resources for competing jobs using an economic front end. Given a mode of access and a set of competing jobs, an economic front end translates values expressed in a common currency to resource shares. Resource share allocations are enforced using resource managers, one per resource type.

on resources where the demand for the resource can, with non-negligible probability, exceed supply in a way that application performance suffers. These are the resources whose allocation should be controlled and priced through the computational economy.

3.2 Resource Managers

Resource managers are the operating system entities which provide resource allocations with associated performance guarantees. Examples of possible design choices for resource managers include priority schedulers [24, 29, 31], real-time schedulers [21, 28], fair-share schedulers [19, 20], proportional-share schedulers [22, 33, 35, 36], and rate-based schedulers [9, 38]. Which resource manager to choose for each resource in a computational economy depends on several factors including resource allocation precision, flexibility, and overhead. Ultimately, for resources whose allocation is under control of the economy, the resource managers for those resources should be capable of exposing and enforcing resource allocations that are, after zero or more layers of translation, meaningful to the user.

In our architecture, we have chosen to use proportional-share schedulers as the resource managers for all basic computational resources (CPU, memory, network, I/O²). Our reasons for doing so are threefold: (i) proportional-share schedulers provide an intuitive model of resource allocation, (ii) there exist efficient algorithms for implementing them, and (iii) they provide flexibility in exposing different entities to which to assign value (e.g., in addition to assigning value simply

²We currently have a CPU stride scheduler implemented on Linux 2.2.5 running on Dell Poweredge 2-way SMPs. We next plan to implement a minimum-funding revocation algorithm for proportional-share memory management

based on shares, given a CPU stride scheduler, reasonable user estimates of CPU time needed, and admission control one could potentially build a market-based system based on deadlines).

Proposed and articulated in detail by Waldspurger [33, 35, 36], proportional-share scheduling provides a simple, intuitive model of resource allocation. In this model, resource rights for a shared resource are encapsulated as tickets. A resource is represented by a total of T tickets. An application holding t tickets competing for use of that resource obtains t/T of the resource. For example, with CPU stride scheduling, an application holding t tickets would obtain an accurate t/T allocation of the CPU over time. This model of allocation is simple to reason about and affords a simple mapping from value to resource allocations by mapping credits (credits is the name of the currency used in our system that can be traded for resources) per minute to a ticket allocation over time.

3.3 Economic Front End

The economic front end is the entity which translates value into resource allocations in terms of shares (i.e., fractions) of a resource as enforced by the resource managers. What policy the front end implements is largely a function of which access modules we use to access the system. For example, different policies are appropriate if users are accessing the system for interactive use in a time-shared environment as opposed to, say, submitting jobs to a batch queue which runs jobs on a cluster. Vickrey auctions [32], for instance, may be appropriate for a batch queue since there is a delay between the time a job is submitted and the time it is executed in which the auction has time to clear. On the other hand, an auction in an interactive system makes less sense as the time to clear becomes an issue (e.g., does the user have to wait after typing a command for an auction to clear?).

Policies will also depend on the entity or entities to which value is being assigned and associated performance guarantees. Whether the system performs admission control is a key issue here as it determines whether the resource allocations that applications receive can represent absolute performance guarantees or whether they represent relative performance guarantees. With admission control, for example, absolute guarantees could be made to manage a futures market in computational resources [17]. Futures could be sold and enforced using proportional-share schedulers and an admission control policy that prevents overselling of resources. (This combination of proportional-share scheduling and admission control would, in effect, be trying to emulate what real-time schedulers accomplish.) However, in having absolute performance guarantees, this implies using admission control which, depending on the access module may or may not be desired.

The choice of policy also reflects trade-offs between usability concerns and game theoretic design points. From the abstract architecture point of view, the appropriate trade-offs to be made in the front end's policy are still very much open. To date, there have been no reported user studies on user behavior on market-based clusters. (There have been few real implementations at all, certainly none on the scale at which we wish to examine this problem.) Without real user behavior data, it is impossible to know, for example, whether the often criticized assumption of hyper-rational human behavior assumed in game theory even matters in practice. If it does not and users tend not to try and exploit the properties of the game, knowing this would provide a lot of freedom in trying to make the system usable, for example. In designing the system, we take the position of giving usability concerns higher priority than making the policy absolutely incentive compatible. Usability will always be an important design point. Ensuring that a policy is incentive compatible may not.

3.4 Access Modules

Access modules provide the means by which users access cluster resources to run applications. Common examples include telnet/rlogin/rsh/ssh for interactive remote execution on a single node, custom remote execution environments [13, 16] or multiple rsh/ssh instances for interactive remote execution of parallel programs on multiple nodes, and batch queue systems for large numbers of sequential and/or parallel jobs.

To support market-based resource management, access modules will need to be augmented so users can assign value to their applications. Assigning value may be as simple as specifying a scalar value that is passed interactively on the command line, or may involve more complex specifications (e.g., specifying a utility function). They close the loop, in that future workload demand and valuation depends on past performance. In keeping with our goal of usability, we have initially chosen to use simple scalar valuations for CPU time. In addition, because interactive, time-shared access to resources is so common, the first access module we have implemented (Section 4.4) provides interactive remote execution for parallel and sequential jobs. To prevent users from bypassing access through the computational economy, we currently disallow general-purpose use of access modules which have yet to be modified (e.g., ssh access is allowed only for administrative purposes).

3.5 End Users and Applications

Although not explicitly part of the system's actual implementation, end users and applications are an important part of the end-to-end architecture. It is the modes of usage and resource demands of the users and their applications that ultimately drive many design choices in the system. It is the users' actual usage of the system that will determine whether market-based resource management is effective or not. Keeping the users in mind requires thinking about how they use clusters (e.g., batch mode or interactive), how sophisticated they can be assumed to be (e.g., how much do they understand about how computer systems work), what the resource demands of their applications are (e.g., what resources do they care about), etc. These factors have significant implications for the design of the other layers of the system.

4 Implementation

To investigate how users behave when using market-based systems and how these systems perform in practice, we have implemented a computational economy for CPU time on a cluster of PCs as part of the UCB Millennium Project. The system allows users to run sequential and parallel programs while assigning a value which specifies the maximum credits per minute the user's application is willing to spend purchasing CPU time. Using a simple, intuitive algorithm, each node independently computes and charges for CPU allocations for competing applications and enforces these allocations using stride scheduling, an efficient, deterministic proportional-share scheduling algorithm.

4.1 Resources: UCB Millennium Cluster

The system consists of 32 2-way Dell Poweredge 2300 multiprocessors running a modified version of the Linux 2.2.5 operating system. Each node has two 500 MHz Intel Pentium III processors, 512 MB of memory, 17.4 GB of local storage, and has network connections to Myrinet [3], a switched, 1.28 Gb/s wormhole-routed network, and a switched 100 Mb/s Ethernet. Resources in our system

are the four basic computational resources on each node (CPU time, physical memory, I/O bandwidth, and network bandwidth), each of which is broken up into time or space-shared shares. At present, our system supports economic resource allocation of CPU shares. Memory, I/O, and network bandwidth are allocated using the default operating system policies.

To enforce CPU resource allocations based on value, we modified the Linux 2.2.5 CPU scheduler by replacing the standard priority scheduling algorithm with stride scheduling. Using stride scheduling, our system is able to achieve much better precision when controlling CPU allocations for different jobs compared with priority scheduling. Such precision is necessary since allocations are being driven by user-specified values which result in users being charged credits, of which they have a finite supply to get their work done. Building on the basic stride scheduling algorithm, we have also added a few extensions in order to support stride scheduling on SMPs and to deal with multithreaded and multiprocess jobs.

Figure 2: Stride scheduling algorithm. In this example, jobs A, B, and C are competing for CPU time on a 2-way SMP. Resource rights to the SMP's 2 CPUs are encapsulated in a pool of 600 tickets. A, B, and C have 100, 200, and 300 tickets respectively, thus they should receive a 1:2:3 allocation of the machine CPUs over time. (Note that with a k-way SMP, having the rights to more than $1/k$ -th the tickets is really the same as having exactly $1/k$ unless the job is multithreaded.) A job's stride is the interval of virtual time, measured in CPU quanta, between that job's being selected to run. (It is inversely proportional to the ticket allocation.) A job's pass is the virtual time when the job will be scheduled. It is incremented by the job's stride each time the job is scheduled. For each CPU quantum on each processor, the stride scheduler chooses the job with the lowest pass that is not already scheduled on another processor, runs it for one scheduling quantum, and increments its pass by its stride.

T.) Jobs with more tickets have shorter strides and hence are scheduled more frequently and obtain a greater fraction of the resource. The algorithm itself is simple: the scheduler picks the job with lowest pass, runs it for a scheduling quantum, increments its pass by its stride, and iterates (see Figure 2). It is deterministic and within resolution of the scheduling quantum schedules jobs in exact proportions based on their ticket allocations.

We extended the basic stride scheduling algorithm to support SMPs and to contain and control the resource usage within a collection of related entities (e.g., all the threads in a process, a collection of processes working together). The former was necessary since our basic processing nodes have multiple processors and the Linux kernel is organized around a centralized run queue. The latter was necessary to prevent a user from running a process, then having that process create replicas of itself by forking or cloning, each of which would then be scheduled with the same value as the original process. Global pass, ticket, and stride values represent aggregate information for all competing jobs and are necessary to support a system where jobs can join and leave the system dynamically. (See [36] for more details.) Making the stride scheduling algorithm SMP-aware simply required a small change in the way the global pass is computed. In particular, when k processes are running concurrently on k CPUs, the global pass must be incremented k times as fast.

To support multithreaded and multiprocess jobs, we isolate all related entities using their own currencies. Each job in the system is scheduled on the basis of the number of base tickets it has. To deal with a multithreaded or multiprocess job i with base ticket allocation t_i , we simply ensure that the aggregate base ticket assignment for all entities forked or cloned from a root process, including the root itself is t_i . We do this by maintaining a linked list of currencies, each of which has an associated linked list of processes/threads that use that currency. The default policy for ticket allocation within a multithreaded or multiprocess job is to perform fair share across all entities. For applications that desire more control, a system call interface is provided that allows applications to manage tickets in their own applications-specific currency.

4.3 Economic Front End: Initial Economic Policy

To translate values to shares of a CPU (i.e., tickets), we have elected to start with a simple, intuitive policy based on opportunity-cost charging³ that is easy for users to reason about. In this scheme, n jobs are competing for some shared resource r , in this case CPUs on a node. Job i has a stated value b_i , which may or may not be the same as true value v_i (e.g., suppose a user is trying to undervalue the value of an application to save credits or perhaps the user does not realize how important a particular run is). The system allocates shares and charges as follows. If $n = 1$, there is only one user demanding the resource. Thus, that user is imposing no burden on the system and not denying anyone else an opportunity since there is no competition for r . In this case, that user is charged nothing and is given all of r . If $n > 1$, multiple jobs are competing for r and jobs receive shares as they would if the b_i 's were tickets. That is, job i with stated value b_i obtains $b_i / \sum_{j=1}^n b_j$ of r over time. When $n > 1$, job i is charged b_i credits per minute. (If multiple jobs are competing, each with $b_i = 0$, each job receives fair share and is not charged.) The computing of shares and charging is computed dynamically as jobs join and leave the system.

A key issue addressed by this policy is the distinction between selling and sharing. Our policy charges users based on the burden they place on other users sharing the system. Under no con-

³Opportunity-cost charging occurs when charging is done based on the opportunity to use a resource. A user who opts to use a resource is charged based on the value of the opportunity to use that same resource that is being denied to other competing users.

tention, this means users use the system for free. Conversely, under high contention, users pay more to use the system. Contrast this approach to that of a profit-center, charging to maximize seller revenue. Selling to maximum seller revenue produces different user incentives, incentives which may result in suboptimal sharing of resources. Under monopoly pricing, for example, it is common for a seller to maximize revenue while underutilizing the underlying resources being sold. For a shared computer system, pricing schemes such as this make little sense when considering our original motivation for computational economies.

Addressing sharing directly, this policy has a number of other desirable properties as well, including simplicity, intuitiveness, and low computational overhead. From a usability perspective, it makes it very easy for users to reason about what the system's response will be to assigning some value to a computation. This property is very important in order to reduce the amount of noise in our experiments. If users are unable to understand what it means to assign value given a particular means of doing so, trying to meaningfully interpret the results of users using such a mechanism will be difficult if not impossible. By making the policy and interface extremely simple (scalars), we increase the chances that most users will have a clear picture of what it means to assign a value to a computation and what the system will do in the face of competition when assigning resources. Another nice property of this policy is that it is computationally simple to implement. The overhead required to compute allocations and charging are straightforward and are even simpler than those needed to implement stride scheduling. Furthermore, because we do not anticipate users using the cluster to run large numbers of very short jobs (e.g., less than a second), the dynamic updating of allocations, which require system calls, should incur fairly minimal overhead.

4.4 Access Modules: REXEC Remote Execution Environment

To allow users to interactively run jobs on the cluster through the economy, we have implemented REXEC, a secure, decentralized remote execution environment for parallel and sequential jobs. Compared to previous remote execution systems (e.g., GLUnix [13], Score-D [16], LSF [39]), REXEC provides a unique set of features including decoupling of node discovery and selection, emulation of local execution on multiple nodes, decentralized control, dynamic discovery and configuration, well-defined failure and cleanup models, and authentication and encryption. In Section 4.4.1, we discuss each of features in more detail. In Section 4.4.2, we briefly describe the REXEC implementation.

4.4.1 Features

Decoupling discovery and selection means that the process of discovering which nodes are available in the system is separated from the process of selecting which nodes the system should run a user's application on. By decoupling these two processes, users are given the flexibility to choose which selection policy they want to use based on their personal preferences as opposed to having the system implement a global policy that everyone is forced to use. For a computational economy, this property is important because we expect users will require multiple selection policies depending on their needs.

Emulation of local execution on multiple nodes means that a program can be run on multiple nodes with propagation of the user's local environment, signals, stdin, stdout, and stderr. This provides users with a familiar execution environment and also allows them to apply standard job control mechanisms (e.g., C-c, C-z) in controlling their jobs. Clearly, not all local behavior will make sense when extended to multiple remote instances of an application (e.g., running top on four nodes

from an xterm). REXEC provides sufficient emulation in the common cases. It does not, however, attempt to address these types of mismatches.

For scalability and availability reasons, REXEC is decentralized. A position we take with REXEC is that any node capable of running user programs should always be available to do so. There should be no false dependencies between artifacts of the remote execution environment and nodes which are perfectly healthy to do useful work. Decentralized control is achieved in two ways: (i) by having each client directly manage the remote execution of a job on multiple nodes and (ii) through replication of the node discovery and selection service. Besides increasing availability and reducing performance bottlenecks, decentralized control also works well with the economy, which is also decentralized (i.e., each entity acts based on local information).

REXEC does not depend on static configuration files or a fixed set of cluster nodes. Instead, all entities in REXEC dynamically discover each other through use of well-known IP multicast channel. In a large cluster of machines, adding or removing a node from the cluster is a fairly common event. Thus, it should not be the case that doing this requires restarting the system or manually editing configuration files. REXEC avoids this completely. Cluster nodes, the discovery and selection servers, and even the account service (for managing user credits in the economy) can all be dynamically discovered.

REXEC detects failures and provides well-defined failure and cleanup models. Remote processes, machines, networks, and so forth will fail from time to time. REXEC detects such failures and performs appropriate actions. A significant shortcoming of many remote execution systems is the lack of a precise failure model. For example, when a user types C-c while running a remote parallel program, what that actually means in terms of cleaning up remote resources is usually not well-defined. REXEC currently provides a single failure and cleanup model which states that if anything in the remote execution fails at any time, the entire program is aborted and all remote resources are freed. For example, freeing resources on a remote node involves termination of an arbitrary tree of child processes (and child processes which might have broken off from the tree and been inherited by the init process) and freeing REXEC resources on that node dedicated to that job.

Lastly, REXEC implements client-side authentication and encrypts all relevant data exchanged between clients and servers using the SSLeay implementation of the Secure Sockets Layer (SSL) Protocol [12]. To use the system, a user presents a certificate, signed by a trusted certificate authority, that establishes the user's identity and uses public key cryptography to prove himself. Using public-key cryptography, this scheme provides significant improvements against attacks compared to traditional password-based schemes. In addition to authentication, REXEC also performs encryption of all relevant data (stdin, stdout, stderr, signals flowing to and from remote programs). This prevents potentially eavesdroppers from snooping on the network and observing input and output to programs users are running on the system.

4.4.2 Implementation

The REXEC system consists of three main programs: *rexecd*, a daemon which runs on each cluster node; *rexec*, the client program that users run to execute jobs using REXEC; and *vexecd*, a replicated daemon which provides node discovery and selection services (Figure 3). Logically, it consists of two layers: REXEC, the physical layer which provides low-level mechanisms for remote execution, failure detection and cleanup, and authentication and encryption on a set of named nodes; and VEXEC, the virtual layer which provides a set of node names based on some selection criteria (e.g.,

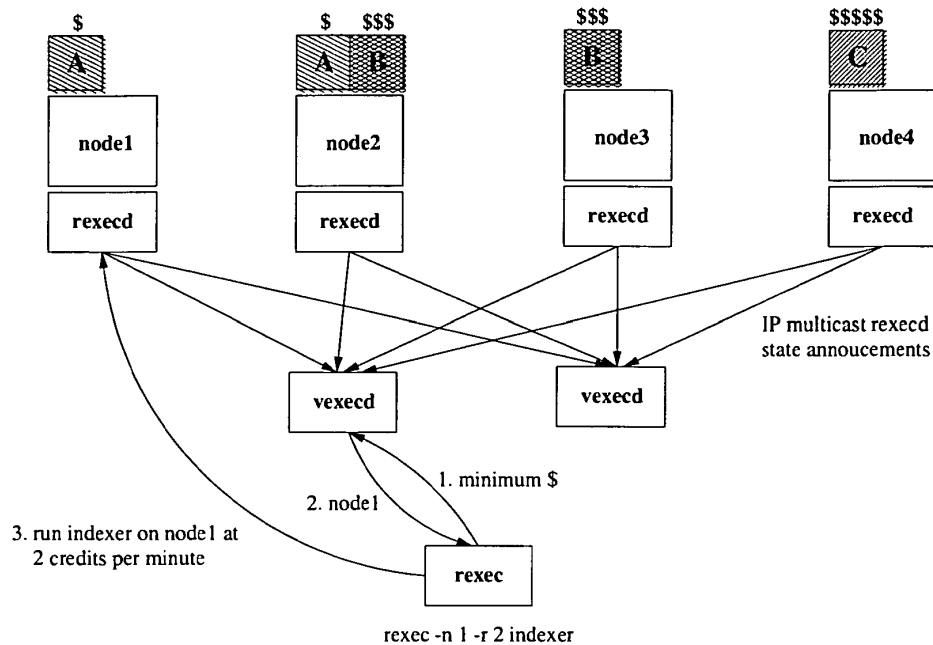


Figure 3: **REXEC remote execution environment.** The REXEC system consists of three main programs: *rexecd*, a daemon which runs on each cluster node; *rexec*, the client program that users run to execute jobs using REXEC; and *vexecd*, a replicated daemon which provides node discovery and selection services (Figure 3). Users run parallel and sequential applications in REXEC using the *rexec* client, which performs two functions: (i) selection of which nodes to run on based on user preferences and (ii) remote execution of the user's application on those nodes through direct SSL/TCP connections to the node *rexecd* daemons. In this example, there are four nodes in the system: node1, node2, node3, and node4 and two instances of *vexecd*, each of which implements a lowest CPU price policy. A user wishes to run a program called *indexer* at rate two credits per minute and wishes to do this on the machine with the lowest CPU price. Contacting a *vexecd* daemon, *rexec* obtains the name of the machine with lowest CPU price (node1). *rexec* then establishes an SSL/TCP connection directly to node1 to run *indexer* at a rate of two credits per minute. *indexer* will then be started on node1 and compete for resources with job A.

cheapest CPUs). Users run parallel and sequential applications in REXEC using the rexec client, which performs two functions: (i) selection of which nodes to run on based on user preferences (e.g., using a user-specified vexecd which implements the user's preferred policy) and (ii) remote execution of the user's application on those nodes through direct SSL/TCP connections to the node rexecd daemons. The REXEC system is implemented mainly at user-level with a few small kernel changes for properly freeing resources for a tree of processes.

To extend REXEC to operate within the framework of the computational economy, we made four changes to the system. First, a vexecd daemon was written that implements a minimum price policy on all the nodes it knows about. Each rexecd in the cluster sends state announcements on a well-known IP multicast channel, periodically and whenever a state change occurs (similar to V [5]). vexecd daemons listen on this channel and maintain a list of nodes they have heard from over a specific window of time. A selection policy is simply an ordering on this list. Second, the rexec client was modified to allow specification of CPU valuation for the user's application. Using a new command line switch (-r maxrate), the user specifies the maximum credits per minute the application can spend purchasing CPU time. Third, rexecd was modified to use an economic front end (a collection of functions that implement the CPU market) to translate user-specified rates into CPU allocations under the stride scheduler whenever the state of the system changes (i.e., whenever a job starts/exits on a node). Finally, with applications competing for resources and being charged for usage, an account service was needed to manage credit usage for each of the users. This service provides simple credit/debit management of user credit accounts. rexecd daemons obtain the IP address and port of the account service at runtime using IP multicast then establish secure SSL/TCP connections to perform transactions against its database.

4.5 End Users and Applications: UCB Millennium Project

As part of the UCB Millennium Project, our system has a user community that spans 17 academic departments on the UC Berkeley campus. These users work on a wide range of problems in areas such as multimedia, civil engineering, computational astrophysics, digital libraries, large-scale Internet systems, physics, and computer-aided design. Computational workloads generated by these users typically take the form of large numbers of sequential jobs (e.g., in exploring a parameter space) or large parallel jobs written using MPI. In addition to Millennium users, there is also a significant opportunity to obtain participation in user studies through a number of the undergraduate and graduate courses in the Berkeley computer science department. Taken together, the Millennium Project and computer science users will form a large, diverse user community. This community will be used to drive the empirical evaluation of our prototype.

5 Related Work

Ferguson's microeconomic load balancing algorithm is one of the earliest examples of applying market-based ideas to cluster resource management [11]. In his algorithm, multiple sequential jobs compete for dedicated slices of CPU time on a collection of heterogenous (in speed) machines interconnected by point-to-point links. At the end of each CPU slice, each machine holds an auction to determine which, of a set of competing jobs, should be granted exclusive use of its CPU for a user-specified slice of time. The winner of the auction is the job with the highest bid amount per unit of time. This winning rate, also referred to as the current machine price, is posted to both the machine's local Bulletin Board of prices and the Bulletin Boards of a local neighborhood of ma-

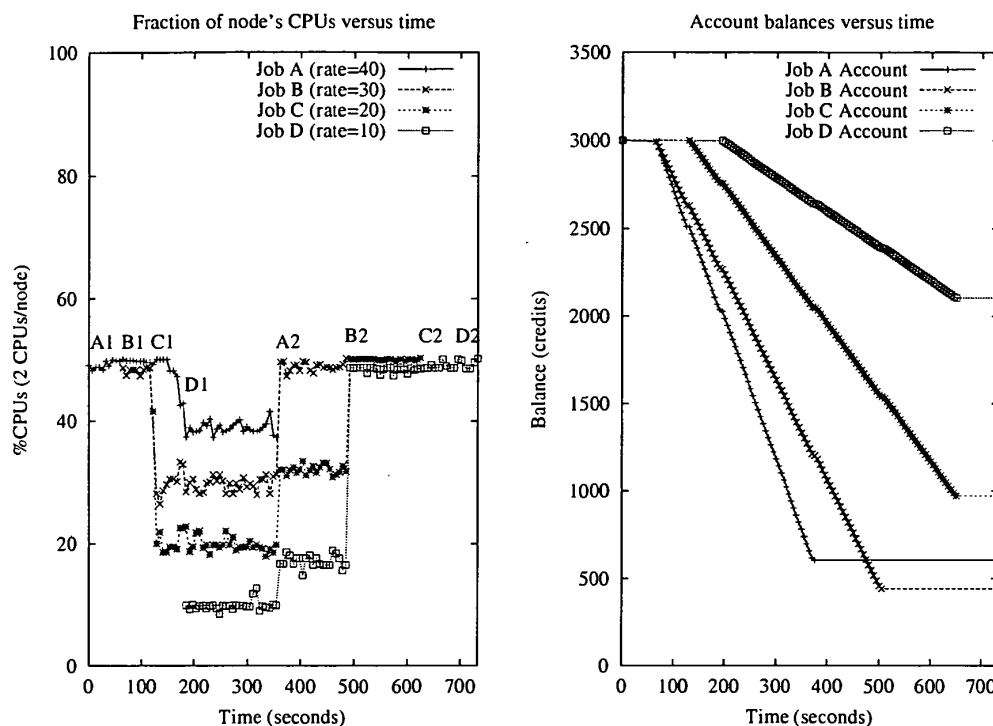


Figure 4: Example of measured CPU allocation and charging on a single node. In this scenario, jobs A, B, C, and D are willing to pay rates of 40, 30, 20, and 10 respectively to compete for CPU resources on a single node. Each node has two CPUs. Job arrival times are labeled A1, B1, C1, and D1. Job departure times are labeled A2, B2, C2, and D2. At any instant in time (e.g., interval C1-B2), we see that the relative CPU allocation of any two jobs is given by the ratio of the rates they are willing to pay. (Note that since all the jobs are single threaded, when two jobs compete, each receives 50% of the node's CPUs, i.e., one CPU.) When multiple jobs compete, each job is charged based on the rate it is willing to pay and is given an allocation in proportion to its rate. When a single job demands the resources, it is given all of the resources and is charged nothing (e.g., intervals A1-B1, C2-D2).

chines. In Ferguson's model, jobs may be submitted on any machine, migrate to different machines for execution, but must always complete on the machine from which they originated. Where a job gets executed is a function of which machine the job was submitted on, Bulletin Board prices in the neighborhood of that machine, and user preferences (e.g., lowest cost, fastest execution).

Extending Ferguson's work to parallel programs, Spawn is a market-based system for scheduling concurrent tree-based applications on a collection of heterogeneous workstations [34]. In Spawn, each application has a user-specified funding rate, which specifies the aggregate funding rate for the entire application, and is organized as a tree of *worker modules*, the computational tasks of the concurrent application, and *manager modules*, entities which control worker creation and relative funding of workers under their control. Using their funding, applications compete for resources with each other by bidding on dedicated slices of CPU time on multiple workstations, each of which periodically runs a sealed-bid second-price auction. Upon winning a workstation's auction, an application is granted exclusive use of that workstation's CPU until its slice expires. Upon using its slice, the application can continue by requesting an extension and continuing to pay market price (i.e., the price to win the next auction) or is terminated.

System	Resources	Resource Mgrs	Economic F.E.	Access Modules	Users/Apps
Ferguson	CPU	Admission control	Sealed bid and Dutch auctions	None	None
Spawn	CPU	Admission control	Vickrey auction	Application manager	None
Popcorn	CPU	Admission control	Vickrey, double, and Clearinghouse auctions	Java API	None
Mariposa	CPU, I/O, disk	N/A	Contract Net; pricing based on load, expected resource usage, history	None	None
SC centers	CPU, memory, disk	Priority scheduler ⁴	nice, priority weighted usage charges	Batch queue with priority, ssh	Numerous

Table 1: Related work summary. This table summarizes related work in the framework of the abstract architecture presented in Section 3. Looking at the data, we find that most of the work so far has focused mainly on the economic front end layer. Very little attention has been paid to the end-to-end problem, how real users and applications use market-based systems in practice, and the implications real usage has on other layers of the system. (Supercomputing centers, though listed here, are a bit of a stretch in being categorized as market-based.) Lack of real users and applications in four of the systems and either lack of or highly specialized access modules clearly shows this (e.g., Popcorn requires each program to be written with the economy in mind using a special API.). As further evidence, notice that Ferguson's algorithm, Spawn, and Popcorn all assume dedicated use of the system. However, in many systems in use today, multiple users sharing resources is an important, common mode of usage.

⁴This is the case for clusters. Some supercomputing centers have specialized vector machines that support more

Popcorn is a wide area infrastructure for market-based CPU scheduling of distributed computations written in Java [26]. In this system, users write distributed Java applications by decomposing their application into a collection of coarse-grain tasks called computelets. Each computelet requires some number of Java Operations (JOPs) to complete. Buyers (users) assign desired prices to computelet or JOP-based contracts based on the computation's value and enter a well-known, centralized market to seek sellers. Sellers are the users selling CPU time on their machines to perform JOPs on behalf of buyers. In the market, a matching of a buy and sell can occur in three different ways, each constituting a different internal market. These ways include a repeated Vickrey auction (sealed-bid second-price auction), a double auction, or a Clearinghouse double auction. It is unclear from the paper what the duration of a contract is. Like Ferguson's algorithm, it is possible that Popcorn also uses user-specified contract lengths and performs all economic policies using rates.

Mariposa is a distributed database and storage system that uses market-based mechanisms for resource management to execute queries [30]. In this system, a client submits a query to a broker with a time-dependent budget $B(t)$, which specifies the value delivered to the client as a function of the query's completion time. A broker, upon receiving a query, computes a parallel, pipelined execution plan to efficiently execute the query as a collection of subqueries. Following that, it solicits bids from multiple servers on contracts to execute these subqueries and checks whether it can execute the client's query within the specified budget. If successful, the query plan is executed. Servers provide the processing and storage capabilities to perform client query processing to execute subqueries. Like brokers, they also perform selfish, local optimizations, in particular by pricing contacts based on the resources required to execute it, long-term revenue collected per storage fragment, and the current load.

Supercomputing centers often use pricing algorithms to charge for resource usage and to give different levels of CPU priority to batch queue jobs submitted to high-end machines, such as vector supercomputers and MPPs. For example, on machines managed by the National Partnership for Advanced Computing Infrastructure (NPACI) [25], each job is charged based on its resource usage, measured in service units (SU), and the queue rate of the queue the job was submitted to. Each SU is roughly equivalent to a CPU hour on the machine the job runs on. The queue rate is a priority that the user assigns to a job which determines how quickly the user's job is run. The idea here is that users assign higher priority to jobs which have higher personal value and that these priorities result in jobs running with greater priority in whatever native CPU scheduling mechanism the underlying machine supports. One nice property of supercomputing center charging is that since charges change very slowly (e.g., different fixed pricing schemes during the day and during the night), users can potentially get a better handle on how to manage their funds since prices are predictable. On the other hand, because prices are not responsive to immediate demand, it is clear that prices during periods of high demand will be underpriced (so demand exceeds supply) and that during periods of low demand, users will be overcharged. Finally, how the prices and constants used in pricing and computing SUs is not obvious and does not appear to change over time (e.g., to reflect long-term averages in observed supply and demand).

6 Conclusion

Enabling technologies in high speed communication and global process scheduling have pushed clusters of computers into the mainstream as general-purpose high-performance computing systems.

sophisticated resource allocation mechanisms.

More generality, however, implies more sharing and this raises new issues in the area of cluster resource management. To address these issues, we proposed a decentralized, market-based approach to resource management based on the idea of proportional resource sharing of basic computing resources. Here, a cluster of computers is organized as a computational economy which optimizes for user value. Cluster nodes act as independent sellers of computing resources and user applications act as buyers who purchase resources based on the personal value delivered to users. We described the three fundamental functional requirements for a market based system: expressing value, translating value, and enforcing value. We then proposed an abstract architecture for market-based cluster resource management based on proportional resource sharing. Using this architecture, we have implemented a 32-node (64 processors) prototype system that provides a market for time-shared CPU usage for sequential and parallel programs. To begin evaluating our ideas, we are currently in the process of studying how users respond to the system by collecting data on real day-to-day usage of the cluster.

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The Four Color Theorem

This page gives a brief summary of a new proof of the Four Color Theorem and a four-coloring algorithm found by Neil Robertson, Daniel P. Sanders, Paul Seymour and Robin Thomas.



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History.

The Four Color Problem dates back to 1852 when Francis Guthrie, while trying to color the map of counties of England noticed that four colors sufficed. He asked his brother Frederick if it was true that **any** map can be colored using four colors in

such a way that adjacent regions (i.e. those sharing a common boundary segment, not just a point) receive different colors. Frederick Guthrie then communicated the conjecture to DeMorgan. The first printed reference is due to Cayley in 1878.

A year later the first 'proof' by Kempe appeared; its incorrectness was pointed out by Heawood 11 years later. Another failed proof is due to Tait in 1880; a gap in the argument was pointed out by Petersen in 1891. Both failed proofs did have some value, though. Kempe discovered what became known as Kempe chains, and Tait found an equivalent formulation of the Four Color Theorem in terms of 3-edge-coloring.

The next major contribution came from Birkhoff whose work allowed Franklin in 1922 to prove that the four color conjecture is true for maps with at most 25 regions. It was also used by other mathematicians to make various forms of progress on the four color problem. We should specifically mention Heesch who developed the two main ingredients needed for the ultimate proof - reducibility and discharging. While the concept of reducibility was studied by other researchers as well, it appears that the idea of discharging, crucial for the unavoidability part of the proof, is due to Heesch, and that it was he who conjectured that a suitable development of this method would solve the Four Color Problem.

This was confirmed by Appel and Haken in 1976, when they published their proof of the Four Color Theorem [1,2].

Why a new proof?

There are two reasons why the Appel-Haken proof is not completely satisfactory.

- Part of the Appel-Haken proof uses a computer, and cannot be verified by hand, and
- even the part that is supposedly hand-checkable is extraordinarily complicated and tedious, and as far as we know, no one has verified it in its entirety.

We have in fact tried to verify the Appel-Haken proof, but soon gave up. Checking the computer part would not only require a lot of programming, but also inputting the descriptions of 1476 graphs, and that was not even the most controversial part of the proof.

We decided that it would be more profitable to work out our own proof. So we did and came up with a proof and an algorithm that are described below.

Outline of the proof.

The basic idea of the proof is the same as Appel and Haken's. We exhibit a set of 633 "configurations", and prove each of them is "reducible". This is a technical concept that implies that no configuration with this property can appear in a minimal counterexample to the Four Color Theorem. It can also be used in an algorithm, for if a reducible configuration appears in a planar graph G , then one can construct in constant time a smaller planar graph G' such that any four-coloring of G' can be converted to a four-coloring of G in linear time.

It has been known since 1913 that every minimal counterexample to the Four Color Theorem is an internally 6-connected triangulation. In the second part of the proof we prove that at least one of our 633 configurations appears in every internally 6-connected planar triangulation (not necessarily a minimal counterexample to the 4CT). This is called proving unavoidability, and uses the "discharging method", first suggested by Heesch. Here our method differs from that of Appel and Haken.

Main features of our proof.

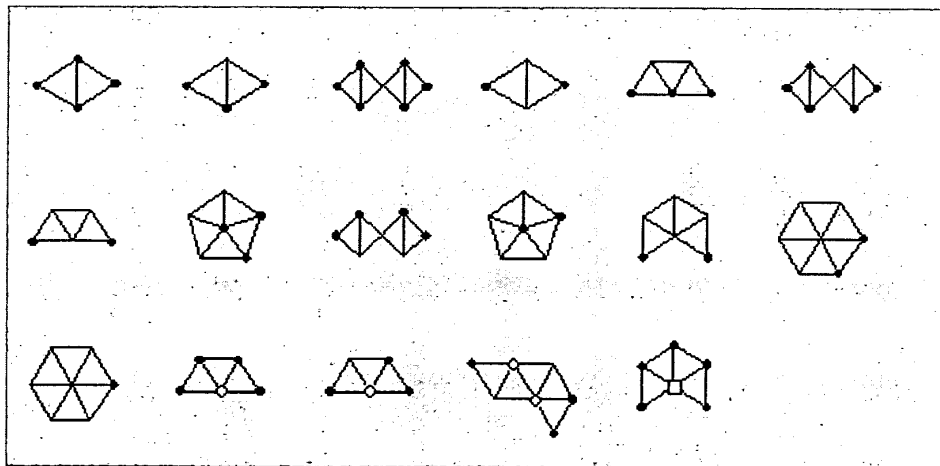
We confirm a conjecture of Heesch that in proving unavoidability, a reducible configuration can be found in the second neighborhood of an "overcharged" vertex; this is how we avoid "immersion" problems that were a major source of complication for Appel and Haken. Our unavoidable set has size 633 as opposed to the 1476 member set of Appel and Haken, and our discharging method uses only 32 discharging rules, instead of the 300+ of Appel and Haken. Finally, we obtain a quadratic algorithm to four-color planar graphs (described later), an improvement over the quartic algorithm of Appel and Haken.

Configurations.

A **near-triangulation** is a non-null connected loopless plane graph such that every finite region is a triangle. A **configuration** K consists of a near-triangulation G and a map g from $V(G)$ to the integers with the following properties:

1. for every vertex v , $G \setminus v$ has at most two components, and if there are two, then the degree of v is $g(v)-2$,
2. for every vertex v , if v is not incident with the infinite region, then $g(v)$ equals the degree of v , and otherwise $g(v)$ is greater than the degree of v ; and in either case $g(v) \geq 4$,
3. K has ring-size at least 2, where the **ring-size** of K is defined to be the sum of $g(v)-\deg(v)-1$, summed over all vertices v incident with the infinite region such that $G \setminus v$ is connected.

When drawing pictures of configurations we use a convention introduced by Heesch. The shapes of vertices indicate the value of $g(v)$ as follows: A solid black circle means $g(v)=5$, a dot (or what appears in the picture as no symbol at all) means $g(v)=6$, a hollow circle means $g(v)=7$, a hollow square means $g(v)=8$, a triangle means $g(v)=9$, and a pentagon means $g(v)=10$. (We do not need vertices v with $g(v) > 11$, and only one vertex with $g(v)=11$, for which we do not use any special symbol.) In the picture below 17 of our 633 reducible configurations are displayed using the indicated convention. The whole set can be viewed by clicking [here](#). (We refer to (3.2) of our paper [7] for the meaning of "thick edges" and "half-edges" in those pictures.)



Any configuration isomorphic to one of the 633 configurations exhibited in [7] is called a **good** configuration. Let T be a triangulation. A configuration $K=(G,g)$ **appears** in T if G is an induced subgraph of T , every finite region of G is a region of T , and $g(v)$ equals the degree of v in T for every vertex v of G . We prove the following two statements.

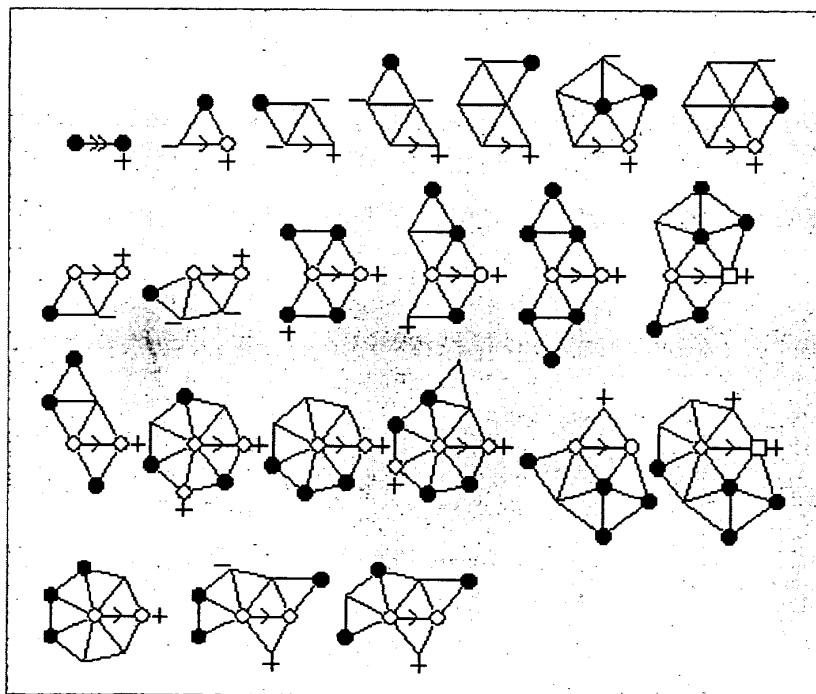
THEOREM 1. If T is a minimal counterexample to the Four Color Theorem, then no good configuration appears in T .

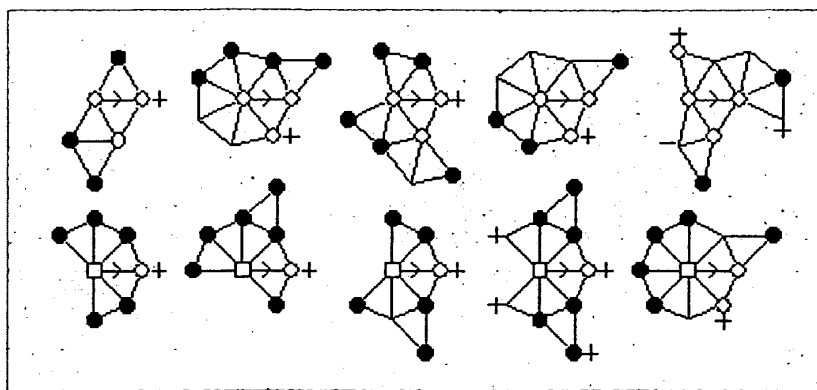
THEOREM 2. For every internally 6-connected triangulation T , some good configuration appears in T .

From the above two theorems it follows that no minimal counterexample exists, and so the 4CT is true. The first proof needs a computer. The second can be checked by hand in a few months, or, using a computer, it can be verified in about 20 minutes.

Discharging rules.

Let T be an internally 6-connected triangulation. Initially, every vertex v is assigned a charge of $10(6 - \deg(v))$. It follows from Euler's formula that the sum of the charges of all vertices is 120; in particular, it is positive. We now redistribute the charges according to the following rules, as follows. Whenever T has a subgraph isomorphic to one of the graphs in the figure below satisfying the degree specifications (for a vertex v of a rule with a minus sign next to v this means that the degree of the corresponding vertex of T is at most the value specified by the shape of v , and analogously for vertices with a plus sign next to them; equality is required for vertices with no sign next to them) a charge of one (two in case of the first rule) is to be sent along the edge marked with an arrow.





This procedure defines a new set of charges with the same total sum. Since the total sum is positive, there is a vertex v in T whose new charge is positive. We show that a good configuration appears in the second neighborhood of v .

If the degree of v is at most 6 or at least 12, then this can be seen fairly easily by a direct argument. For the remaining cases, however, the proofs are much more complicated. Therefore, we have written the proofs in a formal language so that they can be verified by a computer. Each individual step of these proofs is human-verifiable, but the proofs themselves are not really checkable by hand, because of their length.

Pointers.

The theoretical part of our proof is described in [7]. A 10-page survey is available on-line. The computer data and programs are available by anonymous ftp from <ftp://ftp.math.gatech.edu/pub/users/thomas/four> and can be conveniently viewed. An independent set of programs was written by Gasper Fijavz under the guidance of Bojan Mohar.

A quadratic algorithm.

The input to the algorithm will be a plane triangulation G with n vertices. (This is without loss of generality, as any planar graph can be triangulated in linear time.) The output will be a coloring of the vertices of G with four colors.

If G has at most four vertices color each vertex a different color. Otherwise if G has a vertex x of degree $k < 5$, then the circuit C surrounding it is a ' k -ring'. Go to the k -ring analysis below. Otherwise G has minimum degree five. For every vertex we compute its charge as explained above, and find a vertex v of positive charge. It follows from our proof of Theorem 2 that

either a good configuration appears in the second neighborhood of v (in which case it can be found in linear time), or a k -ring violating the definition of internal 6-connection can be found in linear time. In the latter case we go to the k -ring analysis below, in the former case we apply recursion to a certain smaller graph. A four-coloring of G can then be constructed from the four-coloring of this smaller graph in linear time.

Given a k -ring R violating the definition of internal 6-connection a procedure developed by Birkhoff can be used. We apply recursion to two carefully selected subgraphs of G . A four-coloring of G can then be constructed from the four-colorings of the two smaller graphs in linear time.

Discussion.

We should mention that both our programs use only integer arithmetic, and so we need not be concerned with round-off errors and similar dangers of floating point arithmetic. However, an argument can be made that our 'proof' is not a proof in the traditional sense, because it contains steps that can never be verified by humans. In particular, we have not proved the correctness of the compiler we compiled our programs on, nor have we proved the infallibility of the hardware we ran our programs on. These have to be taken on faith, and are conceivably a source of error. However, from a practical point of view, the chance of a computer error that appears consistently in exactly the same way on all runs of our programs on all the compilers under all the operating systems that our programs run on is infinitesimally small compared to the chance of a human error during the same amount of case-checking. Apart from this hypothetical possibility of a computer consistently giving an incorrect answer, the rest of our proof can be verified in the same way as traditional mathematical proofs. We concede, however, that verifying a computer program is much more difficult than checking a mathematical proof of the same length.

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**Part 11: Wireless LAN Medium Access Control
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**Amendment 5: Spectrum and Transmit Power
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**Part 11: Wireless Medium Access Control (MAC)
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Abstract: This amendment specifies the extensions to IEEE 802.11™ for wireless local area networks (WLANs) providing mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in the 5 GHz band in Europe.

Keywords: dynamic frequency selection (DFS), local area network (LAN), transmit power control (TPC)

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Introduction

(This introduction is not part of IEEE 802.11h-2003, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications: Amendment # 5: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe.)

IEEE Std 802.11h-2003

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**IEEE Standard for
Information technology—
Telecommunications and information
exchange between systems—
Local and metropolitan area networks—
Specific requirements**

**Part 11: Wireless Medium Access Control (MAC)
and Physical Layer (PHY) specifications:**

**Amendment 5: Spectrum and Transmit Power
Management Extensions in the 5 GHz band in
Europe**

[This amendment is based on IEEE Std 802.11™, 1999 Edition (Reaff 2003), as amended by IEEE Std 802.11a™-1999, IEEE Std 802.11b™-1999, IEEE Std 802.11b-1999/Cor 1-2001, IEEE Std 802.11d™-2001, and IEEE Std 802.11g™-2003.]

NOTE—The editing instructions contained in this amendment define how to merge the material contained herein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Three editing instructions are used: change, delete, and insert. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed either by using ~~strike through~~ (to remove old material) or underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instructions. Editorial notes will not be carried over into future editions.

1. Overview

1.2 Purpose

Insert the following item at the end of the list at the end of 1.2:

- Defines mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in the 5 GHz band in Europe. The regulations and conformance tests are listed in Clause 2.

2. Normative references

Insert the following citations at the appropriate locations in Clause 2:

ERC/DEC/(99)23, ERC Decision of 29 November 1999 on the harmonized frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs).¹

ETSI EN 301 893, Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive.²

3. Definitions

Insert the following definitions in alphabetical order into Clause 3, renumbering as necessary:

3.53 dynamic frequency selection (DFS): Facilities mandated to satisfy requirements in some regulatory domains for radar detection and uniform channel spreading in the 5 GHz band. These facilities may also be used for other purposes, such as automatic frequency planning.

3.54 dynamic frequency selection (DFS) owner: A station (STA) in an independent basic service set (IBSS) that takes responsibility for selecting the next channel after radar is detected operating in a channel. Due to the nature of IBSSs, it cannot be guaranteed that there will be a single DFS owner at any particular time and the protocol is robust to this situation.

3.55 effective isotropic radiated power (EIRP): The equivalent power of a transmitted signal in terms of an isotropic (omnidirectional) radiator. Normally the EIRP equals the product of the transmitter power and the antenna gain (reduced by any coupling losses between the transmitter and antenna).

3.56 5 GHz band in Europe: Refers to the nineteen 20 MHz channels between 5 GHz and 6 GHz in which wireless local area network (WLAN) operation is allowed in the CEPT regulatory domain.

3.57 link margin: Ratio of the received signal power to the minimum desired by the station (STA). The STA may incorporate rate information and channel conditions, including interference, into its computation of link margin. The specific algorithm for computing the link margin is implementation dependent.

3.58 receive power: Mean power measured at the antenna connector.

3.59 received power indicator (RPI): A quantized measure of the received power level as seen at the antenna connector.

3.60 transmit power: The effective isotropic radiated power (EIRP) when referring to the operation of a 5 GHz 802.11™ orthogonal frequency division multiplexing (OFDM) physical layer (PHY) in a country where so regulated.

3.61 transmit power control (TPC): Facilities mandated to satisfy requirements in some regulatory domains for maximum transmit power and transmit power mitigation in the 5 GHz band. These facilities may also be used for other purposes, e.g., reduction of interference, range control reduction of power consumption.

¹ERC documents are available from European Radiocommunications Office, Midtermolen 1, DK-2100, Copenhagen, Denmark (<http://www.ero.dk>).

²ETSI documents are available from ETSI, 650 Route des Lucioles, F-06921 Sophia Antipolis Cedex, France (<http://www.etsi.org>).

3.62 uniform spreading: A regulatory requirement per ERC/DEC/(99)23 for a channel selection mechanism that provides uniform loading across a minimum set of channels in the regulatory domain.³

4. Abbreviations and acronyms

Insert the following abbreviations in alphabetical order into Clause 4:

DFS	dynamic frequency selection
RLAN	radio local area network
RPI	receive power indicator
TPC	transmit power control

5. General description

5.3 Logical service interfaces

Insert the following items at the end of the list of architectural services in 5.3 as follows:

- j) DFS
- k) TPC

5.3.1 Station service (SS)

Insert the following items at the end of the list of SSs in 5.3.1 as follows:

- e) DFS
- f) TPC

5.4 Overview of the services

Change the first paragraph in 5.4 as follows:

There are ~~nine~~ several services specified by IEEE 802.11. Six of the services are used to support medium access control (MAC) service data unit (MSDU) delivery between stations (STAs). Three of the services are used to control IEEE 802.11 LAN access and confidentiality. Two of the services are used to provide spectrum management.

Insert the following text for 5.4.4 through 5.4.4.2 after 5.4.3.3 as follows:

5.4.4 Spectrum management services

Two services are required to satisfy requirements in some regulatory domains for operation in the 5 GHz band. These services are called transmit power control (TPC) and dynamic frequency selection (DFS).

³For information on references, see Clause 2.

5.4.4.1 TPC

ERC/DEC/(99)23 requires radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

The TPC service provides for the following:

- Association of STAs with an access point (AP) in a basic service set (BSS) based on the STAs power capability.
- Specification of regulatory and local maximum transmit power levels for the current channel.
- Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements.
- Adaptation of transmit power based on a range of information, including path loss and link margin estimates.

5.4.4.2 DFS

ERC/DEC/(99)23 requires RLANs operating in the 5 GHz band to implement a mechanism to avoid co-channel operation with radar systems and to ensure uniform utilization of available channels. The DFS service is used to satisfy these regulatory requirements.

The DFS service provides for the following:

- Association of STAs with an AP in a BSS based on the STAs' supported channels.
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs.
- Testing channels for radar before using a channel and while operating in a channel.
- Discontinuing operations after detecting radar in the current channel to avoid interference with radar.
- Detecting radar in the current and other channels based on regulatory requirements.
- Requesting and reporting of measurements in the current and other channels.
- Selecting and advertising a new channel to assist the migration of a BSS or independent BSS (IBSS) after radar is detected.

5.5 Relationships between services

Change the following list in 5.5 as follows:

- a) Class 1 frames (permitted from within States 1, 2, and 3):
 - 2) Management frames
 - i) Probe request/response
 - ii) Beacon
 - iii) Authentication: Successful authentication enables a STA to exchange Class 2 frames. Unsuccessful authentication leaves the STA in State 1.
 - iv) Deauthentication: Deauthentication notification when in State 2 or State 3 changes the STA's state to State 1. The STA shall become authenticated again prior to sending Class 2 frames.
 - v) Announcement traffic indication message (ATIM)
 - vi) Action

5.7 Message information contents that support the services

5.7.2 Association

Change the following list in 5.7.2 as follows:

Association request

- Message type: Management
- Message subtype: Association request
- Information items:
 - IEEE address of the STA initiating the association
 - IEEE address of the AP with which the initiating STA will associate
 - ESS ID
 - Power capability
 - Supported channels
- Direction of message: From STA to AP

5.7.3 Reassociation

Change the following list in 5.7.3 as follows:

Reassociation request

- Message type: Management
- Message subtype: Reassociation request
- Information items:
 - IEEE address of the STA initiating the reassociation
 - IEEE address of the AP with which the initiating STA will reassociate
 - IEEE address of the AP with which the initiating STA is currently associated
 - ESS ID
 - Power capability
 - Supported channels
- Direction of message:
 - From STA to AP (The AP with which the STA is requesting reassociation)

Insert the following text for 5.7.8 after 5.7.7 as follows:

5.7.8 Spectrum management

The spectrum management services are supported by the following action message:

Spectrum Management Action

- Message type: Management
- Message subtype: Spectrum Management Action
- Information items:
 - Action identification
 - Dialog token
 - Action dependent information
 - Direction of message: From STA to STA

7. Frame formats

7.1 MAC frame formats

7.1.3 Frame fields

7.1.3.1 Frame Control field

7.1.3.1.2 Type and Subtype fields

Insert the Management/Action row before the Management/Reserved row and change the Management/Reserved row in Table 1 as follows:

Table 1—Valid type and subtype combinations

Type value b3 b2	Type description	Subtype value b7 b6 b5 b4	Subtype description
00	Management	1101	Action
00	Management	~~1101~~ 1110–1111	Reserved

7.2 Format of individual frame types

7.2.3 Management frames

7.2.3.1 Beacon frame format

Change the order 11 information field and insert the order 14–18 information fields in Table 5 as follows:

Table 5—Beacon frame body

Order	Information	Notes
11	Country	The Country information element shall be present when dot11MultiDomainCapabilityEnabled is true <u>or</u> dot11SpectrumManagementRequired is true.
14	Power Constraint	Power Constraint element shall be present if dot11SpectrumManagementRequired is true.
15	Channel Switch Announcement	Channel Switch Announcement element may be present if dot11SpectrumManagementRequired is true.
16	Quiet	Quiet element may be present if dot11SpectrumManagementRequired is true.
17	IBSS DFS	IBSS DFS element shall be present if dot11SpectrumManagementRequired is true in an IBSS.
18	TPC Report	TPC Report element shall be present if dot11SpectrumManagementRequired is true.

7.2.3.4 Association Request frame format

Insert the order 6 and 7 information fields in Table 7 as follows:

Table 7—Association Request frame body

Order	Information	Notes
6	Power Capability	The Power Capability element shall be present if dot11SpectrumManagementRequired is true.
7	Supported Channels	The Supported Channels element shall be present if dot11SpectrumManagementRequired is true.

7.2.3.6 Reassociation Request frame format

Insert the order 7 and 8 information fields in Table 9 as follows:

Table 9—Reassociation Request frame body

Order	Information	Notes
7	Power Capability	The Power Capability element shall be present if dot11SpectrumManagementRequired is true.
8	Supported Channels	The Supported Channels element shall be present if dot11SpectrumManagementRequired is true.

7.2.3.9 Probe Response frame format

Change Table 12 from order 10 information field to the end of the table as follows:

Table 12—Probe Response frame body

Order	Information	Notes
10	Country	Included if dot11MultiDomainCapabilityEnabled or dot11SpectrumManagementRequired is true.
11	FH Parameters	FH Parameters, as specified in 7.3.2.10, may be included if dot11MultiDomainCapabilityEnabled is true.
12	FH Pattern Table	FH Pattern Table information, as specified in 7.3.2.11, may be included if dot11MultiDomainCapability-Enabled is true.
13	<u>Power Constraint</u>	<u>Shall be included if dot11SpectrumManagementRequired is true.</u>
14	<u>Channel Switch Announcement</u>	<u>May be included if dot11SpectrumManagementRequired is true.</u>
15	<u>Quiet</u>	<u>May be included if dot11SpectrumManagementRequired is true.</u>

Table 12—Probe Response frame body (continued)

Order	Information	Notes
<u>16</u>	<u>IBSS DFS</u>	<u>Shall be included if dot11SpectrumManagementRequired is true in an IBSS.</u>
<u>17</u>	<u>TPC Report</u>	<u>Shall be included if dot11SpectrumManagementRequired is true.</u>
18		Reserved
19	ERP Information	The ERP Information element is present within Beacon frames generated by STAs using ERP PHYs and is optionally present in other cases.
20	Extended Supported Rates	The Extended Supported Rates element is present whenever there are more than eight supported rates, and it is optional otherwise.
~~43~~ <u>21</u> – <i>n</i>	Requested information elements	Elements requested by the Request information element of the Probe Request frame.

Insert 7.2.3.12 after 7.2.3.11 as follows:

7.2.3.12 Action frame format

The frame body of a management frame of subtype Action contains the information shown in Table 15a.

Table 15a—Action frame body

Order	Information
1	Action

7.3 Management frame body components

7.3.1 Fixed fields

7.3.1.4 Capability Information field

Change the second paragraph in 7.3.1.4 as follows:

The length of the Capability Information field is 2 octets. The Capability Information field consists of the following subfields: extended service set (ESS), IBSS, contention-free (CF)-Pollable, CF-Poll Request, Privacy, Short Preamble, Packet Binary Convolutional Code (PBCC), Channel Agility, Spectrum Management, Short Slot Time, and DSSS-OFDM. The format of the Capability Information field is as illustrated in Figure 27. No subfield is supplied for ERP as a STA supports ERP operation if it includes all of the Clause 19 mandatory rates in its supported rate set.

Change the contents of Figure 27 as shown:

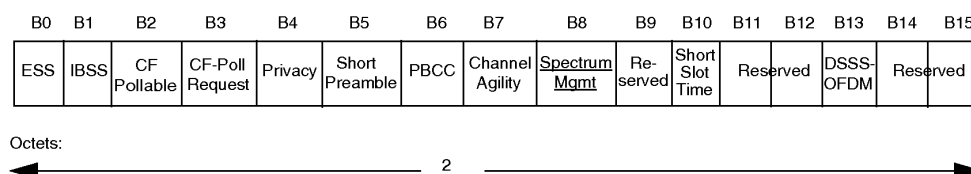


Figure 27—Capability Information fixed field

Insert the following text after the paragraph that starts “Bit 7 of the ...” in 7.3.1.4:

A STA shall set the Spectrum Management subfield in the Capability Information field to 1 if the STA’s dot11SpectrumManagementRequired is true; otherwise, it shall be set to 0.

7.3.1.7 Reason Code field

Insert reason codes 10 and 11 and change the Reserved reason code row in Table 18 as follows:

Table 18—Reason codes

Reason code	Meaning
10	Disassociated because the information in the Power Capability element is unacceptable
11	Disassociated because the information in the Supported Channels element is unacceptable
~~12~~ –65 535	Reserved

7.3.1.9 Status Code field

Insert status codes 22-24 and change the Reserved status code row in Table 19 as follows:

Table 19—Status codes

Status code	Meaning
22	Association request rejected because Spectrum Management capability is required
23	Association request rejected because the information in the Power Capability element is unacceptable
24	Association request rejected because the information in the Supported Channels element is unacceptable
~~25~~ –65 535	Reserved

Insert 7.3.1.11 after 7.3.1.10 and renumber figures and tables as necessary:

7.3.1.11 Action field

The Action field provides a mechanism for specifying extended management actions. The format of the Action field is shown in Figure 33a.

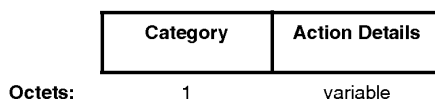


Figure 33a—Action field

The Category field shall be set to one of the nonreserved values shown in Table 19a. If a STA receives a unicast Action frame with an unrecognized Category field or some other syntactic error and the most significant bit (MSB) of the Category field set to 0, then the STA shall return the Action frame to the source without change except that the MSB of the Category field shall be set to 1.

The Action Details field contains the details of the action. The details of the actions allowed in each category are described in the appropriate subclause referenced in Table 19a.

Table 19a—Category values

Name	Value	See subclause
Spectrum management	0	7.4.1
Reserved	1–127	—
Error	128–255	—

7.3.2 Information elements

Change Table 20 from element identifier (ID) 17 to the end of the table as follows:

Table 20—Element IDs

Information element	Element ID
Reserved	17– <u>31</u>
<u>Power Constraint</u>	<u>32</u>
<u>Power Capability</u>	<u>33</u>
<u>TPC Request</u>	<u>34</u>
<u>TPC Report</u>	<u>35</u>
<u>Supported Channels</u>	<u>36</u>
<u>Channel Switch Announcement</u>	<u>37</u>

Table 20—Element IDs (continued)

Information element	Element ID
<u>Measurement Request</u>	<u>38</u>
<u>Measurement Report</u>	<u>39</u>
<u>Quiet</u>	<u>40</u>
<u>IBSS DFS</u>	<u>41</u>
ERP Information	42
Reserved	43–49
Extended Supported Rates	50
Reserved	51–255

Insert 7.3.2.15 through 7.4.1.5 after 7.3.2.14 and renumber figures and tables as appropriate:

7.3.2.15 Power Constraint element

The Power Constraint element contains the information necessary to allow a STA to determine the local maximum transmit power in the current channel. The format of the Power Constraint element is shown in Figure 46a.

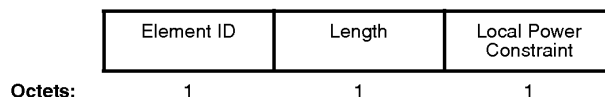


Figure 46a—Power Constraint element format

The Length field shall be set to 1.

The Local Power Constraint field shall be set to a value that allows the mitigation requirements to be satisfied in the current channel. The field is coded as an unsigned integer in units of decibels. The local maximum transmit power for a channel is thus defined as the maximum transmit power level specified for the channel in the Country element minus the local power constraint specified for the channel [from the management information base (MIB)] in the Power Constraint element.

The Power Constraint element is included in Beacon frames, as described in 7.2.3.1, and Probe Response frames, as described in 7.2.3.9. The use of Power Constraint elements is described in 11.5.2.

7.3.2.16 Power Capability element

The Power Capability element specifies the minimum and maximum transmit powers with which a STA is capable of transmitting in the current channel. The format of the Power Capability element is shown in Figure 46b.

The Length field shall be set to 2.

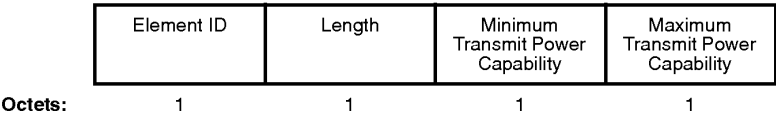


Figure 46b—Power Capability element format

The Minimum Transmit Power Capability field shall be set to the nominal minimum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a signed integer in units of decibels relative to 1 mW.

The Maximum Transmit Power Capability field shall be set to the nominal maximum transmit power with which the STA is capable of transmitting in the current channel, with a tolerance ± 5 dB. The field is coded as a signed integer in units of decibels relative to 1 mW.

The Power Capability element is included in Association Request frames, as described in 7.2.3.4, and Reassociation Request frames, as described in 7.2.3.6. The use of Power Capability elements is described in 11.5.1.

7.3.2.17 TPC Request element

The TPC Request element contains a request for a STA to report transmit power and link margin information using a TPC Report element. The format of the TPC Request element is shown in Figure 46c.



Figure 46c—TPC Request element format

The Length field shall be set to 0.

The TPC Request element is included in TPC Request frames, as described in 7.4.1.3. The use of TPC Request elements and frames is described in 11.5.4.

7.3.2.18 TPC Report element

The TPC Report element contains transmit power and link margin information sent in response to a TPC Request element. A TPC Report element is included in a Beacon frame or Probe Response frame without a corresponding request. The format of the TPC Report element is shown in Figure 46d.

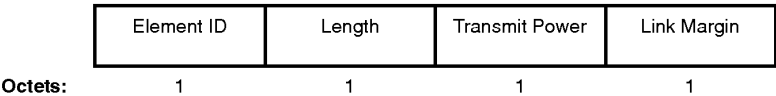


Figure 46d—TPC Report element format

The Length field shall be set to 2.

The Transmit Power field shall be set to the transmit power used to transmit the frame containing the TPC Report element. The field is coded as a signed integer in units of decibels relative to 1 mW. The maximum tolerance for the transmit power value reported in the TPC Response element shall be ± 5 dB. This tolerance is defined as the difference, in decibels, between the reported power value and the actual EIRP of the STA (measured when transmitting 1500 octet frames).

The Link Margin field contains the link margin at the time and for the rate at which the frame containing the TPC Request element was received. The field is coded as a signed integer in units of decibels. The Link Margin field shall be set to 0 and shall be ignored when a TPC Report element is included in a Beacon frame or Probe Response frame. The measurement method of Link Margin is beyond the scope of this amendment.

The TPC Report element is included in TPC Report frames, as described in 7.4.1.4; Beacon frames, as described in 7.2.3.1; and Probe Response frames, as described in 7.2.3.9. The use of TPC Report elements and frames is described in 11.5.4.

7.3.2.19 Supported Channels element

The Supported Channels element contains a list of channel subbands (from those channels defined in 17.3.8.3.3) in which a STA is capable of operating. The format of the Supported Channels element is shown in Figure 46e.

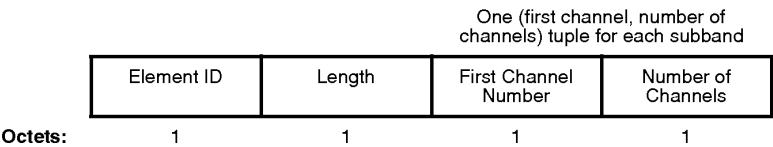


Figure 46e—Supported Channels element format

The Length field is variable and depends on the number of subbands, defined by a First Channel Number–Number of Channels pair, that are included in the element.

The First Channel Number field shall be set to the first channel (as defined in 17.3.8.3.3) in a subband of supported channels.

The Number of Channels field shall be set to the number of channels in a subband of supported channels.

The Supported Channels element is included in Association Request frames, as described in 7.2.3.4, and Reassociation Request frames, as described in 7.2.3.6. The use of the Supported Channels element is described in 11.6.1 and 11.6.7.

7.3.2.20 Channel Switch Announcement element

The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 46f.

The Length field shall be set to 3.

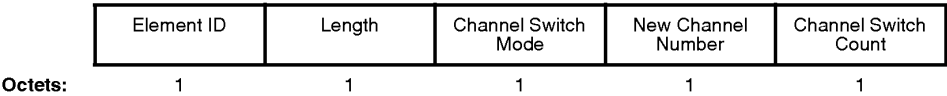


Figure 46f—Channel Switch Announcement element format

The Channel Switch Mode field indicates any restrictions on transmission until a channel switch. An AP in a BSS or a STA in an IBSS shall set the Channel Switch Mode field to either 0 or 1 on transmission. A Channel Switch Mode set to 1 means that the STA in a BSS to which the frame containing the element is addressed shall transmit no further frames within the BSS until the scheduled channel switch. A STA in an IBSS may treat a Channel Switch Mode field set to 1 as advisory. A Channel Switch Mode set to 0 does not impose any requirement on the receiving STA.

The New Channel Number field shall be set to the number of the channel to which the STA is moving (as defined in 17.3.8.3.3).

The Channel Switch Count field either shall be set to the number of target beacon transmission times (TBTTs) until the STA sending the Channel Switch Announcement element switches to the new channel or shall be set to 0. A value of 1 indicates that the switch will occur immediately before the next TBTT. A value of 0 indicates that the switch will occur at any time after the frame containing the element is transmitted.

The Channel Switch Announcement element is included in Channel Switch Announcement frames, as described in 7.4.1.5, and may be included in Beacon frames, as described in 7.2.3.1, and Probe Response frames, as described in 7.2.3.9. The use of Channel Switch Announcement elements and frames is described in 11.6.7.

7.3.2.21 Measurement Request element

The Measurement Request element contains a request that the receiving STA undertake the specified measurement action. The format of the Measurement Request element is shown in Figure 46g.

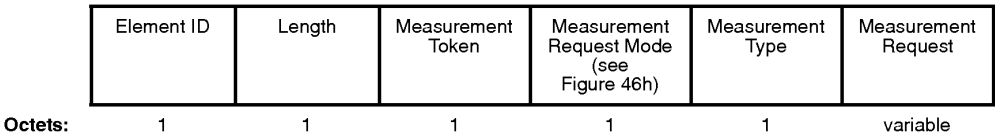


Figure 46g—Measurement Request element format

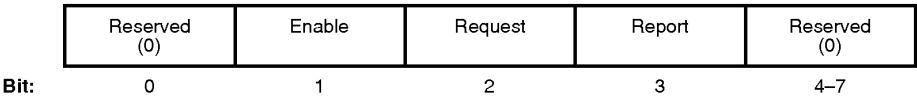


Figure 46h—Measurement Request Mode field

The Length field is variable and depends on the length of the Measurement Request field. The minimum value of the Length field is 3 (based on a minimum length for the Measurement Request field of 0 octets).

The Measurement Token shall be set to a nonzero number that is unique among the Measurement Request elements in a particular Measurement Request frame.

The Measurement Request Mode field (shown in Figure 46h) is a bit field with the following bits defined:

- Enable bit (bit 1) indicates whether this element is used to request the destination STA to enable or disable the sending of measurement requests and autonomous measurement reports of a specified type to this STA. The Enable bit shall be set to 1 when the Request bit and Report bit are valid. The Enable bit shall be set to 0 when the Request bit and Report bit are invalid.
- Request bit (bit 2) indicates whether the STA receiving the request shall enable or disable measurement requests of the type specified in the Measurement Type field. The Request bit shall be set to 1 when enabling a measurement request. The Request bit shall be set to 0 when disabling a measurement request or when the Request bit is invalid (i.e., when the Enable bit is set to 0 or when the Measurement Type field contains a reserved measurement request type value).
- Report bit (bit 3) indicates whether the STA receiving the request shall enable or disable autonomous measurement reports of the type corresponding to the measurement report specified in the Measurement Type field. The Report bit shall be set to 1 when enabling an autonomous measurement report. The Report bit shall be set to 0 when disabling an autonomous measurement report or when the Report bit is invalid (i.e., when the Enable bit is set to 0 or when the Measurement Type field contains a reserved measurement report type value).
- All other bits are reserved and shall be set to 0.

The use of the Enable, Request, and Report bits is also summarized in Table 20a. See 11.6.6 for the description of how a STA shall handle requests to enable or disable measurement requests and autonomous reports.

Table 20a—Summary of use of Enable, Request, and Report bits

Bits			Meaning of bits
Enable	Request	Report	
0	0	0	When Enable bit is set to 0, Request and Report bits are invalid and shall be set to 0.
0	0	1	Not allowed.
0	1	0	Not allowed.
0	1	1	Not allowed.
1	0	0	The transmitting STA is requesting that it be sent neither measurement requests nor autonomous measurement reports of the types indicated in the Measurement Type field.
1	1	0	The transmitting STA is indicating it will accept measurement requests and requesting it not be sent autonomous measurement reports of the types indicated in the Measurement Type field.
1	0	1	The transmitting STA is requesting it not be sent measurement requests and indicating it will accept autonomous measurement reports of the types indicated in the Measurement Type field.
1	1	1	The transmitting STA is indicating it will accept measurement requests and autonomous measurement reports of the type indicated in the Measurement Type field.

The Measurement Type field shall be set to a number that identifies a measurement request or a measurement report. The Measurement Types that have been allocated for measurement requests are shown in Table 20b and measurement reports are shown in Table 20c (in 7.3.2.22).

Table 20b—Measurement Type definitions for measurement requests

Name	Measurement Type
Basic request	0
Clear channel assessment (CCA) request	1
Receive power indication (RPI) histogram request	2
Reserved	3–255

The Measurement Request field shall be null when the Enable bit is set to 1 and shall contain the specification of the measurement request, as described in 7.3.2.21.1 through 7.3.2.21.3, when the Enable bit is set to 0.

The Measurement Request element is included in a Measurement Request frame as described in 7.4.1.1. The use of Measurement Request elements and frames is described in 11.6.6.

7.3.2.21.1 Basic request

A Measurement Type in the Measurement Request element may indicate a basic request. The response to a basic request is a basic report. It is mandatory for a STA in a BSS to generate a basic report in response to a basic request if the request is received from the AP with which it is associated, except as specified in 11.6.6. The Measurement Request field corresponding to a basic request is shown in Figure 46i.

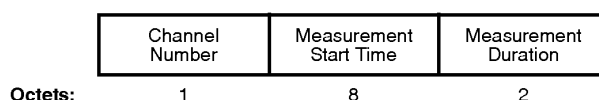


Figure 46i—Measurement Request field format for a basic request

The Channel Number field shall be set to the channel number for which the measurement request applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the timing synchronization function (TSF) timer at the time ($\pm 32\mu\text{s}$) at which the requested basic request measurement shall start. A value of 0 shall indicate it shall start immediately.

The Measurement Duration field shall be set to the duration of the requested measurement, expressed in time units (TUs).

7.3.2.21.2 CCA request

A Measurement Type in the Measurement Request element may indicate a CCA request. A response to a CCA request is a CCA report. It is optional for a STA to generate a CCA report in response to a CCA Request. The Measurement Request field corresponding to a CCA request is shown in Figure 46j.

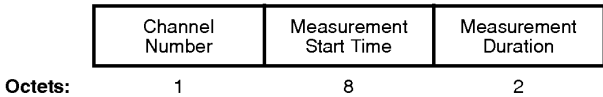


Figure 46j—Measurement Request field format for a CCA request

The Channel Number field shall be set to the channel number for which the measurement request applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the TSF at the time ($\pm 32\mu s$) at which the requested CCA request measurement shall start. A value of 0 shall indicate it shall start immediately.

The Measurement Duration field shall be set to the duration of the requested measurement, expressed in TUs.

7.3.2.21.3 RPI histogram request

A Measurement Type in the Measurement Request element may indicate an RPI histogram request. A response to an RPI histogram request is an RPI histogram report. It is optional for a STA to generate a RPI histogram report in response to a RPI histogram request. The Measurement Request field corresponding to an RPI histogram request is shown in Figure 46k.

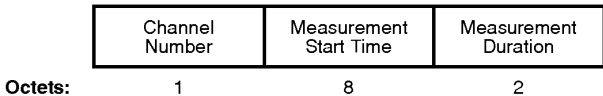


Figure 46k—Measurement Request field format for a RPI histogram request

The Channel Number field shall be set to the channel number for which the measurement request applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the TSF at the time ($\pm 32\mu s$) at which the requested RPI histogram request measurement shall start. A value of 0 shall indicate it shall start immediately.

The Measurement Duration field shall be set to the duration of the requested measurement, expressed in TUs.

7.3.2.22 Measurement Report element

The Measurement Report element contains a measurement report. The format of the Measurement Report element is shown in Figure 46l.

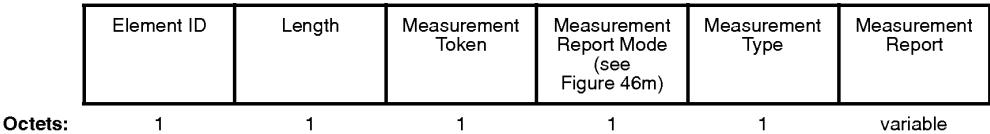


Figure 46l—Measurement Report element format

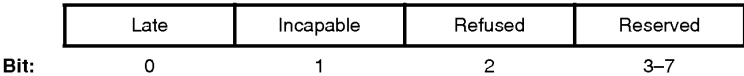


Figure 46m—Measurement Report Mode field

The Length field is variable and depends on the length of the Measurement Report field. The minimum value of the Length field is 3.

The Measurement Token field shall be set to the Measurement Token in the corresponding Measurement Request element. If the Measurement Report element is being sent autonomously, then the Measurement Token shall be set to 0.

The Measurement Report Mode field (shown in Figure 46m) is a bit field with the following bits defined:

- Late bit (bit 0) indicates whether this STA is unable to carry out a measurement request because it received the request after the requested measurement time. The Late bit shall be set to 1 to indicate the request was too late. The Late bit shall be set to 0 to indicate the request was received in time for the measurement to be executed.
- Incapable bit (bit 1) indicates whether this STA is incapable of generating a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Incapable bit shall be set to 1 to indicate the STA is incapable. The Incapable bit shall be set to 0 to indicate the STA is capable or the report is autonomous.
- Refused bit (bit 2) indicates whether this STA is refusing to generate a report of the type specified in the Measurement Type field that was previously requested by the destination STA of this Measurement Report element. The Refused bit shall be set to 1 to indicate the STA is refusing. The Refused bit shall be set to 0 to indicate the STA is not refusing or the report is autonomous.
- All other bits are reserved and shall be set to 0.

The Measurement Type field shall be set to a number that identifies the measurement report. The Measurement Types that have been allocated are shown in Table 20c.

The Measurement Report field shall be null when the Late bit is set to 1, the Incapable bit is set to 1, or the Refused bit is set to 1. Otherwise, it shall contain the specification of the measurement report, as described in 7.3.2.22.1 through 7.3.2.22.3.

The Measurement Report element is included in a Measurement Report frame as described in 7.4.1.2. The use of Measurement Report elements and frames is described in 11.6.6.

Table 20c—Measurement Type definitions for measurement reports

Name	Measurement Type
Basic report	0
CCA report	1
RPI histogram report	2
Reserved	3–255

7.3.2.22.1 Basic report

A Measurement Type in the Measurement Report element may indicate a basic report. The format of the Measurement Report field corresponding to a basic report is shown in Figure 46n. It is mandatory for a STA to support the generation of this report.

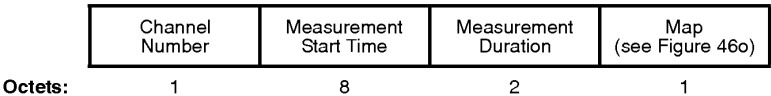


Figure 46n—Measurement Report field format for a basic report

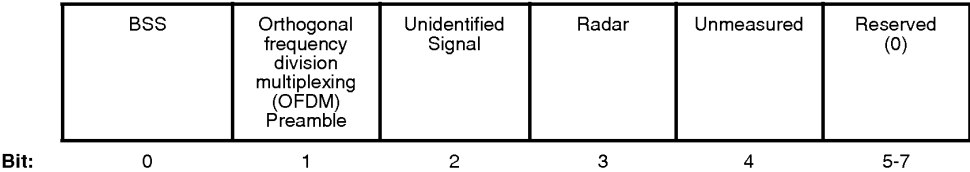


Figure 46o—Map field format

The Channel Number field shall be set to the channel number to which the basic report applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the TSF at the time ($\pm 32\mu\text{s}$) at which the basic report measurement started.

The Measurement Duration field shall be set to the duration over which the basic report was measured, expressed in TUs.

The Map field is coded as a bit field, as shown in Figure 46o, and shall contain the following bits:

- BSS bit, which shall be set to 1 when at least one valid MAC protocol data unit (MPDU) was received in the channel during the measurement period from another BSS or IBSS. Otherwise, the BSS bit shall be set to 0.
- OFDM Preamble bit, which shall be set to 1 when at least one sequence of short training symbols, as defined in 17.3.3, was detected in the channel during the measurement period without a subsequent

valid Signal field (see 17.3.4). This may indicate the presence of an OFDM preamble, such as high-performance RLAN/2 (HIPERLAN/2). Otherwise, the OFDM Preamble bit shall be set to 0.

- Unidentified Signal bit, which may be set to 1 when significant power is detected in the channel during the measurement period that cannot be characterized as radar, an OFDM preamble, or a valid MPDU. Otherwise, the Unidentified Signal bit shall be set to 0. The definition of significant power is implementation dependent.
- Radar bit, which shall be set to 1 when radar was detected operating in the channel during the measurement period. The algorithm to detect radar shall satisfy regulatory requirements and is outside the scope of this amendment. Otherwise, the Radar bit shall be set to 0.
- Unmeasured bit, which shall be set to 1 when this channel has not been measured. Otherwise, the Unmeasured bit shall be set to 0. When the Unmeasured field is set to 1, all the other bit fields shall be set to 0.

7.3.2.22.2 CCA report

A Measurement Type in the Measurement Report element may indicate a CCA report. It is optional for a STA to support the generation of this report. The format of the Measurement Report field corresponding to a CCA report is shown in Figure 46p.

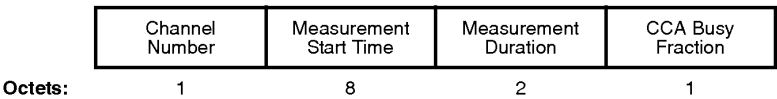


Figure 46p—Measurement Report field format for a CCA report

The Channel Number field shall contain the channel number to which the CCA report applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the TSF at the time ($\pm 32\mu\text{s}$) at which the CCA report measurement started.

The Measurement Duration field shall be set to the duration over which the CCA report was measured, expressed in TUs.

The CCA Busy Fraction field shall contain the fractional duration over which CCA indicated the channel was busy during the measurement duration. The resolution of the CCA busy measurement is in microseconds. The CCA Busy Fraction value is defined as $\text{Ceiling}(255 * [\text{Duration CCA indicated channel was busy (microseconds)}]) / (1024 * [\text{Measurement duration (TUs)}])$.

7.3.2.22.3 RPI histogram report

A Measurement Type in the Measurement Report element may indicate an RPI histogram report. It is optional for a STA to support the generation of this report. The format of the Measurement Report field corresponding to an RPI histogram report is shown in Figure 46q.

The Channel Number field shall be set to the channel number to which the RPI histogram report applies (as defined in 17.3.8.3.3).

The Measurement Start Time field shall be set to the TSF at the time ($\pm 32\mu\text{s}$) at which the RPI histogram report measurement started.

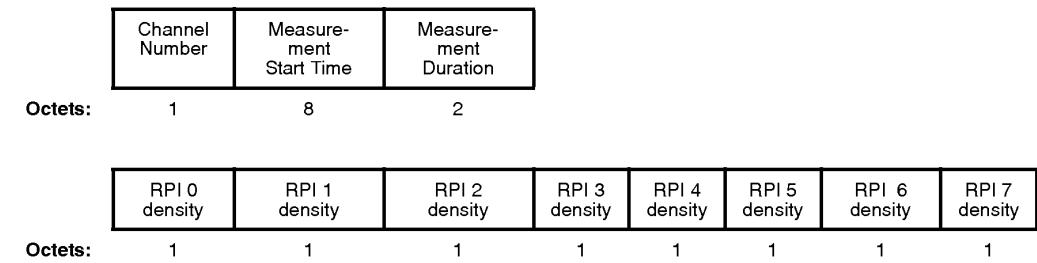


Figure 46q—Measurement Report field format for an RPI histogram report

The Measurement Duration field shall be set to the duration over which the RPI histogram report was measured, expressed in TUs.

The RPI histogram report shall contain the RPI densities observed in the channel for the eight RPI levels defined in Table 20d. To compute the RPI densities, the STA shall measure the received power level on the specified channel, as detected at the antenna connector, as a function of time over the measurement duration. The maximum tolerance of the received power measurements shall be ± 5 dB. Furthermore, the received signal power measurement should be a monotonic function of the actual power at the antenna. The time resolution of the received power measurements is in microseconds. The received power measurements are converted to a sequence of RPI values by quantizing the measurements according to Table 4. The RPI densities are then computed for each of the eight possible RPI values using Ceiling (255 * [Duration receiving at RPI value (microseconds) / (1024 * Measurement duration)]). The sum of the RPI densities will be approximately 255, but could be up to 262 because of rounding effects.

Table 20d—RPI definitions for an RPI histogram report

RPI	Power observed at the antenna (dBm)
0	Power ≤−87
1	−87 < Power ≤−82
2	−82 < Power ≤−77
3	−77 < Power ≤−72
4	−72 < Power ≤−67
5	−67 < Power ≤−62
6	−62 < Power ≤−57
7	−57 < Power

The RPI histogram report provides an additional mechanism for a STA to gather information on the state of a channel from other STAs. The STA may use this information to assist in the choice of new channel, to help avoid false radar detections, and to assess the general level of interference present on a channel.

7.3.2.23 Quiet element

The Quiet element defines an interval during which no transmission shall occur in the current channel. This interval may be used to assist in making channel measurements without interference from other STAs in the BSS or IBSS. The format of the Quiet element is shown in Figure 46r.

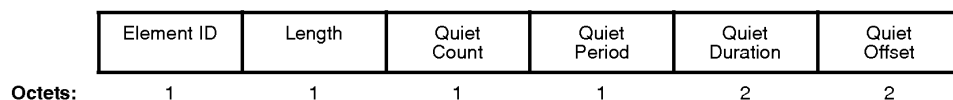


Figure 46r—Quiet element format

The Length field shall be set to 6.

The Quiet Count field shall be set to the number of TBTTs until the beacon interval during which the next quiet interval shall start. A value of 1 indicates the quiet interval will start during the beacon interval starting at the next TBTT. A value of 0 is reserved.

The Quiet Period field shall be set to the number of beacon intervals between the start of regularly scheduled quiet intervals defined by this Quiet element. A value of 0 indicates that no periodic quiet interval is defined.

The Quiet Duration field shall be set to the duration of the quiet interval, expressed in TUs.

The Quiet Offset field shall be set to the offset of the start of the quiet interval from the TBTT specified by the Quiet Count field, expressed in TUs. The value of the Quiet Offset field shall be less than one beacon interval.

The Quiet element may be included in Beacon frames, as described in 7.2.3.1, and Probe Response frames, as described in 7.2.3.9. The use of Quiet elements is described in 11.6.2.

7.3.2.24 IBSS DFS element

The IBSS DFS element contains information for DFS operation in an IBSS. The format of the IBSS DFS element is shown in Figure 46s.

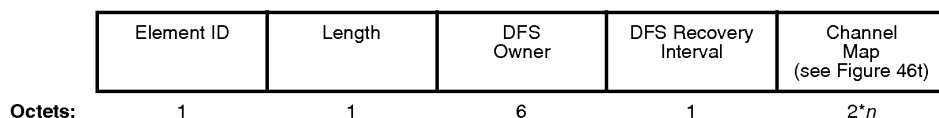


Figure 46s—IBSS DFS element format

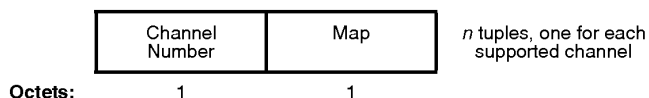


Figure 46t—Channel Map field format

The Length field is variable.

The DFS Owner field shall be set to the individual IEEE MAC address of the STA that is the currently known DFS Owner in the IBSS.

The DFS Recovery Interval field indicates the time interval that shall be used for DFS owner recovery, expressed as an integral number of beacon intervals. The DFS Recovery Interval value is static throughout the lifetime of the IBSS and is determined by the STA that starts the IBSS.

The Channel Map field shown in Figure 46t shall contain a Channel Number field and a Map field (see 7.3.2.22.1) for each channel supported by the STA transmitting the IBSS DFS element. Note that n in Figure 46s is the number of channels supported by the STA.

The IBSS DFS element may be included in Beacon frames, as described in 7.2.3.1, and Probe Response frames, as described in 7.2.3.9. The use of IBSS DFS elements is described in 11.6.7.2.

7.4 Action frame format details

This subclause describes the Action frame formats, including the Action Details field, allowed in each of the action categories defined in Table 19a in 7.3.1.11.

7.4.1 Spectrum management action details

Five Action frame formats are defined for spectrum management. An Action field, in the octet field immediately after the Category field, differentiates the five formats. The Action field values associated with each frame format are defined in Table 20e.

Table 20e—Spectrum management Action field values

Action field value	Description
0	Measurement Request
1	Measurement Report
2	TPC Request
3	TPC Report
4	Channel Switch Announcement
5–255	Reserved

7.4.1.1 Measurement Request frame format

The Measurement Request frame uses the Action frame body format and is transmitted by a STA requesting another STA to measure one or more channels. The format of the Measurement Request frame body is shown in Figure 46u.

The Category field shall be set to 0 (representing spectrum management).

The Action field shall be set to 0 (representing a Measurement Request frame).

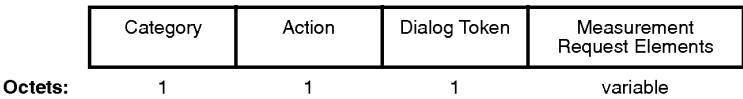


Figure 46u—Measurement Request frame body format

The Dialog Token field shall be set to a nonzero value chosen by the STA sending the measurement request to identify the request/report transaction.

The Measurement Request Elements field shall contain one or more of the Measurement Request elements described in 7.3.2.21. The number and length of the Measurement Request elements in a Measurement Request frame is limited by the maximum allowed MAC management PDU (MMPDU) size.

7.4.1.2 Measurement Report frame format

The Measurement Report frame uses the Action frame body format and is transmitted by a STA in response to a Measurement Request frame or by a STA autonomously providing measurement information. The format of the Measurement Report frame body is shown in Figure 46v.

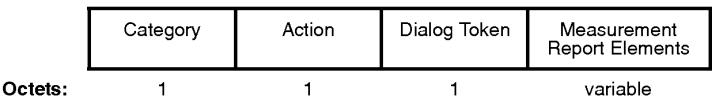


Figure 46v—Measurement Report frame body format

The Category field shall be set to 0 (representing spectrum management).

The Action field shall be set to 1 (representing a Measurement Report frame).

The Dialog Token field shall be set to the value in any corresponding Measurement Request frame. If the Measurement Report frame is not being transmitted in response to a Measurement Request frame, then the Dialog token shall be set to 0.

The Measurement Report Elements field shall contain one or more of the Measurement Report elements described in 7.3.2.22. The number and length of the Measurement Report elements in a Measurement Report frame is limited by the maximum allowed MMPDU size.

7.4.1.3 TPC Request frame format

The TPC Request frame uses the Action frame body format and is transmitted by a STA requesting another STA for transmit power and link margin information. The format of the TPC Request frame body is shown in Figure 46w.

The Category field shall be set to 0 (representing spectrum management).

The Action field shall be set to 2 (representing a TPC Request frame).

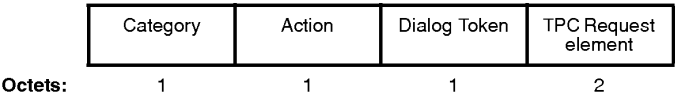


Figure 46w—TPC Request frame body format

The Dialog Token field shall be set to a nonzero value chosen by the STA sending the request to identify the transaction.

The TPC Request element shall be set as described in 7.3.2.17.

7.4.1.4 TPC Report frame format

The TPC Report frame uses the Action frame body format and is transmitted by a STA in response to a TPC Request frame. The format of the TPC Report frame body is shown in Figure 46x.

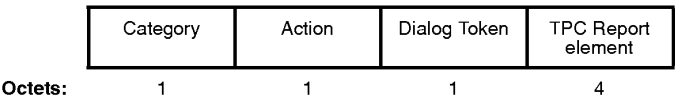


Figure 46x—TPC Report frame body format

The Category field shall be set to 0 (representing spectrum management).

The Action field shall be set to 3 (representing a TPC Report frame).

The Dialog Token field shall be set to the Dialog Token value in the corresponding TPC Request frame.

The TPC Report element shall be set as described 7.3.2.18.

7.4.1.5 Channel Switch Announcement frame format

The Channel Switch Announcement frame uses the Action frame body format and is transmitted by an AP in a BSS or a STA in an IBSS to advertise a channel switch. The format of the Channel Switch Announcement frame body is shown in Figure 46y.

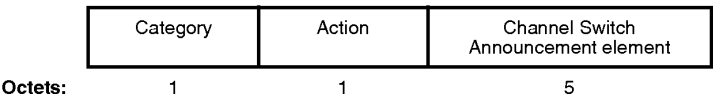


Figure 46y—Channel Switch Announcement frame body format

The Category field shall be set to 0 (representing spectrum management).

The Action field shall be set to 4 (representing a Channel Switch Announcement frame).

The Channel Switch Announcement element shall be set as described 7.3.2.20.

9. MAC sublayer functional description

9.2 Distributed coordination function (DCF)

9.2.3 Interframe space (IFS)

9.2.3.2 Point coordination function (PCF) IFS (PIFS)

Change the first paragraph of 9.2.3.2 as follows:

The PIFS shall be used only by STAs operating under the PCF to gain priority access to the medium at the start of the contention-free period (CFP) or by a STA to transmit a Channel Switch Announcement frame. A STA using the PCF shall be allowed to transmit CF traffic after its carrier sense (CS) mechanism (see 9.2.1) determines that the medium is idle at the TxPIFS slot boundary as defined in 9.2.10. A STA may also transmit a Channel Switch Announcement frame after its CS mechanism (see 9.2.1) determines that the medium is idle at the TxPIFS slot boundary. The use of the PIFS by STAs operating under the PCF is described in 9.3. The use of PIFS by STAs transmitting a Channel Switch Announcement frame is described in 11.6.7.1.

10. Layer management

10.3 MAC sublayer management entity (MLME) service access point (SAP) interface

10.3.2 Scan

10.3.2.2 MLME-SCAN.confirm

10.3.2.2.2 Semantics of the service primitive

Insert the following elements at the end of the untitled table listing the elements of BSSDescription in 10.3.2.2.2:

Name	Type	Valid range	Description
Country	As defined in the Country element	As defined in the Country element	The information required to identify the regulatory domain in which the STA is located and to configure its physical layer (PHY) for operation in that regulatory domain. Present only when TPC functionality is required, as specified in 11.5, or when dot11MultiDomainCapabilityEnabled is true.
IBSS DFS Recovery Interval	Integer	1–255	Only present if BSSType = INDEPENDENT. The time interval that shall be used for DFS recovery. Present only when DFS functionality is required, as specified in 11.6.

10.3.6 Associate

10.3.6.1 MLME-ASSOCIATE.request

10.3.6.1.2 Semantics of the service primitive

Change the following primitive parameter list in 10.3.6.1.2:

```
MLME-ASSOCIATE.request(
    PeerSTAAddress,
    AssociateFailureTimeout,
    CapabilityInformation,
    ListenInterval,
    Supported Channels
)
```

Insert the following row at the end of the untitled table defining the primitive parameters in 10.3.6.1.2:

Name	Type	Valid range	Description
Supported Channels	As defined in the Supported Channels element	As defined in the Supported Channels element	The list of channels in which the STA is capable of operating. Present only when DFS functionality is required, as specified in 11.6.

10.3.7 Reassociate

10.3.7.1 MLME-REASSOCIATE.request

10.3.7.1.2 Semantics of the service primitive

Change the following primitive parameter list in 10.3.7.1.2:

```
MLME-REASSOCIATE.request(
    NewAPAddress,
    ReassociateFailureTimeout,
    CapabilityInformation,
    ListenInterval,
    Supported Channels
)
```

Insert the following row at the end of the untitled table defining the primitive parameters in 10.3.7.1.2:

Name	Type	Valid range	Description
Supported Channels	As defined in the Supported Channels element	As defined in the Supported Channels element	The list of channels in which the STA is capable of operating. Present only when DFS functionality is required, as specified in 11.6.

10.3.10 Start

10.3.10.1 MLME-START.request

10.3.10.1.2 Semantics of the service primitive

Change the following primitive parameter list in 10.3.10.1.2:

```
MLME-START.request(
    SSID,
    BSSType,
    BeaconPeriod,
    DTIMPeriod,
    CF parameter set,
    PHY parameter set,
    IBSS parameter set,
    ProbeDelay,
    CapabilityInformation,
    BSSBasicRateSet,
    OperationalRateSet,
    Country,
    IBSS DFS Recovery Interval
)
```

Insert the following rows at the end of the untitled table defining the primitive parameters in 10.3.10.1.2:

Name	Type	Valid range	Description
Country	As defined in the Country element	As defined in the Country element	The information required to identify the regulatory domain in which the STA is located and to configure its PHY for operation in that regulatory domain. Present only when TPC functionality is required, as specified in 11.5, or when dot11MultiDomainCapabilityEnabled is true.
IBSS DFS Recovery Interval	Integer	1–255	Present only if BSSType = INDEPENDENT. The time interval that shall be used for DFS recovery. Present only when DFS functionality is required, as specified in 11.6.

Insert 10.3.11 through 10.3.16.2.4 after 10.3.10.2.4 as follows:

10.3.11 Spectrum management protocol layer model

The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and station management entity (SME). This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 67a).

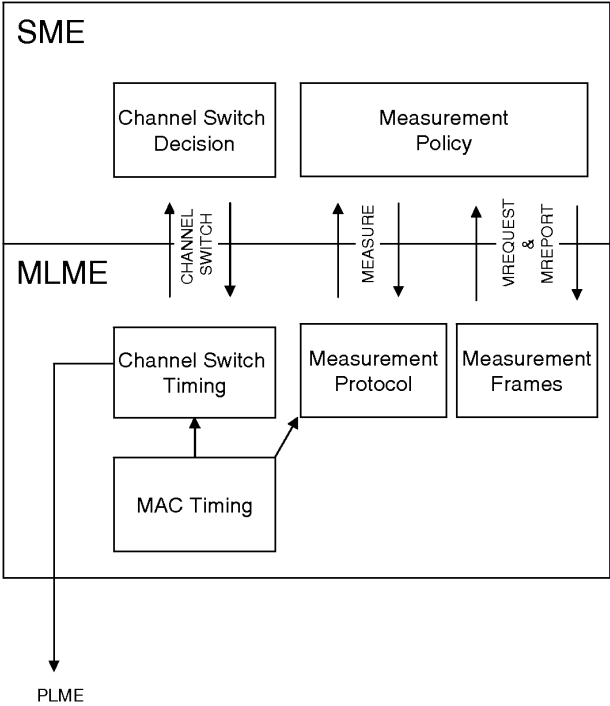


Figure 67a—Layer management model

The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 67b and Figure 67c depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 67d illustrates the TPC adaptation process. Lastly, Figure 67e depicts the management process for a channel switch using a Channel Switch Announcement frame.

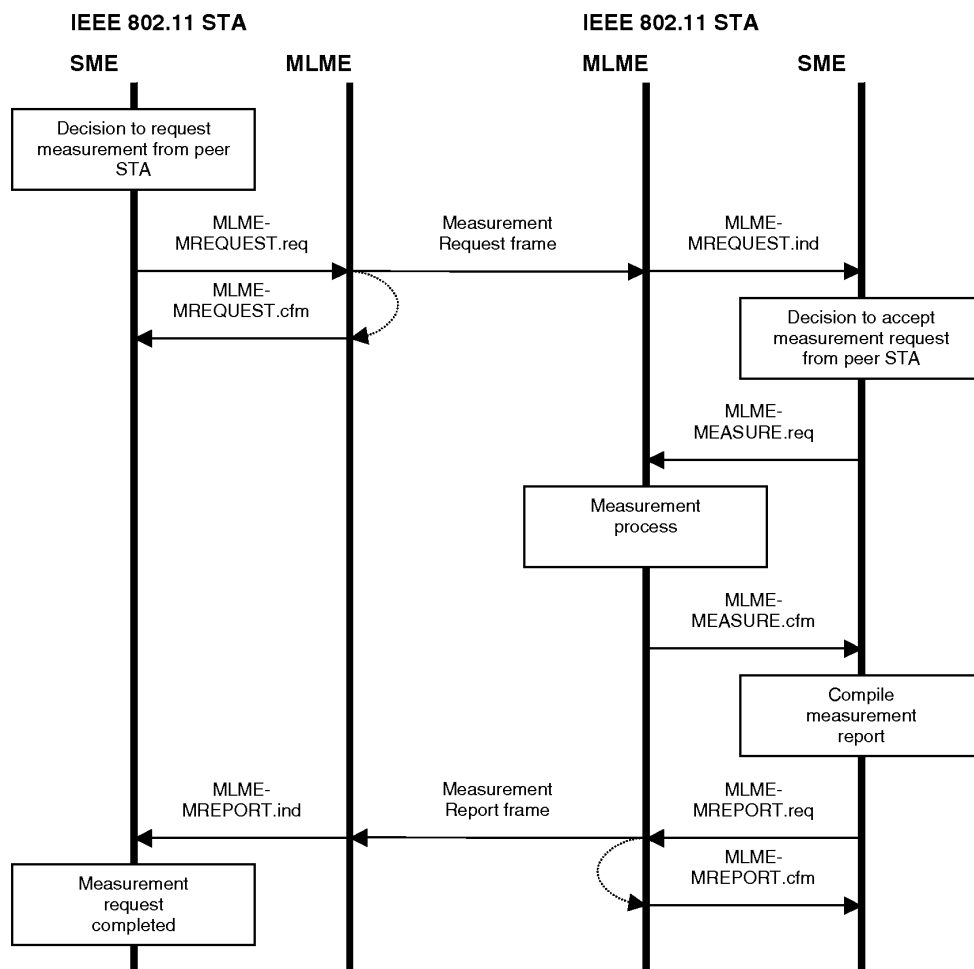


Figure 67b—Measurement request—accepted

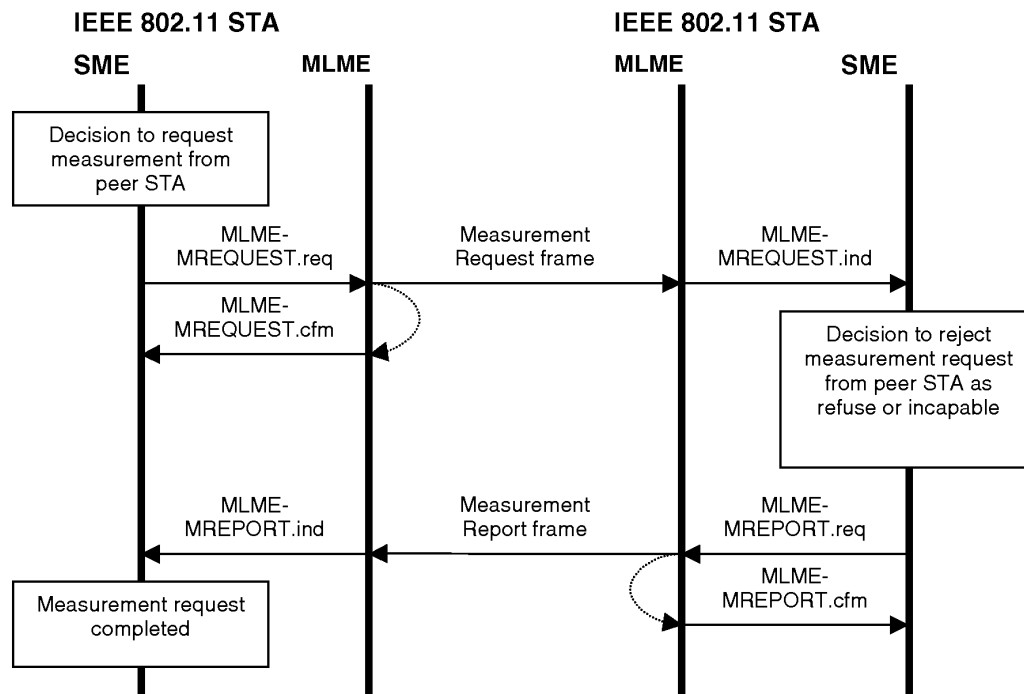


Figure 67c—Measurement request - rejected

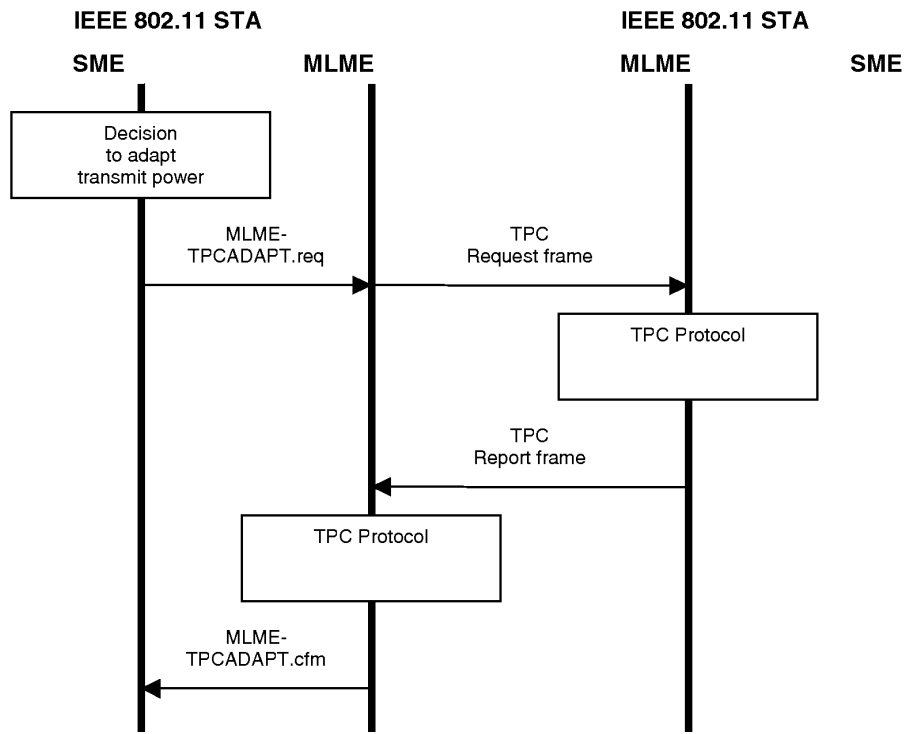


Figure 67d—TPC adaptation

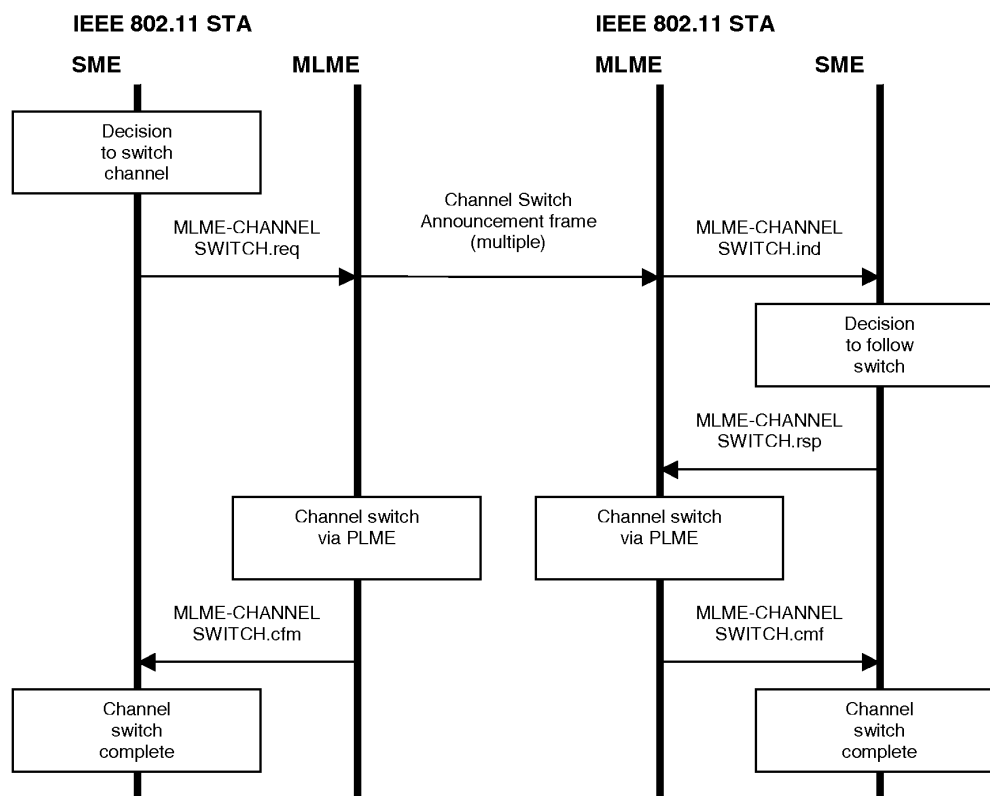


Figure 67e—Channel switch

10.3.12 Measurement request

This set of primitives supports the signaling of measurement requests between peer SMEs.

10.3.12.1 MLME-MREQUEST.request

10.3.12.1.1 Function

This primitive requests the transmission of a measurement request to a peer entity.

10.3.12.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```

MLME-MREQUEST.request(
    Peer MAC Address,
    Dialog Token,
    Measurement Request Set
)
    
```

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual or group MAC Address	The address of the peer MAC entity to which the measurement request shall be set.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element	Set of measurement requests, each as defined in the Measurement Request element	A set of measurement requests, each containing a Measurement Token, Measurement Request Mode, Measurement Type, and a Measurement Request.

10.3.12.1.3 When generated

This primitive is generated by the SME to request that a Measurement Request frame be sent to a peer entity to initiate one or more measurements.

10.3.12.1.4 Effect of receipt

On receipt of this primitive, the MLME shall construct a Measurement Request frame containing the set of Measurement Request elements specified. This frame shall then be scheduled for transmission.

10.3.12.2 MLME-MREQUEST.confirm

10.3.12.2.1 Function

This primitive reports the result of a request to send a Measurement Request frame.

10.3.12.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MREQUEST.confirm(
    ResultCode
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID PARAMETERS, or UNSPECIFIED FAILURE	Reports the outcome of a request to send a Measurement Request frame.

10.3.12.2.3 When generated

This primitive is generated by the MLME when the request to transmit a Measurement Request frame completes.

10.3.12.2.4 Effect of receipt

On receipt of this primitive, the SME shall evaluate the result code.

10.3.12.3 MLME-MREQUEST.indication

10.3.12.3.1 Function

This primitive indicates that a Measurement Request frame has been received requesting the measurement of one or more channels.

10.3.12.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MREQUEST.indication(
    Peer MAC Address,
    Dialog Token,
    Measurement Request Set
)
```

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual Address	The address of the peer MAC entity from which the measurement request was received.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element	Set of measurement requests, each as defined in the Measurement Request element	A set of measurement requests, each containing a Measurement Token, Measurement Request Mode, Measurement Type, and a Measurement Request.

10.3.12.3.3 When generated

This primitive is generated by the MLME when a valid Measurement Request frame is received.

10.3.12.3.4 Effect of receipt

On receipt of this primitive, the SME shall either reject the request or commence the requested measurements.

10.3.13 Channel measurement

This set of primitives supports the requesting and reporting of measurement data.

10.3.13.1 MLME-MEASURE.request

10.3.13.1.1 Function

This primitive is generated by the SME to request that the MLME initiate specified measurements.

10.3.13.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MEASURE.request(
    Dialog Token,
    Measurement Request Set
)
```

Name	Type	Valid range	Description
Dialog Token	Integer	0–255	The Dialog Token to identify the measurement transaction.
Measurement Request Set	Set of measurement requests, each as defined in the Measurement Request element	Set of measurement requests, each as defined in the Measurement Request element	A set of measurement requests, each containing a Measurement Token, Measurement Request Mode, Measurement Type, and a Measurement Request.

10.3.13.1.3 When generated

This primitive is generated by the SME to request that the MLME initiate the specified measurements.

10.3.13.1.4 Effect of receipt

On receipt of this primitive, the MLME shall commence the measurement process.

10.3.13.2 MLME-MEASURE.confirm

10.3.13.2.1 Function

This primitive reports the result of a measurement.

10.3.13.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MEASURE.confirm(
    ResultCode,
    Dialog Token,
    Measurement Report Set
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID PARAMETERS, or UNSPECIFIED FAILURE	The outcome of the measurement request.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element	Set of measurement reports, each as defined in the Measurement Report element	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and a Measurement Report.

10.3.13.2.3 When generated

This primitive is generated by the MLME to report the results when a measurement set completes.

10.3.13.2.4 Effect of receipt

On receipt of this primitive, the SME shall evaluate the result code and, if appropriate, shall store the channel measurements pending communication to the requesting entity or for local use.

10.3.14 Measurement report

This set of primitives supports the signaling of measurement reports.

10.3.14.1 MLME-MREPORT.request

10.3.14.1.1 Function

This primitive supports the signaling of measurement reports between peer SMEs.

10.3.14.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MREPORT.request(
    Peer MAC Address,
    Dialog Token,
    Measurement Report Set
)
```

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual MAC Address	The address of the peer MAC entity to which the measurement report shall be set.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction. Set to 0 for an autonomous report.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element	Set of measurement reports, each as defined in the Measurement Report element	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and a Measurement Report.

10.3.14.1.3 When generated

This primitive is generated by the SME to request that a frame be sent to a peer entity to report the results of measuring one or more channels.

10.3.14.1.4 Effect of receipt

On receipt of this primitive, the MLME shall construct a Measurement Report frame containing the set of measurement reports. This frame shall then be scheduled for transmission.

10.3.14.2 MLME-MREPORT.confirm

10.3.14.2.1 Function

This primitive reports the result of a request to send a Measurement Report frame.

10.3.14.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-MREPORT.confirm(
    ResultCode
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID PARAMETERS, or UNSPECIFIED FAILURE	Reports the outcome of a request to send a Measurement Request frame.

10.3.14.2.3 When generated

This primitive is generated by the MLME when the request to transmit a Measurement Report frame completes.

10.3.14.2.4 Effect of receipt

On receipt of this primitive, the SME shall evaluate the result code.

10.3.14.3 MLME-MREPORT.indication

10.3.14.3.1 Function

This primitive indicates that a Measurement Report frame has been received from a peer entity. This management report may be in response to an earlier measurement request (e.g., MLME-MREQUEST.request) or may be an autonomous report.

10.3.14.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-MREPORT.indication(
 Peer MAC Address,
 Dialog Token,
 Measurement Report Set
)

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual MAC Address	The address of the peer MAC entity from which the Measurement Report frame was received.
Dialog Token	Integer	0–255	The dialog token to identify the measurement transaction. Set to 0 for an autonomous report.
Measurement Report Set	Set of measurement reports, each as defined in the Measurement Report element	Set of measurement reports, each as defined in the Measurement Report element	A set of measurement reports, each containing a Measurement Token, Measurement Report Mode, Measurement Type, and a Measurement Report.

10.3.14.3.3 When generated

This primitive is generated by the MLME when a valid Measurement Report frame is received.

10.3.14.3.4 Effect of receipt

On receipt of this primitive, measurement data may be available for SME processes, such as channel selection.

10.3.15 Channel switch

10.3.15.1 MLME-CHANNELSWITCH.request

10.3.15.1.1 Function

This primitive requests a switch to a new operating channel.

10.3.15.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSWITCH.request(
    Mode,
    Channel Number,
    Channel Switch Count
)
```

Name	Type	Valid range	Description
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.3.3	Specifies the new channel number.
Channel Switch Count	Integer	0–255	Specifies the number of TBTTs until the channel switch event, as described for the Channel Switch Announcement element.

10.3.15.1.3 When generated

This primitive is generated by the SME to schedule a channel switch and announce this switch to peer entities in the BSS.

10.3.15.1.4 Effect of receipt

On receipt of this primitive, the MLME shall schedule the channel switch event and announce this switch to other STAs in the BSS using the Channel Switch Announcement frame or element. The MLME shall ensure the timing of frame transmission takes into account the activation delay. The actual channel switch may be achieved at the appropriate time through the MLME-PLME interface using the PLME-SET primitive of the dot11CurrentFrequency MIB attribute.

10.3.15.2 MLME-CHANNELSWITCH.confirm

10.3.15.2.1 Function

This primitive reports the result of a request to switch channel.

10.3.15.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSWITCH.confirm(
    ResultCode
)
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID PARAMETERS, or UNSPECIFIED FAILURE	Reports the result of a channel switch request.

10.3.15.2.3 When generated

This primitive is generated by the MLME when a channel switch request completes. Possible unspecified failure causes include an inability to schedule a channel switch announcement.

10.3.15.2.4 Effect of receipt

The SME is notified of the results of the channel switch procedure.

10.3.15.3 MLME-CHANNELSWITCH.indication

10.3.15.3.1 Function

This primitive indicates that a channel switch announcement has been received from a peer entity.

10.3.15.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-CHANNELSWITCH.indication(
 Peer MAC Address,
 Mode,
 Channel Number,
 Channel Switch Count
)

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual MAC Address	The address of the peer MAC entity from which the Measurement Report frame was received.
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.3.3	Specifies the new channel number.
Channel Switch Count	Integer	0–255	Specifies the number of TBTTs until the channel switch event, as described for the Channel Switch Announcement element.

10.3.15.3.3 When generated

This primitive is generated by the MLME when a valid Channel Switch Announcement frame is received.

10.3.15.3.4 Effect of receipt

On receipt of this primitive, the SME shall decide whether to accept the switch.

10.3.15.4 MLME-CHANNELSWITCH.response

10.3.15.4.1 Function

This primitive is used to schedule an accepted channel switch.

10.3.15.4.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-CHANNELSWITCH.response(
    Mode,
    Channel Number,
    Channel Switch Count
)
```

Name	Type	Valid range	Description
Mode	Integer	0, 1	Channel switch mode, as defined for the Channel Switch Announcement element.
Channel Number	Integer	As defined in 17.3.8.3.3	Specifies the new channel number.
Channel Switch Count	Integer	0–255	Specifies the number of TBTTs until the channel switch event, as described for the Channel Switch Announcement element.

10.3.15.4.3 When generated

This primitive is generated by the SME to schedule an accepted channel switch request.

10.3.15.4.4 Effect of receipt

On receipt of this primitive, the MLME shall schedule the channel switch. The actual channel switch may be achieved at the appropriate time through the MLME-PLME interface using the PLME-SET primitive of the dot11CurrentFrequency MIB attribute.

10.3.16 TPC request

This set of primitives supports the adaptation of transmit power between peer entities as described in 11.5.4.

10.3.16.1 MLME-TPCADAPT.request

10.3.16.1.1 Function

This primitive supports the adaptation of transmit power between peer entities as specified in 11.5.4.

10.3.16.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TPCADAPT.request(
Peer MAC Address,
Dialog Token
)

Name	Type	Valid range	Description
Peer MAC Address	MACAddress	Any valid individual or group MAC Address	The address of the peer MAC entity to which the TPC request shall be set.
Dialog Token	Integer	0–255	The dialog token to identify the TPC transaction.

10.3.16.1.3 When generated

This primitive is generated by the SME to request that a TPC Request frame be sent to a peer entity to request that entity to report transmit power and link margin information.

10.3.16.1.4 Effect of receipt

On receipt of this primitive, the MLME shall construct a TPC Request frame. This frame shall then be scheduled for transmission.

10.3.16.2 MLME-TPCADAPT.confirm

10.3.16.2.1 Function

This primitive reports the result of the TPC adaptation procedure.

10.3.16.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-TPCADAPT.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID PARAMETERS, or UNSPECIFIED FAILURE	Reports the outcome of a request to send a TPC Request frame.

10.3.16.2.3 When generated

This primitive is generated by the MLME when the TPC adaptation procedure completes.

10.3.16.2.4 Effect of receipt

The SME is notified of the results of the TCP adaptation procedure.

11. MLME

Insert 11.5 through 11.6.7.2 after 11.4 as follows and renumber figures and tables, as appropriate:

11.5 TPC procedures

ERC/DEC/(99)23 requires RLANs operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. This amendment describes such a mechanism, referred to as transmit power control (TPC).

This subclause describes TPC procedures that may be used to satisfy these and similar future regulatory requirements in Europe. The procedures may also satisfy comparable needs in other regulatory domains and other frequency bands and may be useful for other purposes (e.g., reduction of interference, range control, reduction of power consumption).

STAs shall use the TPC procedures defined in this subclause if dot11SpectrumManagementRequired is true. dot11SpectrumManagementRequired shall be set to TRUE when regulatory authorities require TPC. It may also be set to TRUE in other circumstances. The TPC procedures provide for the following:

- Association of STAs with an AP in a BSS based on the STA's power capability (see 11.5.1).
- Specification of regulatory and local maximum transmit power levels for the current channel (see 11.5.2).
- Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory and local requirements (see 11.5.3).
- Adaptation of transmit power based on a range of information, including path loss and link margin estimates (see 11.5.4).

For the purposes of TPC, the following statements apply:

- A STA with dot11SpectrumManagementRequired set to TRUE shall not operate in a BSS or IBSS unless the Spectrum Management bit is set to 1 in the Capability Information field in Beacon frames and Probe Response frames received from other STAs in the BSS or IBSS, *with the following exception.*

- A STA may operate when the Spectrum Management bit is set to 0 if the STA can determine that it is in a regulatory domain that does not require TPC or can ensure that it will meet regulatory requirements even if TPC is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the beacon, user confirmation, or configuration information within the device. Potential methods to ensure regulations are met even if TPC is not employed include using a transmit power that is below the legal maximum (including any mitigation factor).
- A STA shall set dot11SpectrumManagementRequired to TRUE before associating with a BSS or IBSS in which the Spectrum Management bit is set to 1 in the Capability Information field in Beacon frames and Probe Response frames received from the BSS or IBSS.
- APs may allow association of devices that do not have the Spectrum Management bit set to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from the STA to account for the existence of legacy devices that do not support TPC, but do meet regulatory requirements.

11.5.1 Association based on transmit power capability

A STA shall provide an AP with its minimum and maximum transmit power capability for the current channel when associating or reassociating, using a Power Capability element in Association Request frames or Reassociation Request frames.

An AP may use the minimum and maximum transmit power capability of associated STAs as an input into the algorithm used to determine the local transmit power constraint for any BSS it maintains. The specification of the algorithm is beyond the scope of this amendment.

An AP may reject an association or reassociation request from a STA if it considers the STA's minimum or maximum transmit power capability is unacceptable. For example, a STA's power capability might be unacceptable if it violates local regulatory constraints or increases the probability of hidden stations by a significant degree. The criteria for accepting or rejecting an association or reassociation on the basis of transmit power capability are beyond the scope of this amendment.

11.5.2 Specification of regulatory and local maximum transmit power levels

A STA shall determine a regulatory maximum transmit power for the current channel. The STA shall use the minimum of the following:

- Any regulatory maximum transmit power received in a Country element from the AP in its BSS or another STA in its IBSS and
- Any regulatory maximum transmit power for the channel in the current regulatory domain known by the STA from other sources.

A STA shall determine a local maximum transmit power for the current channel. The STA shall use the minimum of the following:

- Any local maximum transmit power received in the combination of a Country element and a Power Constraint element from the AP in its BSS or another STA in its IBSS and
- Any local maximum transmit power for the channel regulatory domain known by the STA from other sources.

Any calculation of the local maximum transmit power for the channel shall ensure the mitigation requirements for the channel in the current regulatory domain can be satisfied. The conservative approach is to set the local maximum transmit power level equal to the regulatory maximum transmit power level minus the mitigation requirement. However, it may be possible to satisfy the mitigation requirement using a higher local maximum transmit power level. A lower local maximum transmit power level may be used for other purposes (e.g., range control, reduction of interference).

The regulatory and local maximum transmit powers may change in a STA during the life of a BSS. However, network stability should be considered when deciding how often or by how much these maximums are changed. The regulatory and local maximum transmit powers shall not change during the life of an IBSS.

An AP in a BSS and a STA in an IBSS shall advertise the regulatory maximum transmit power for the current channel in Beacon frames and Probe Response frames using a Country element. An AP in a BSS and a STA in an IBSS shall advertise the local maximum transmit power for the current channel in Beacon frames and Probe Response frames using the combination of a Country element and a Power Constraint element.

11.5.3 Selection of a transmit power

A STA may select any transmit power for transmissions in a channel within the following constraints:

- A STA shall determine a regulatory maximum transmit power and a local maximum transmit power for a channel in the current regulatory domain before transmitting in the channel.
- An AP shall use a transmit power less than or equal to the regulatory maximum transmit power level for the channel. However, the AP shall also ensure the regulatory mitigation requirement is met.
- A STA that is not an AP shall use a transmit power less than or equal to the local maximum transmit power level for the channel.

11.5.4 Adaptation of the transmit power

A STA may use any criteria, and in particular any path loss and link margin estimates, to dynamically adapt the transmit power for transmissions of an MPDU to another STA. The adaptation methods or criteria are beyond the scope of this amendment.

A STA may use a TPC Request frame to request another STA to respond with a TPC Report frame containing link margin and transmit power information. A STA receiving a TPC Request frame shall respond with a TPC Report frame containing the power used to transmit the response in the Transmit Power field and the estimated link margin in a Link Margin field.

An AP in a BSS or a STA in an IBSS shall autonomously include a TPC Report element with the Link Margin field set to 0 and containing transmit power information in the Transmit Power field in any Beacon frame or Probe Response frame it transmits.

11.6 DFS procedures

ERC/DEC/(99)23 requires RLANs operating in the 5 GHz band to implement a mechanism to avoid co-channel operation with radar systems and to ensure uniform utilization of available channels. This amendment describes such a mechanism, referred to as dynamic frequency selection (DFS).

This subclause describes DFS procedures that may be used to satisfy these and similar future regulatory requirements in Europe. The procedures may also satisfy comparable needs in other regulatory domains and frequency bands and may be useful for other purposes.

STAs shall use the DFS procedures defined in this subclause if dot11SpectrumManagementRequired is true. dot11SpectrumManagementRequired shall be set to TRUE when regulatory authorities require DFS. It may also be set to TRUE in other circumstances. The DFS procedures provide for the following:

- Associating STAs with an AP in a BSS based on the STAs' supported channels (see 11.6.1).
- Quieting the current channel so it can be tested for the presence of radar with less interference from other STAs (see 11.6.2).
- Testing channels for radar before using a channel and while operating in a channel (see 11.6.3).

- Discontinuing operations after detecting radar in the current channel to avoid further interfering with the radar (see 11.6.4).
- Detecting radar in the current and other channels based on regulatory requirements (see 11.6.5).
- Requesting and reporting measurements in the current and other channels (see 11.6.6).
- Selecting and advertising a new channel to assist the migration of a BSS or IBSS after radar is detected (see 11.6.7).

For the purposes of DFS, the following statements apply:

- A STA with dot11SpectrumManagementRequired set to TRUE shall not operate in a BSS or IBSS unless the Spectrum Management bit is set to 1 in the Capability Information field in Beacon frames and Probe Response frames received from other STAs in the BSS or IBSS, *with the following exception*.
- A STA may operate when the Spectrum Management bit is set to 0 if the STA can determine that it is in a regulatory domain that does not require DFS or can ensure that it will meet regulatory requirements even if DFS is not employed. Potential methods for determining the regulatory domain include receiving a country indication in the beacon, user confirmation, or configuration information within the device. Potential methods to ensure regulations are met even if DFS is not employed include independently detecting radar and ceasing operation on channels on which radar is detected.
- A STA shall set dot11SpectrumManagementRequired to TRUE before associating with a BSS or IBSS in which the Spectrum Management bit is set to 1 in the Capability Information field in Beacon frames and Probe Response frames received from the BSS or IBSS.
- APs may allow association of devices that do not have the Spectrum Management bit set to 1 in the Capability Information field in Association Request frames and Reassociation Request frames received from a STA to account for the existence of legacy devices that do not support DFS, but do meet regulatory requirements.

11.6.1 Association based on supported channels

A STA shall provide an AP with a list of the channels in which it can operate when associating or reassociating using a Supported Channels element in Association Request frames or Reassociation Request frames.

An AP may use the supported channels list for associated STAs as an input into an algorithm used to select a new channel for the BSS. The specification of the algorithm is beyond the scope of this amendment.

An AP may reject an association or reassociation request from a STA if it considers the STA's supported channel list is unacceptable. For example, a STA's supported channel list might be unacceptable if it can operate only in a limited number of channels. The criteria for accepting or rejecting associations or reassociations are beyond the scope of this amendment.

11.6.2 Quieting channels for testing

An AP in a BSS may schedule quiet intervals by transmitting one or more Quiet elements in Beacon frames and Probe Response frames. The AP may stop scheduling quiet intervals or change the value of the Quiet Period field, the Quiet Duration field, and the Quiet Offset field in Quiet elements as required. Only the most recently received Beacon frame or Probe Response frame defines all future quiet intervals; therefore, quiet intervals based on older Beacon frames or Probe Response frames shall be discarded.

Only the STA starting an IBSS may specify a schedule of quiet intervals, by transmitting one or more Quiet elements in the first Beacon frame establishing the IBSS. All STAs in an IBSS shall continue these quiet interval schedules by including appropriate Quiet elements in any transmitted Beacon frames or Probe Response frames.

Multiple independent quiet intervals may be scheduled, to ensure that not all quiet intervals have the same timing relationship to TBTT, by including multiple Quiet elements in Beacon frames or Probe Response frames.

Control of the channel is lost at the start of a quiet interval, and the network allocation vector (NAV) is set by all the STAs in the BSS or IBSS for the length of the quiet interval. Transmission of any MPDU and any associated acknowledgment shall be complete before the start of the quiet interval. If, before starting transmission of an MPDU, there is not enough time remaining to allow the transmission to complete before the quiet interval starts, the STA shall defer the transmission by selecting a random backoff time, using the present contention window (CW) (without advancing to the next value in the series). The short retry counter and long retry counter for the MSDU are not affected.

11.6.3 Testing channels for radars

A STA shall not transmit in a channel unless it has been tested for the presence of radars according to regulatory requirements (see ETSI EN 301 893).

11.6.4 Discontinuing operations after detecting radars

If a STA is operating in a channel and detects radar operating in the channel or accepts that another STA has detected radar operating in the channel then the STA shall discontinue transmissions according to regulatory requirements (see ETSI EN 301 893).

11.6.5 Detecting radars

The methods to detect radars operating in a channel that satisfy regulatory requirements (see ETSI EN 301 893) are beyond the scope of this amendment.

11.6.6 Requesting and reporting of measurements

A STA may measure one or more channels itself or a STA may request other STAs in the same BSS or IBSS to measure one or more channels on its behalf, either in a quiet interval or during normal operation.

When requesting other STAs to measure one or more channels, a STA shall use a Measurement Request frame containing one or more Measurement Request elements. The measurement request may be sent to an individual or group destination address. Addressing requests to multiple STAs should be used with care to avoid a reply storm.

The measurement requests effectively allowed by these rules are shown in Table 26a.

Table 26a—Allowed measurement requests

Service set	Source of request	Destination of request	Type of measurement request allowed
BSS	AP	STA	Individual or group
	STA	AP	Individual only
	STA	STA	None
IBSS	STA	STA	Individual or group

A STA that successfully requests another STA to perform a measurement on another channel should not transmit MSDUs or MMPDUs to that STA during the interval defined for the measurement plus any required channel switch intervals. In determining this period, a STA shall assume that any required channel switches take less than `dot11ChannelSwitchTime` per switch.

A STA that receives a Measurement Request frame from a STA in its BSS or IBSS shall parse the frame's Measurement Request elements in order, with measurements starting at the times specified by the Measurement Request elements. A STA may ignore any group addressed Measurement Request frames.

Any result of a measurement request shall be returned without undue delay to the requesting STA in Measurement Report elements using one or more Measurement Report frames. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request.

A STA shall report it is too late to undertake a measurement request if it receives the request after the specified starting time for the measurement.

A STA shall report it is refusing a measurement request if all of the following conditions exist:

- The STA is capable of undertaking a measurement request,
- The STA does not want to undertake the measurement request at this time, and
- The measurement request is not mandatory (NOTE: measurements are specified as mandatory or optional in 7.3.2.19).

A STA shall report it is incapable a measurement request if any of the following conditions exists:

- The STA is incapable of undertaking an optional measurement request, or
- The STA does not support the channel specified in a mandatory measurement request, or
- The STA does not support any requested parallel measurements in the same or different channels.

The Measurement Report frames shall contain the same Dialog Token field as the corresponding Measurement Request frame, and each Measurement Report element shall contain the same Measurement Token field as the corresponding Measurement Request element.

A STA may autonomously report measurements to another STA in its BSS or IBSS using a Measurement Report frame with a Dialog Token field set to 0 with one or more Measurement Report elements. A STA in an IBSS may also autonomously report measurements to other STAs in the IBSS using the Channel Map field in the IBSS DFS element in a Beacon frame or Probe Response frame.

A STA may enable or disable measurement requests or autonomous measurement reports from another STA by transmitting Measurement Request elements with the Enable bit set to 1 and the Request bit and Report bit set to 0 or 1, as appropriate. These elements do not require a corresponding Measurement Report element in a Measurement Report frame. All measurement requests and reports are enabled by default. An AP may ignore a request to disable a mandatory measurement request. All others requests shall be honored.

11.6.7 Selecting and advertising a new channel

An attempt may be made to move a BSS to a new operating channel. It is an objective that disruption to the BSS is minimized in this process, although it should be recognized that a channel switch might not successfully move all STAs. It should also be stressed that the channel switch process is distinct from the regulatory requirement to cease transmission on a particular channel in the presence of radar.

11.6.7.1 Selecting and advertising a new channel in an infrastructure BSS

The decision to switch to a new operating channel in an infrastructure BSS shall be made only by the AP. An AP may make use of the information in Supported Channel elements and the results of measurements undertaken by the AP and other STAs in the BSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this amendment, but shall satisfy applicable regulatory requirements, including uniform spreading rules and channel testing rules. The AP shall attempt to select a new channel that is supported by all associated STAs, although it should be noted that this might not always be possible.

An AP shall inform associated STAs that the AP is moving to a new channel and maintain the association by advertising the switch using Channel Switch Announcement elements in Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time. The AP may force STAs in the BSS to stop transmissions until the channel switch takes place using the Channel Switch Mode field in the Channel Switch Announcement element. If possible, the channel switch should be scheduled so that all STAs in the BSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch. The AP may send the Channel Switch Announcement frame in a BSS without performing a backoff, after determining the wireless medium (WM) is idle for one PIFS period.

A STA that receives a Channel Switch Announcement element may choose not to perform the specified switch, but to take alternative action. For example, it may choose to move to a different BSS.

A STA in a BSS that is not the AP shall not transmit the Channel Switch Announcement element.

11.6.7.2 Selecting and advertising a new channel in an IBSS

DFS in an IBSS is complicated by the following:

- There is no central AP function for collating measurements or coordinating a channel switch. If STAs make independent decisions to switch channel in the presence of radar, there is a danger that all STAs will announce a switch to differing channels if several of them detect the radar.
- There is no association protocol that can be used to
 - Exchange supported channel information and
 - Determine membership of the IBSS at a given instant for requesting measurements.
- Beaconsing is a shared process; therefore, it cannot be guaranteed that a STA that has something to send (e.g., a channel switch message) will be the next STA to beacon.

The DFS owner service, IBSS DFS element, and Channel Switch Announcement frame address these complications.

- The DFS owner service provides a central point of coordination for a channel switch. It attempts to minimize the probability that multiple STAs concurrently decide to switch to different channels. The DFS Owner field and DFS Recovery Interval field within the IBSS DFS element support the DFS owner service.
- Each STA shall include a Channel Map field within the IBSS DFS elements that it transmits. The channel map communicates the STA-supported channel set and basic measurement reports for that STA.
- The ability to send a Channel Switch Announcement element within a management frame other than a Beacon frame or Probe Response frame is essential.

The potential for hidden nodes within an IBSS means that the IBSS channel switch protocol is best effort. All members of an IBSS shall have an individual responsibility to cease transmission on a particular channel in the presence of radar.

A STA at which an IBSS is started shall be a DFS owner in that IBSS. That STA shall include its MAC address in the DFS Owner field of the IBSS DFS element and DFS Recovery Interval field from the MLME.START.request parameter. The purpose of the DFS owner is to coordinate a channel switch when required. All STAs within a spectrum-managed IBSS shall have the ability to become DFS owner.

Each STA in an IBSS shall adopt the DFS owner and the DFS owner recovery interval from any valid IBSS DFS element when the frame contained a matching service set identifier (SSID) and the value of the timestamp is later than the STA's TSF timer. The STA shall include the adopted values within the IBSS DFS elements it transmits. Because all STAs in an IBSS participate in sending Beacon frames, this process will always, over a number of beacon intervals, result in a unified view of one DFS owner throughout the IBSS.

If a STA detects radar and wants to attempt a channel switch using the DFS owner, the STA shall broadcast one or more Measurement Report frames indicating the presence of the radar.

A DFS owner receiving a Measurement Report frame indicating the presence of radar in the current channel shall select and advertise a new operating channel (including the possibility of no change). The DFS owner may make use of information received in Channel Map fields and from measurements undertaken by other members of the IBSS to assist the selection of the new channel. The algorithm to choose a new channel is beyond the scope of this amendment, but shall satisfy any regulatory requirements, including uniform spreading rules and channel testing rules. The DFS owner shall attempt to select a new channel that is supported by all members of the IBSS. It should be noted that this process might be imperfect in that the DFS owner may have incomplete knowledge and there may be no suitable channel.

The DFS owner shall attempt to make the members of the IBSS aware of the new operating channel by broadcasting at least one Channel Switch Announcement frame. The DFS owner shall also include the Channel Switch Announcement element in all Beacon frames, Probe Response frames, or Channel Switch Announcement frames until the intended channel switch time. A STA that receives a valid Channel Switch Announcement element shall repeat this element in all Beacon frames and Probe Response frames that it transmits. The DFS owner may attempt to silence STAs in the IBSS until the channel switch takes place using the Channel Switch Mode field in the Channel Switch Announcement element. If possible, the channel switch should be scheduled so that all STAs in the IBSS, including STAs in power save mode, have the opportunity to receive at least one Channel Switch Announcement element before the switch.

If a STA does not receive a valid Channel Switch Announcement element from the DFS owner within DFS recovery time measured from the end of the frame within which radar notification was first transmitted by the STA or received from another STA, then it shall enter a DFS owner recovery mode. In DFS owner recovery mode, the STA shall assume the role of DFS owner, shall select a new operating channel, and shall advertise the new channel by transmitting a Channel Switch Announcement frame using the contention resolution algorithm defined for beacon transmission at TBTT in 11.1.2.2. The STA shall also include the Channel Switch Announcement element in all Beacon frames and Probe Response frames until the intended channel switch time. A STA that is not the DFS owner shall not initiate a channel switch.

If the STA receives a valid Channel Switch Announcement element from another member of the IBSS, the STA shall leave DFS owner recovery mode prior to the channel switch and adopt the received channel switch information. If the Channel Switch Announcement element was within a Beacon frame or Probe Response frame, the STA shall also adopt the DFS owner address from the IBSS DFS element. If the Channel Switch Announcement element was within a Channel Switch Announcement frame, the STA shall adopt the DFS owner from the transmitter address (TA) of the received frame.

There are several circumstances when DFS owner recovery is required (e.g., if the original DFS owner has left the network or if the original measurement report was not received by the initial DFS owner). It should be noted that DFS owner recovery might temporarily give rise to more than one DFS owner within the IBSS. This risk is mitigated by the random nature of the IBSS DFS recovery mechanism. However, because all

STAs in an IBSS participate in sending Beacon frames, over a number of beacon periods, there will be convergence from multiple DFS owners to one DFS owner.

17. Orthogonal frequency division multiplexing (OFDM) PHY specification for the 5 GHz band

17.3 OFDM physical layer convergence procedure (PLCP) sublayer

17.3.8 Physical medium dependent (PMD) operating specifications (general)

17.3.8.3 Operating channel frequencies

17.3.8.3.3 Channelization

Change first two rows and insert a new third row in Table 94 as follows:

Table 94—Valid operating channel numbers by regulatory domain and band

Regulatory domain	Band (GHz)	Operating channel numbers	Channel center frequencies (MHz)
United States <u>CEPT</u>	U-NII lower band (5.15–5.25)	36	5180
		40	5200
		44	5220
		48	5240
United States <u>CEPT</u>	U-NII middle band (5.25–5.35)	52	5260
		56	5280
		60	5300
		64	5320
CEPT	(5.47–5.725)	100	5500
		104	5520
		108	5540
		112	5560
		116	5580
		120	5600
		124	5620
		128	5640
		132	5660
		136	5680
		140	5700

Delete the first paragraph after Table 94:

Figure 123 shows the channelization scheme for this standard, which shall be used with the FCC U-NII frequency allocation. The lower and middle U-NII sub-bands accommodate eight channels in a total bandwidth of 200 MHz. The upper U-NII band accommodates four channels in a 100 MHz bandwidth. The centers of the outermost channels shall be at a distance of 30 MHz from the band's edges for the lower and middle U-NII bands, and 20 MHz for the upper U-NII band.

Change the third paragraph after Table 94 as follows:

The center frequency is indicated in Figure 123 for the US frequency channel plan; however, no subcarrier is allocated on the center frequency as described in Figure 121.

17.3.9 PMD transmit specifications

17.3.9.1 Transmit power levels

Change the first paragraph of 17.3.9.1 as follows:

The maximum allowable output power ~~according to FCC regulations by regulatory domain~~ is shown in Table 95.

Change Table 95 as follows:

Table 95—Transmit power level ~~for the United States~~ by regulatory domain

Frequency band (GHz)	<u>United States</u> (Maximum output power with up to 6 dBi antenna gain) (mW)	<u>CEPT</u> (EIRP)
5.15–5.25	40 (2.5 mW/MHz)	<u>200 mW</u>
5.25–5.35	200 (12.5 mW/MHz)	<u>200 mW</u>
<u>5.470–5.725</u>	=	<u>1 W</u>
5.725–5.825	800 (50 mW/MHz)	=

Annex A

(normative)

Protocol Implementation Conformance Statement (PICS) proforma⁴

A.4 PICS proforma—IEEE Std 802.11, 1999 Edition

A.4.3 IUT configuration

Insert the following at the end of the table in A.4.3:

Item	IUT configuration	References	Status	Support
*CF10	Is spectrum management operation supported?	7.3.1.4, 11.6	CF6:O	Yes, No

Insert A.4.12 after A.4.11 as follows:

A.4.12 Spectrum management extensions

Item	IUT configuration	References	Status	Support
SM1	Country, Power Constraint, and transmit power control (TPC) Report elements included in Beacon and Probe Response frames	7.2.3.1, 7.2.3.9, 7.3.2.9, 7.3.2.13, 7.3.2.16	CF9: M	Yes, No
SM2	Spectrum Management Capability bit	7.3.1.4	CF9: M	Yes, No
SM3	Power Capability and Supported Channels elements in Association and Reassociation frames	7.2.3.4, 7.2.3.5, 11.6.1	CF9:M	Yes, No
SM4	Action frame protocol for spectrum management actions	7.3.1.11, 7.4	CF9:M	Yes, No
	Measurement Request frame	7.4.1.1	CF9:M	Yes, No
	Measurement Report frame	7.4.1.2	CF9:M	Yes, No
	TPC Request frame	7.4.1.3	CF9:M	Yes, No
	TPC Report frame	7.4.1.4	CF9:M	Yes, No
	Channel Switch Announcement frame	7.4.1.5	CF9:M	Yes, No

⁴Copyright release for PICS proformas: Users of this standard may freely reproduce the PICS proforma in this annex so that it can be used for its intended purpose and may further publish the completed PICS.

Item	IUT configuration	References	Status	Support
SM5	Measurement requests Basic request Clear channel assessment (CCA) request Receive power indication (RPI) histogram Enabling/disabling requests and reports	7.3.2.19.1 7.3.2.19.2 7.3.2.19.3 7.3.2.19	CF9:M CF9:O CF9:O CF9:M	Yes, No Yes, No, N/A Yes, No, N/A Yes, No
SM6	Measurement reports Basic report CCA report RPI histogram report Refusal to measure	7.3.2.20.1 7.3.2.20.2 7.3.2.20.3 7.3.2.20	CF9:M CF9:O CF9:O CF9:M	Yes, No Yes, No, N/A Yes, No, N/A Yes, No
SM7	Quiet interval Access point (AP)-defined Quiet interval Station (STA)-defined Quiet interval STA support for Quiet interval	7.2.3.1, 7.2.3.9, 7.3.2.21, 11.6.2 7.2.3.1, 7.2.3.9, 7.3.2.21, 11.6.2 7.2.3.1, 7.2.3.9, 7.3.2.21, 11.6.2	(CF1 and CF9):M (CF2 and CF9):M CF9:M	Yes, No Yes, No Yes, No
SM8	Association control based on spectrum management capability	11.5, 11.6	(CF1 and CF9):M	Yes, No
SM9	Association control based on transmit power capability	11.5.1	(CF1 and CF9):M	Yes, No
SM10	Maximum transmit power Levels AP determination and communication of local maximum transmit power level STA determination and communication of local maximum transmit power level	11.5.2 11.5.2	(CF1 and CF9):M (CF2 and CF9):M	Yes, No Yes, No
SM11	Selection of transmit power	11.5.3	CF9:M	Yes, No
SM12	Adaptation of transmit power TPC report in Beacon and Probe Response frames Dynamic transmit power adaptation	11.5.4 11.5.4	CF9:M CF9:O	Yes, No Yes, No, N/A
SM13	Testing channels for radars	11.6.3	CF9:M	Yes, No
SM14	Detecting and discontinuing operations after detection of a radar	11.6.4	CF9:M	Yes, No
SM15	Requesting and reporting of measurements	11.6.6	CF9:M	Yes, No
SM16	Autonomous reporting of radars	11.6.6	CF9:M	Yes, No
SM17	Independent basic service set (IBSS) dynamic frequency selection (DFS) Element including channel map	7.3.2.22	(CF2 and CF9): M	Yes, No
SM18	DFS owner function	11.6.7	(CF2 and CF9): M	Yes, No

Item	IUT configuration	References	Status	Support
SM19	DFS owner recovery procedure	11.6.7	(CF2 and CF9): M	Yes, No
SM20	Channel switch procedure			
	Transmission of channel switch announcement and channel switch procedure by an AP	11.6.7	(CF1 and CF9): M	Yes, No
	Transmission of channel switch announcement and channel switch procedure by a STA	11.6.7	(CF2 and CF9): M	Yes, No
	Reception of channel switch announcement and channel switch procedure by a STA	11.6.7	CF9:M	Yes, No

Annex D

(normative)

ASN.1 encoding of the MAC and PHY MIB

In “Major Sections” of Annex D, add the following text to the end of the Station Management attributes:

```
dot11SpectrumManagementTable ::= {dot11smt 8}
```

In the dot11StationConfig table of Annex D, change the dot11StationConfigEntry sequence list as follows:

```
Dot11StationConfigEntry ::=
    SEQUENCE {
        dot11StationID                MacAddress,
        dot11MediumOccupancyLimit      INTEGER,
        dot11CFPollable                 TruthValue,
        dot11CFPPeriod                  INTEGER,
        dot11CFPMaxDuration              INTEGER,
        dot11AuthenticationResponseTimeOut Unsigned32,
        dot11PrivacyOptionImplemented   TruthValue,
        dot11PowerManagementMode        INTEGER,
        dot11DesiredSSID                 OCTET STRING,
        dot11DesiredBSSType              INTEGER,
        dot11OperationalRateSet          OCTET STRING,
        dot11BeaconPeriod                INTEGER,
        dot11DTIMPeriod                 INTEGER,
        dot11AssociationResponseTimeOut Unsigned32,
        dot11DisassociateReason          INTEGER,
        dot11DisassociateStation         MacAddress,
        dot11DeauthenticateReason        INTEGER,
        dot11DeauthenticateStation       MacAddress,
        dot11AuthenticateFailStatus      INTEGER,
        dot11AuthenticateFailStation     MacAddress,
        dot11MultiDomainCapabilityImplemented TruthValue,
        dot11MultiDomainCapabilityEnabled TruthValue,
        dot11CountryString               OCTET STRING,
        dot11SpectrumManagementImplemented TruthValue,
        dot11SpectrumManagementRequired   TruthValue }
```

Insert the following elements to the end of the dot11StationConfigEntry element definitions after dot11CountryString:

```
dot11SpectrumManagementImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute, when TRUE, indicates that the station
        implementation is capable of supporting spectrum management."
```

```

        The capability is disabled otherwise. The default value of this
        attribute is FALSE."
 ::= { dot11StationConfigEntry 24 }

dot11SpectrumManagementRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "A STA will use the defined TPC and DFS procedures if and only
        if this attribute is TRUE. The default value of this attribute
        is FALSE."
 ::= { dot11StationConfigEntry 25 }

```

Insert the following dot11SpectrumManagement table after the end of the dot11MultiDomainCapability table:

```

-- *****
-- * dot11SpectrumManagement TABLE
-- *****

dot11SpectrumManagementTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11SpectrumManagementEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "(Conceptual) table of attributes for spectrum management"
 ::= { dot11smt 8 }

dot11SpectrumManagementEntry OBJECT-TYPE
    SYNTAX Dot11SpectrumManagementEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An entry (conceptual row) in the Spectrum Management Table.
        IfIndex - Each 802.11 interface is represented by an ifEntry.
        Interface tables in this MIB are indexed by ifIndex."
    INDEX { ifIndex, dot11SpectrumManagementIndex }
 ::= { dot11SpectrumManagementTable 1 }

Dot11SpectrumManagementEntry ::=
    SEQUENCE {
        dot11SpectrumManagementIndex      Integer32,
        dot11MitigationRequirement         Integer32,
        dot11ChannelSwitchTime             Integer32,
        dot11PowerCapabilityMax             Integer32,
        dot11PowerCapabilityMin            Integer32 }

dot11SpectrumManagementIndex OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION

```

```

        "The auxiliary variable used to identify instances of the
        columnar objects in the Spectrum Management Table."
    ::= { dot11SpectrumManagementEntry 1 }

dot11MitigationRequirement OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall indicate the mitigation requirement in dB
        required. The default value of this attribute shall be 3 dB."
    ::= { dot11SpectrumManagementEntry 2 }

dot11ChannelSwitchTime OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This attribute shall indicate assumed channel switch time,
        measured in TUs. The unit of this attribute is TUs. The default
        value of this attribute shall be 2 TUs. The minimum value shall
        be 1 TU."
    ::= { dot11SpectrumManagementEntry 3 }

dot11PowerCapabilityMax OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute shall indicate the maximum transmit Power
        Capability of this station. The unit of this attribute is dBm.
        The default value of this attribute shall be 0 dBm."
    ::= { dot11SpectrumManagementEntry 4 }

dot11PowerCapabilityMin OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This attribute shall indicate the minimum transmit Power
        Capability of this station. The unit of this attribute is dBm.
        The default value of this attribute shall be -100 dBm."
    ::= { dot11SpectrumManagementEntry 5 }

-- *****
-- * End of dot11SpectrumManagement TABLE
-- *****

```

Electronic Acknowledgement Receipt	
EFS ID:	7190431
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	11-MAR-2010
Filing Date:	05-JAN-2010
Time Stamp:	15:22:29
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	InformationDisclosureState ment.pdf	54999 aeb06a7e55ec6525bca79a2d3c79b5f0479f4ea	no	1
Warnings:					
Information:					

This is not an USPTO supplied IDS fillable form					
2	Information Disclosure Statement (IDS) Filed (SB/08)	1449-160-125.pdf	953303 9da6feb68dc80b6dea8663bc1ad2401dca3d141	no	10
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	NPL Documents	IEEE8802-11.pdf	19324410 c2f36cc86974fe48487da3f75e3deff19819dd89	no	531
Warnings:					
Information:					
4	NPL Documents	Barr.pdf	518318 0120afb0c034ef7dd9809424a3d0eb4d80a820e4	no	9
Warnings:					
Information:					
5	NPL Documents	Youssef.pdf	615586 1d4d65e32efefc4971d3ff1ae1b2daf2e985bf0d	no	9
Warnings:					
Information:					
6	NPL Documents	Leung.pdf	570041 f81fd374f2fb0946f247c039d1244badea3d43b2	no	7
Warnings:					
Information:					
7	NPL Documents	ZapaterEtAl.pdf	534623 fbcd9030e1e91fdbb3c551f2b79a7e9f00549c59b	no	8
Warnings:					
Information:					
8	NPL Documents	Klotz.pdf	301766 02d5acb424bce2fbf15b63c957bc29e8657d69aa	no	9
Warnings:					
Information:					
9	NPL Documents	ChunEtAl.pdf	1262469 2045395b9e46af0637a85d0c548701319554394a	no	19
Warnings:					
Information:					

10	NPL Documents	TheFourColorTheorem.pdf	380466 6ade672874500d942d4388430dbd6eccc286a061	no	8
Warnings:					
Information:					
11	NPL Documents	IEEEStandard80211h-2003.pdf	655130 0d798969aa88568c894b333a77c948f21a8b7f08	no	75
Warnings:					
Information:					
Total Files Size (in bytes):			25171111		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Backes	
Serial No.: 12/652,146	Group Art Unit: 2618
Filed: 01/05/2010	Examiner: Unknown
Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network	
Attorney Docket No.: 160-125	
Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	

INFORMATION DISCLOSURE STATEMENT

Dear Sir:

Applicants respectfully request consideration of the references submitted herewith and listed on the attached PTO-1449. The Examiner is respectfully requested to initial next to each reference indicating that it has been considered and return a copy of the PTO-1449 to applicant with the first action on the merits in this application.

No fees are believed due in connection with this filing. If any fees are due in connection with this filing, the Commissioner is hereby authorized to charge payment of the fees associated with this communication or credit any overpayment to Deposit Account No. 504416.

Respectfully submitted,

I hereby certify that this correspondence is being electronically filed
with the Commissioner for Patents, P.O. Box 1450, Alexandria, VA
22313-1450 on the date shown below

Date of Deposit: April 6, 2010

Typed Name Christine M. Morrisette

Signature: /Christine M. Morrisette/

/Holmes W. Anderson/

Holmes W. Anderson
Attorney/Agent for Applicant(s)
Reg. No. 37272

Date: April 6, 2010

Telephone No.: 978-264-4001

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Substitute for form 1449B/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>		Complete if Known			
		Application Number	12/652,146		
		Filing Date	01/05/2010		
		First Named Inventor	Backes		
		Group Art Unit	2618		
		Examiner Name	Unknown		
Sheet	1	of	2	Attorney Docket Number	160-125

U.S. Patent Documents			
Examiner Initials*	Cite ₁ No.		T ²
		U.S. Application No. 10/781,204, Apparatus for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,159, Patent No. 7,215,973, Apparatus for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/781,219, Patent No. 7,369,858, Apparatus for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 10/781,535, Patent No. 7,228,149, Method for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,474, Patent No. 7,221,954, Method for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/780,775, Patent No. 7,295,537, Method for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 10/781,191, Patent No. 7,653,407, Program for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,137, Program for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/781,536, Patent No. 7,149,539, Program for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 12/437,085, Program for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 12/359,683, Program for Selecting an Optimum Access Point in a Wireless Network	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Substitute for form 1449B/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>		Complete if Known			
		Application Number	12/652,146		
		Filing Date	01/05/2010		
		First Named Inventor	Backes		
		Group Art Unit	2618		
		Examiner Name	Unknown		
Sheet	2	of	2	Attorney Docket Number	160-125

U.S. Patent Documents			
Examiner Initials*	Cite ¹ No.		T ²
		U.S. Application No. 12/359,545, Method for Selecting an Optimum Access Point in a Wireless Network on a Common Channel	
		U.S. Application No. 11/866,445, Wireless Network Apparatus and System Filed of the Invention	
		U.S. Application No. 11/676,542, Program for Distributed Channel Selection, Power Adjustment and Load Balancing Decisions in a Wireless Network	
		U.S. Application No. 10/673,636, Patent No. 7,606,573, A Wireless Switched Network	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231

Electronic Acknowledgement Receipt	
EFS ID:	7357604
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	06-APR-2010
Filing Date:	05-JAN-2010
Time Stamp:	11:29:28
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Filed (SB/08)	InformationDisclosureState ment.pdf	54996 83e7618e195fa1375c0e2d01ecdd2304358 6572f	no	1
Warnings:					
Information:					

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2	Information Disclosure Statement (IDS) Filed (SB/08)	1449.pdf	126449 859b957ced7ac10f57ccd6dc15f0086dc45fbb3c	no	2
Warnings:					
Information:					
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Total Files Size (in bytes):				181445	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	160-125	1578
34845	7590	10/28/2010		
Anderson Gorecki & Manaras LLP			EXAMINER	
33 NAGOG PARK			BEAMER, TEMICA M	
ACTON, MA 01720			ART UNIT	PAPER NUMBER
			2617	
			NOTIFICATION DATE	DELIVERY MODE
			10/28/2010	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

handerson@smmalaw.com
officeadmin@smmalaw.com
cmorrisette@smmalaw.com

Office Action Summary	Application No. 12/652,146	Applicant(s) BACKES ET AL.
	Examiner TEMICA M. BEAMER	Art Unit 2617

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 1/5/2010.
2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-6 is/are pending in the application.
4a) Of the above claim(s) _____ is/are withdrawn from consideration.
5) ☐ Claim(s) _____ is/are allowed.
6) ☒ Claim(s) 1-6 is/are rejected.
7) ☐ Claim(s) _____ is/are objected to.
8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)	4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)	5) ☐ Notice of Informal Patent Application
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____	6) ☐ Other: _____

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1-6 are rejected under 35 U.S.C. 102(b) as being anticipated by Oberholtzer et al (Oberholtzer), U.S. Patent No. 5,465,399.

Regarding claims 1 and 4, Oberholtzer discloses an apparatus/method for use in a wireless network, comprising: control circuitry; and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level (col. 7, lines 15-26), and to transmit a signal with information indicative of a level of attenuation of the communication signals by the variable power transmitter relative to the maximum power level (col. 7, lines 35-47, col. 7, lines 49-62).

Regarding claims 2 and 5, Oberholtzer discloses a receiver operative to receive, from a second wireless device, a signal with information indicative of level of attenuation of signals by the second wireless device relative to the maximum power level, and wherein the control circuitry is operative to store the information in a memory (col. 7, lines 35-47, col. 7, lines 49-67).

Regarding claims 3 and 6, Oberholtzer discloses wherein the control circuitry is further operative to communicate with the second wireless device to select a power level for transmission of wireless signals (col. 15, lines 22-27).

Conclusion

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is (571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Application/Control Number: 12/652,146
Art Unit: 2617

Page 4

/Temica M. Beamer/
Primary Examiner, Art Unit 2617

Notice of References Cited	Application/Control No. 12/652,146	Applicant(s)/Patent Under Reexamination BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2617	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-5,465,399	11-1995	Oberholtzer et al.	455/69
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

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CONFIRMATION NO. 1578

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.		
12/652,146	01/05/2010	455	2617	160-125		
RULE						
APPLICANTS Floyd Backes, Sharon, NH; Gary Vacon, East Falmouth, MA; Paul Callahan, Carlisle, MA; William Hawe, Hollis, NH; Roger Durand, Amherst, NH;						
** CONTINUING DATA ***** This application is a CON of 10/781,137 02/18/2004 PAT 7,774,013 which claims benefit of 60/449,602 02/24/2003 and claims benefit of 60/466,448 04/29/2003 and claims benefit of 60/472,320 05/21/2003 and claims benefit of 60/472,239 05/21/2003						
** FOREIGN APPLICATIONS *****						
** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 01/15/2010						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and /TEMICA M BEAMER/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY NH	SHEETS DRAWINGS 62	TOTAL CLAIMS 6	INDEPENDENT CLAIMS 2
ADDRESS Anderson Gorecki & Manaras LLP 33 NAGOG PARK ACTON, MA 01720 UNITED STATES						
TITLE Program for Adjusting Channel Interference between Access Points in a Wireless Network						
FILING FEE RECEIVED 1360	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB

SEARCH NOTES			
Search Notes		Date	Examiner
WEST text search		10/23/2010	TMB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant										☐ CPA										☐ T.D.										☐ R.1.47									
CLAIM			DATE																																				
Final	Original	10/23/2010																																					
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			Application Number	12/652,146
			Filing Date	01/05/2010
			First Named Inventor	Backes
			Art Unit	2618
			Examiner Name	Unknown
			Attorney Docket Number	160-125
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Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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		Number - Kind Code ² (if known)			
		US-2001/0046879	Nov. 2001	Schramm et al.	
		US-2001/0048744	Dec. 2001	Kimura	
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		US-2007/0111730	May 2007	Baker et al.	
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Substitute for form 1449B/PTO				Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>				Application Number	12/652,146
				Filing Date	01/05/2010
				First Named Inventor	Backes
				Group Art Unit	2618
				Examiner Name	Unknown
Sheet	10	of	10	Attorney Docket Number	160-125

OTHER PRIOR ART -- NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite ₁ No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T ²
		IEEE, Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications, Standard 802.11, 1999 edition, Reference number ISO/IEC 8802-11:1999(E), 528 Pages.	
		MICHAEL BARR, Toward a Smaller Java, Embedded.com, June 14, 2002, Pages 1-9.	
		Moustafa Youssef, "Handling Samples Correlation in the Horus System", IEEE INFOCOM 2004	
		Kin K. Leung "Integrated Link Adaptation and Power Control for Wireless IP Networks", At&T Labs-research, January 19, 2000.	
		Ana Zapater et al., "Development and implementation of a Bluetooth Networking Infrastructure for the a Notebook - University Scenario", Institute of Communications Engineering, University of Hannover, May 13, 2003	
		Walter Klotz, "Graph Coloring Algorithms", 1999	
		Brent N. Chun et. Al., "Market-based Proportional resource Sharing for Flusters", University of California at Berkeley computer Science Division, September 1999.	
		The Four Color Theorem, Web page, author(s) unknow, updated November 13, 1995.	
		IEEE Std 802.11h-2003, IEEE Standard for Information technology Telecommunications and Information exchange between systems Local and metropolitan area networks Specific requirements, October 14, 2003, 59 pages.	

Examiner Signature	/Temica Beamer/	Date Considered	09/12/2010

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.B./

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Substitute for form 1449B/PTO		Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>		Application Number	12/652,146
		Filing Date	01/05/2010
		First Named Inventor	Backes
		Group Art Unit	2618
		Examiner Name	Unknown
		Attorney Docket Number	160-125
Sheet	1	of	2

U.S. Patent Documents			
Examiner Initials*	Cite ₁ No.		T ²
		U.S. Application No. 10/781,204, Apparatus for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,159, Patent No. 7,215,973, Apparatus for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/781,219, Patent No. 7,369,858, Apparatus for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 10/781,535, Patent No. 7,228,149, Method for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,474, Patent No. 7,221,954, Method for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/780,775, Patent No. 7,295,537, Method for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 10/781,191, Patent No. 7,653,407, Program for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 10/781,137, Program for Adjusting Channel Interference between Access Points in a Wireless Network	
		U.S. Application No. 10/781,536, Patent No. 7,149,539, Program for Self-Adjusting Power at a Wireless Station to Reduce Inter-channel Interference	
		U.S. Application No. 12/437,085, Program for Adjusting Channel Interference between Devices in a Wireless Network	
		U.S. Application No. 12/359,683, Program for Selecting an Optimum Access Point in a Wireless Network	

Examiner Signature	/Temica Beamer/	Date Considered	09/12/2010

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231

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Substitute for form 1449B/PTO		Complete if Known	
INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>		Application Number	12/652,146
		Filing Date	01/05/2010
		First Named Inventor	Backes
		Group Art Unit	2618
		Examiner Name	Unknown
Sheet	2	of	2
		Attorney Docket Number	160-125

U.S. Patent Documents			
Examiner Initials*	Cite ₁ No.		T ²
		U.S. Application No. 12/359,545, Method for Selecting an Optimum Access Point in a Wireless Network on a Common Channel	
		U.S. Application No. 11/866,445, Wireless Network Apparatus and System Filed of the Invention	
		U.S. Application No. 11/676,542, Program for Distributed Channel Selection, Power Adjustment and Load Balancing Decisions in a Wireless Network	
		U.S. Application No. 10/673,636, Patent No. 7,606,573, A Wireless Switched Network	

Examiner Signature	/Temica Beamer/	Date Considered	09/12/2010

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.B./

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Backes	
Application No.: 12/652,146	Group Art Unit: 2617
Filed: 01/05/2010	Examiner: Beamer
Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network	Confirmation No.: 1578
Attorney Docket No.: 160-125	
Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	

RESPONSE UNDER 37 CFR 1.111

Dear Sir:

Please enter this response to the Office Action of October 28, 2010.

In the claims:

1. (currently amended) Apparatus ~~for use in a wireless network~~, comprising:
 - control circuitry; and
 - a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference, and to transmit a signal with information indicative of a power level of attenuation of the communication signals by the at which a variable power transmitter of an associated device should be set relative to the maximum power level in order to reduce undesirable interference.
2. (currently amended) The apparatus of claim 1 further including a receiver operative to receive, from ~~a second wireless~~ the associated device, a signal with information indicative of the power level of attenuation of signals adopted by the second wireless associated device relative to the maximum power level, and wherein the control circuitry is operative to store the information in a memory.
3. (currently amended) The apparatus of claim ~~[[2]]~~ 1 wherein the control circuitry is further operative to communicate with the ~~second wireless~~ associated device to select a power level for another device transmission of wireless signals.
4. (currently amended) A method ~~for operating a device in a wireless network~~, comprising:
 - selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference;

causing the first device to transmit ~~transmitting~~ communication signals at the selected power level; and

causing the first device to transmit ~~transmitting~~ a signal to a second device with information indicative of the selected ~~a level of attenuation of the communication signals relative to a maximum~~ power level such that the second device adopts the selected power level.

5. (currently amended) The method of claim 4 including the further step of receiving, from [[a]] the second ~~the~~ [[wireless]] device, a signal with information indicative of the power level of ~~attenuation of signals by the second~~ [[wireless]] device ~~relative to the maximum power level~~, and storing the information in a memory.

6. (currently amended) The method of claim ~~[[5]]~~ 4 including the further step of communicating with the second [[wireless]] device to select a power level for another device ~~transmission of wireless signals.~~

REMARKS

Claims 1-6 are pending in this application. All of the pending claims were rejected. Claims 1-6 are currently amended. Reconsideration and further examination are respectfully requested.

Claims 1-6 are rejected under 35 U.S.C. 102(b) as being anticipated by US 5,465,399 (Oberholtzer). Oberholtzer describes a technique for controlling transmitted power in a radio network by having a member station incrementally increase its own transmit power until another member station responds. There is no indication that Oberholtzer contemplates one device instructing another device to adjust transmit power in order to reduce undesirable interference. Consequently, the utility of the Oberholtzer technique in a hierarchical network environment such as WLAN or cellular is questionable. The pending claims have therefore been amended to more clearly define features which provide utility in the context of a hierarchical network. It is believed that these features distinguish Oberholtzer.

Applicants have made a diligent effort to place the claims in condition for allowance. However, should there remain unresolved issues that require adverse action, it is respectfully requested that the Examiner telephone Applicants' Attorney at the number listed below so that such issues may be resolved as expeditiously as possible. For these reasons, and in view of the above amendments, this application is now considered to be in condition for allowance and such action is earnestly solicited.

Respectfully Submitted,

March 7, 2011
Date

/Holmes W. Anderson/
Holmes W. Anderson, Reg. No. 37,272
Attorney/Agent for Applicant(s)
Anderson Gorecki & Manaras LLP
33 Nagog Park
Acton, MA 01720
(978) 264-4001

Docket No. 160-125
Dd: 01/28/2010

Electronic Patent Application Fee Transmittal				
Application Number:		12652146		
Filing Date:		05-Jan-2010		
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd Backes		
Filer:		Holmes W. Anderson/Christine Morrisette		
Attorney Docket Number:		160-125		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 2 months with \$0 paid	1252	1	490	490

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				490

Electronic Acknowledgement Receipt	
EFS ID:	9598633
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	07-MAR-2011
Filing Date:	05-JAN-2010
Time Stamp:	14:20:36
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$ 490
RAM confirmation Number	572
Deposit Account	504416
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Extension of Time	ExtensionOfTime.pdf	83466 d31d023e56d2a016ab3f788f5dd1df77dc361c3	no	1
Warnings:					
Information:					
2		Amendment.pdf	63970 1d737d26d60888c9868c2f9748e8b75c03384d01	yes	5
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Amendment/Req. Reconsideration-After Non-Final Reject		1	1	
	Claims		2	3	
	Applicant Arguments/Remarks Made in an Amendment		4	5	
Warnings:					
Information:					
3	Fee Worksheet (PTO-875)	fee-info.pdf	30342 92a06069cd38f954d4638b9e7584f0cfa9f06f	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			177778		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) FY 2009 <i>(Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).)</i>		Docket Number (Optional) 160-125
Application Number 12/652146		Filed 1/5/2010
For Program for Adjusting Channel Interference between Access Points in a Wireless Network		
Art Unit 2617		Examiner Beamer
This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.		
The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):		
☐ One month (37 CFR 1.17(a)(1))	<u>Fee</u> \$ 130	<u>Small Entity Fee</u> \$ 65
☒ Two months (37 CFR 1.17(a)(2))	\$ 490	\$ 245
☐ Three months (37 CFR 1.17(a)(3))	\$ 1,110	\$ 555
☐ Four months (37 CFR 1.17(a)(4))	\$ 1,730	\$ 865
☐ Five months (37 CFR 1.17(a)(5))	\$ 2,350	\$ 1,175
☐ Applicant claims small entity status. See 37 CFR 1.27.		
☐ A check in the amount of the fee is enclosed.		
☐ Payment by credit card. Form PTO-2038 is attached.		
☐ The Director has already been authorized to charge fees in this application to a Deposit Account.		
☒ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number <u>504416</u> .		
WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.		
I am the ☐ applicant/inventor.		
☐ assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).		
☒ attorney or agent of record. Registration Number <u>37272</u>		
☐ attorney or agent under 37 CFR 1.34. Registration number if acting under 37 CFR 1.34 <u> </u>		
<u>/Holmes W. Anderson/</u> Signature		<u>March 7, 2011</u> Date
<u>Holmes W. Anderson</u> Typed or printed name		<u>978-264-4001</u> Telephone Number
NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.		
☐ Total of <u> </u> forms are submitted.		

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed	

APPLICATION AS FILED – PART I					OTHER THAN SMALL ENTITY				
(Column 1)		(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A		N/A		N/A		
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A		N/A		N/A		
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A		N/A		N/A		
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		X \$ =		X \$ =		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =		X \$ =		X \$ =		
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))			If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
					TOTAL		TOTAL		

* If the difference in column 1 is less than zero, enter "0" in column 2.

APPLICATION AS AMENDED – PART II					OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	03/07/2011	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)			
Total (37 CFR 1.16(i))	*	6	Minus	** 20	=	0	X \$52=	0			
Independent (37 CFR 1.16(h))	*	2	Minus	*** 3	=	0	X \$220=	0			
☐ Application Size Fee (37 CFR 1.16(s))											
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		TOTAL ADD'L FEE	0			

(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)				
Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =	X \$ =	X \$ =				
Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =	X \$ =	X \$ =				
☐ Application Size Fee (37 CFR 1.16(s))											
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		TOTAL ADD'L FEE				

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
 ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
 *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
 The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	160-125	1578
34845 7590 05/26/2011 Anderson Gorecki & Manaras LLP 33 NAGOG PARK ACTON, MA 01720			EXAMINER BEAMER, TEMICA M	
			ART UNIT	PAPER NUMBER
			2617	
			NOTIFICATION DATE	DELIVERY MODE
			05/26/2011	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

handerson@smmalaw.com
officeadmin@smmalaw.com
cmorrisette@smmalaw.com

Office Action Summary	Application No. 12/652,146	Applicant(s) BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2617	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 07 March 2011.
2a) ☒ This action is **FINAL**. 2b) ☐ This action is non-final.
3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 4) ☒ Claim(s) 1-6 is/are pending in the application.
4a) Of the above claim(s) _____ is/are withdrawn from consideration.
5) ☐ Claim(s) _____ is/are allowed.
6) ☒ Claim(s) 1-6 is/are rejected.
7) ☐ Claim(s) _____ is/are objected to.
8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

- 9) ☐ The specification is objected to by the Examiner.
10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
11) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)	4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)	5) ☐ Notice of Informal Patent Application
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____	6) ☐ Other: _____

DETAILED ACTION

Response to Arguments

1. Applicant's arguments with respect to claims 1-6 have been considered but are moot in view of the new ground(s) of rejection.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

3. Claims 1-6 are rejected under 35 U.S.C. 103(a) as being unpatentable over Oberholtzer et al (Oberholtzer), U.S. Patent No. 5,465,399 in view of Gilhousen et al (Gilhousen), U.S. Patent No. 5,257,283.

Regarding claims 1 and 4, Oberholtzer discloses an apparatus/method for use in a wireless network, comprising: control circuitry; and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level (col. 7, lines 15-26), and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set (col. 7, lines 35-47, col. 7, lines 49-62).

Oberholtzer further discloses wherein each member station reports reception quality of received signals and if the received signals are of poor quality, the transmit power level is adjusted (col. 2, line 66-col. 3, line 11).

Oberholtzer, however, fails to disclose wherein the selected power is repeatedly adjusted in order to reduce undesirable interference. In a similar field of endeavor, Gilhousen discloses a spread spectrum transmitter power control method and system. Gilhousen further discloses wherein multiple mobile stations in the system repeatedly adjust transmission power in order to reduce undesirable system interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

At the time of invention, it would have been obvious to a person of ordinary skill in the art to modify Oberholtzer with the teachings of Gilhousen for the purpose of increasing system quality for improved communication.

Regarding claims 2 and 5, the combination of Oberholtzer and Gilhousen discloses a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device , and wherein the control circuitry is operative to store the information in a memory (Oberholtzer, col. 7, lines 35-47, col. 7, lines 49-67).

Regarding claims 3 and 6, the combination of Oberholtzer and Gilhousen discloses wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device (Oberholtzer, col. 15, lines 22-27).

Conclusion

4. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is (571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TEMICA M. BEAMER/
Primary Examiner, Art Unit 2617

Notice of References Cited	Application/Control No. 12/652,146	Applicant(s)/Patent Under Reexamination BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2617	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-5,257,283	10-1993	Gilhousen et al.	455/522
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant				☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE							
Final	Original	10/23/2010	05/23/2011						
	1	✓	✓						
	2	✓	✓						
	3	✓	✓						
	4	✓	✓						
	5	✓	✓						
	6	✓	✓						

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB

SEARCH NOTES		
Search Notes	Date	Examiner
WEST text search	10/23/2010	TMB
WEST text search	5/23/2011	TMB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Request for Continued Examination (RCE) Transmittal Address to: Mail Stop RCE Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	Application Number	12/652146
	Filing Date	1/5/2010
	First Named Inventor	Backes
	Art Unit	2617
	Examiner Name	Beamer
	Attorney Docket Number	160-125

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.

Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. **Submission required under 37 CFR 1.114** Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).
- a. ☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.
- i. ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ii. ☐ Other _____
- b. ☒ Enclosed
- i. ☒ Amendment/Reply
- ii. ☐ Affidavit(s)/Declaration(s)
- iii. ☐ Information Disclosure Statement (IDS)
- iv. ☐ Other _____
2. **Miscellaneous**
- a. ☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of _____ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)
- b. ☐ Other _____
3. **Fees** The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.
- a. ☒ The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any overpayments, to Deposit Account No. 504416.
- i. ☒ RCE fee required under 37 CFR 1.17(e)
- ii. ☐ Extension of time fee (37 CFR 1.136 and 1.17)
- iii. ☐ Other _____
- b. ☐ Check in the amount of \$ _____ enclosed
- c. ☐ Payment by credit card (Form PTO-2038 enclosed)

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.**SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED**

Signature	/Holmes W. Anderson/	Date	8/16/2011
Name (Print/Type)	Holmes W. Anderson	Registration No.	37272

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop RCE, Commissioner For Patents, P.O. Box 1450, Alexandria, VA 22313-1450 or facsimile transmitted to the U.S. Patent and Trademark Office on the date shown below.

Signature	/Christine Morrisette/	Date	8/16/2011
Name (Print/Type)	Christine Morrisette		

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop RCE, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Backes	
Application No.: 12/652,146	Group Art Unit: 2617
Filed: 01/05/2010	Examiner: Beamer
Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network	Confirmation No.: 1578
Attorney Docket No.: 160-125	
Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	

RESPONSE UNDER 37 CFR 1.111

Dear Sir:

Please enter this response to the Final Office Action of May 26, 2011.

In the claims:

1. (previously presented) Apparatus, comprising:

control circuitry; and

a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference.

2. (previously presented) The apparatus of claim 1 further including a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device, and wherein the control circuitry is operative to store the information in a memory.

3. (previously presented) The apparatus of claim 1 wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device.

4. (previously presented) A method, comprising:

selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference;

causing the first device to transmit communication signals at the selected power level;

and

causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

5. (previously presented) The method of claim 4 including the further step of receiving, from the second device, a signal with information indicative of the power level of the second device, and storing the information in a memory.

6. (previously presented) The method of claim 4 including the further step of communicating with the second device to select a power level for another device.

REMARKS

Claims 1-6 are pending in this application. All of the pending claims were rejected. None of the claims are currently amended. Reconsideration and further examination are respectfully requested.

Claims 1-6 are rejected based on Oberholtzer in view of Gilhousen. Neither reference teaches one device instructing another device to adjust transmit power in order to reduce undesirable interference. Gilhousen is cited as teaching the limitation, but the cited passage specifically describes countering Rayleigh fading and never mentions interference. Withdrawal of the rejections is therefore requested.

Respectfully Submitted,

August 16, 2011
Date

/Holmes W. Anderson/
Holmes W. Anderson, Reg. No. 37,272
Attorney/Agent for Applicant(s)
Anderson Gorecki & Manaras LLP
33 Nagog Park
Acton, MA 01720
(978) 264-4001

Docket No. 160-125
Dd: 08/26/2011

Electronic Patent Application Fee Transmittal				
Application Number:		12652146		
Filing Date:		05-Jan-2010		
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd Backes		
Filer:		Holmes W. Anderson/Christine Morrissette		
Attorney Docket Number:		160-125		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Request for continued examination	1801	1	810	810
Total in USD (\$)				810

Electronic Acknowledgement Receipt	
EFS ID:	10747239
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	16-AUG-2011
Filing Date:	05-JAN-2010
Time Stamp:	15:02:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$810
RAM confirmation Number	1492
Deposit Account	504416
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Continued Examination (RCE)	RCE.pdf	88560 6510ac61753007ee43e36c04260fac31dd3c2d4b	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
2		Amendment.pdf	58399 a140d8586ff33408bcffdc2fecb6268855c7d70	yes	4
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Amendment Submitted/Entered with Filing of CPA/RCE		1	1	
	Claims		2	3	
	Applicant Arguments/Remarks Made in an Amendment		4	4	
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30299 a809e0dd6fc8461e897d436631b22c762f2f09cac	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			177258		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed	

APPLICATION AS FILED – PART I					OTHER THAN SMALL ENTITY				
(Column 1)		(Column 2)		SMALL ENTITY ☐		OR		SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)			RATE (\$)	FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A				N/A		
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A				N/A		
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A				N/A		
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 = *			X \$ =	OR		X \$ =		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 = *			X \$ =	OR		X \$ =		
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).								
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.									
TOTAL					TOTAL				

APPLICATION AS AMENDED – PART II					OTHER THAN SMALL ENTITY						
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR		SMALL ENTITY	
AMENDMENT	08/16/2011	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			RATE (\$)	ADDITIONAL FEE (\$)	
Total (37 CFR 1.16(i))	*	6	Minus	** 20	=	0	OR		X \$52=	0	
Independent (37 CFR 1.16(h))	*	2	Minus	*** 3	=	0	OR		X \$220=	0	
☐ Application Size Fee (37 CFR 1.16(s))											
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
TOTAL ADD'L FEE						TOTAL ADD'L FEE					
0						0					

(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR		SMALL ENTITY	
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			RATE (\$)	ADDITIONAL FEE (\$)		
Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =	OR		X \$ =	=		
Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =	OR		X \$ =	=		
☐ Application Size Fee (37 CFR 1.16(s))											
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
TOTAL ADD'L FEE					TOTAL ADD'L FEE						
0					0						

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
 ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
 *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
 The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Legal Instrument Examiner:
/DAVINA G. BUTLER/



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	160-125	1578
34845 7590 09/06/2011 Anderson Gorecki & Manaras LLP 33 NAGOG PARK ACTON, MA 01720			EXAMINER BEAMER, TEMICA M	
			ART UNIT	PAPER NUMBER
			2617	
			NOTIFICATION DATE	DELIVERY MODE
			09/06/2011	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

handerson@smmalaw.com
officeadmin@smmalaw.com
cmorrisette@smmalaw.com

Office Action Summary	Application No.	Applicant(s)	
	12/652,146	BACKES ET AL.	
	Examiner	Art Unit	
	TEMICA M. BEAMER	2617	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 16 August 2011.

2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5) ☒ Claim(s) 1-6 is/are pending in the application.

5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) ____ is/are allowed.

7) ☒ Claim(s) 1-6 is/are rejected.

8) ☐ Claim(s) ____ is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12) ☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)	4) ☐ Interview Summary (PTO-413)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)	Paper No(s)/Mail Date. ____.
3) ☐ Information Disclosure Statement(s) (PTO/SB/08)	5) ☐ Notice of Informal Patent Application
Paper No(s)/Mail Date ____.	6) ☐ Other: ____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments filed 8/16/2011 have been fully considered but they are not persuasive. Applicant argues that both Oberholtzer and Gilhousen fail to disclose instructing another device to adjust transmit power in order to reduce undesirable interference. Applicant further argues that the passages cited in Gilhousen discloses countering Rayleigh fading and never mentions interference. The examiner, however, disagrees.

Oberholtzer and Gilhousen disclose methods of adjusting transmission power in order to increase system performance. Specifically, Gilhousen discloses in several passages that power control commands are sent to various station to adjust the transmission power in order to reduce in interference in the system (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11 and col. 8, lines 33-42).

Therefore, the examiner maintains that the combination of Oberholtzer and Gilhousen discloses the invention as presently claimed. The rejection to the claims is set forth below.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such

that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

3. Claims 1-6 are rejected under 35 U.S.C. 103(a) as being unpatentable over Oberholtzer et al (Oberholtzer), U.S. Patent No. 5,465,399 in view of Gilhousen et al (Gilhousen), U.S. Patent No. 5,257,283.

Regarding claims 1 and 4, Oberholtzer discloses an apparatus/method for use in a wireless network, comprising: control circuitry; and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level (col. 7, lines 15-26), and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set (col. 7, lines 35-47, col. 7, lines 49-62).

Oberholtzer further discloses wherein each member station reports reception quality of received signals and if the received signals are of poor quality, the transmit power level is adjusted (col. 2, line 66-col. 3, line 11).

Oberholtzer, however, fails to disclose wherein the selected power is repeatedly adjusted in order to reduce undesirable interference. In a similar field of endeavor, Gilhousen discloses a spread spectrum transmitter power control method and system. Gilhousen further discloses wherein multiple mobile stations in the system repeatedly adjust transmission power in order to reduce undesirable system interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

At the time of invention, it would have been obvious to a person of ordinary skill in the art to modify Oberholtzer with the teachings of Gilhousen for the purpose of increasing system quality for improved communication.

Regarding claims 2 and 5, the combination of Oberholtzer and Gilhousen discloses a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device , and wherein the control circuitry is operative to store the information in a memory (Oberholtzer, col. 7, lines 35-47, col. 7, lines 49-67).

Regarding claims 3 and 6, the combination of Oberholtzer and Gilhousen discloses wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device (Oberholtzer, col. 15, lines 22-27).

Conclusion

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is (571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TEMICA M. BEAMER/
Primary Examiner, Art Unit 2617

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant					☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE								
Final	Original	10/23/2010	05/23/2011	08/29/2011						
	1	✓	✓	✓						
	2	✓	✓	✓						
	3	✓	✓	✓						
	4	✓	✓	✓						
	5	✓	✓	✓						
	6	✓	✓	✓						

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB
	updated search	8/29/2011	TMB

SEARCH NOTES			
Search Notes		Date	Examiner
WEST text search		10/23/2010	TMB
WEST text search		5/23/2011	TMB
updated search		8/29/2011	TMB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Backes	
Application No.: 12/652,146	Group Art Unit: 2617
Filed: 01/05/2010	Examiner: Beamer
Title: Program for Adjusting Channel Interference between Access Points in a Wireless Network	Confirmation No.: 1578
Attorney Docket No.: 160-125	
Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	

RESPONSE UNDER 37 CFR 1.111

Dear Sir:

Please enter this response to the Office Action of September 6, 2011.

In the claims:

1. (previously presented) Apparatus, comprising:

control circuitry; and

a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference.

2. (previously presented) The apparatus of claim 1 further including a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device, and wherein the control circuitry is operative to store the information in a memory.

3. (previously presented) The apparatus of claim 1 wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device.

4. (previously presented) A method, comprising:

selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference;

causing the first device to transmit communication signals at the selected power level;

and

causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

5. (previously presented) The method of claim 4 including the further step of receiving, from the second device, a signal with information indicative of the power level of the second device, and storing the information in a memory.

6. (previously presented) The method of claim 4 including the further step of communicating with the second device to select a power level for another device.

REMARKS

Claims 1-6 are pending in this application. All of the pending claims were rejected. None of the claims are currently amended. Reconsideration and further examination are respectfully requested.

Claims 1-6 are rejected based on Oberholtzer in view of Gilhousen. Applicant previously pointed out that neither reference teaches one device instructing another device to adjust transmit power in order to reduce undesirable interference. In the Response To Arguments the examiner states that "Oberholtzer and Gilhousen disclose methods of adjusting transmission power in order to increase system performance." The examiner will appreciate that increasing system performance is a somewhat ambiguous goal because improving some aspect of one device or parameter is typically accomplished at the expense of one or more aspects of some other device or parameter. For example, there are tradeoffs between transmission rate, signal power, range, and interference. Consequently, instructing another device to adjust power to increase system performance is not equivalent to instructing another device to adjust transmit power in order to reduce undesirable interference. An example of this distinction is described in Gilhousen at column 7:63-68 as follows:

A cell-site positioned in an unusually noisy location or geographic region might be allowed to use a higher than normal inbound power level. However, such a higher power level for in-cell operation will result in higher levels of interference to immediate neighbors of this cell.

The examiner cannot reasonably maintain that Gilhousen teaches one device instructing another device to adjust transmit power in order to reduce undesirable interference by sending

instructions to increase system performance because Gilhousen specifically teaches increasing system performance by increasing interference.

Claims 1 and 4 distinguish the cited combination for the reasons stated above. Claims 2-3 and 5-6 further define the claimed invention and are allowable for the same reasons. Withdrawal of the rejections is therefore requested.

Respectfully Submitted,

February 6, 2012
Date

/Holmes W. Anderson/
Holmes W. Anderson, Reg. No. 37,272
Attorney/Agent for Applicant(s)
Anderson Gorecki & Manaras LLP
33 Nagog Park
Acton, MA 01720
(978) 264-4001

Docket No. 160-125
Dd: 12/06/2011

Electronic Patent Application Fee Transmittal				
Application Number:		12652146		
Filing Date:		05-Jan-2010		
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd Backes		
Filer:		Holmes W. Anderson/Christine Morrisette		
Attorney Docket Number:		160-125		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 2 months with \$0 paid	1252	1	560	560

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				560

Electronic Acknowledgement Receipt	
EFS ID:	12006814
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Holmes W. Anderson/Christine Morrisette
Filer Authorized By:	Holmes W. Anderson
Attorney Docket Number:	160-125
Receipt Date:	06-FEB-2012
Filing Date:	05-JAN-2010
Time Stamp:	15:09:01
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$560
RAM confirmation Number	1451
Deposit Account	504416
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Extension of Time	ExtensionOfTime.pdf	85788 3c49235b00dabf6b5142f22b08c80e88d5259ea3	no	1
Warnings:					
Information:					
2		Amendment.pdf	62649 ae6462c9db852156bc1ec38b66113bd8a3a77e39	yes	5
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Amendment/Req. Reconsideration-After Non-Final Reject		1	1	
	Claims		2	3	
	Applicant Arguments/Remarks Made in an Amendment		4	5	
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30151 db69c0595eb5d0435f5f05bdb75b365e47b2ad1d	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			178588		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) FY 2009 <i>(Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).)</i>		Docket Number (Optional) 160-125
Application Number 12/652146		Filed 1/5/2010
For Program for Adjusting Channel Interference between Access Points in a Wireless Network		
Art Unit 2617		Examiner Beamer
This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.		
The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):		
☐ One month (37 CFR 1.17(a)(1))	<u>Fee</u> \$ 150	<u>Small Entity Fee</u> \$ 75
☒ Two months (37 CFR 1.17(a)(2))	\$ 560	\$ 280
☐ Three months (37 CFR 1.17(a)(3))	\$ 1,270	\$ 635
☐ Four months (37 CFR 1.17(a)(4))	\$ 1,980	\$ 990
☐ Five months (37 CFR 1.17(a)(5))	\$ 2,690	\$ 1,345
☐ Applicant claims small entity status. See 37 CFR 1.27.		
☐ A check in the amount of the fee is enclosed.		
☐ Payment by credit card. Form PTO-2038 is attached.		
☐ The Director has already been authorized to charge fees in this application to a Deposit Account.		
☒ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number <u>504416</u> .		
WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.		
I am the ☐ applicant/inventor.		
☐ assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).		
☒ attorney or agent of record. Registration Number <u>37272</u>		
☐ attorney or agent under 37 CFR 1.34. Registration number if acting under 37 CFR 1.34 <u> </u>		
<u>/Holmes W. Anderson/</u> Signature		<u>February 6, 2012</u> Date
<u>Holmes W. Anderson</u> Typed or printed name		<u>978-264-4001 x 105</u> Telephone Number
NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.		
☐ Total of <u> </u> forms are submitted.		

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed		
APPLICATION AS FILED – PART I											
(Column 1)			(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY		
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)			RATE (\$)	FEE (\$)			
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A				N/A				
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A				N/A				
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A				N/A				
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		OR		X \$ =				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =				X \$ =				
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))			If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).								
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))											
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL				TOTAL				
APPLICATION AS AMENDED – PART II											
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT	02/06/2012	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 6	Minus	** 20	= 0	X \$ =		OR	X \$60=	0	
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X \$ =		OR	X \$250=	0	
	☐ Application Size Fee (37 CFR 1.16(s))										
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0		
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY		
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)			RATE (\$)	ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =		OR	X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =		OR	X \$ =		
	☐ Application Size Fee (37 CFR 1.16(s))										
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.											

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application Nos:

11/556,249

11/102,954

11/102,997

11/103,401

11/103,410

10/780,838

10/780,843

10/781,204

10/807,005

10/855,178

11/050,568

12/359,683

12/359,782

12/356,232

11/676,542

12/652,146

12/359,545

Customer No.: 30678

Revocation and Power of Attorney

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

All previous powers of attorney and authorizations of agent are hereby revoked, and the undersigned hereby appoints the attorneys and agents of Connolly Bove Lodge & Hutz LLP associated with U.S. Patent and Trademark Office ("PTO") Customer Number 30678 to prosecute these applications and any U.S., foreign, or international applications under the Patent Cooperation Treaty based on them and to transact all business in the PTO connected therewith, and to receive all communications from the PTO, including the patent documents. Further details about each application are found in the Appendix to this paper. The authority under this Power of Attorney of each person listed under the aforementioned PTO Customer Number shall

4741452

automatically terminate and be revoked upon such person ceasing to be associated with Connolly Bove Lodge & Hutz LLP.

Designation of Correspondence Address

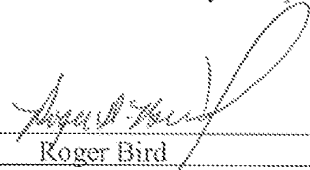
Please associate these applications with PTO Customer Number 30678 and send all notices, official letters, documents, communications, and other correspondence regarding these applications to the address:

Connolly Bove Lodge & Hutz LLP
1875 Eye Street NW, Suite 1100
Washington, DC 20006

or to the address currently associated with PTO Customer Number 30678. Please also record the respective Attorney Docket Numbers in the attached appendix in any applicable databases.

Certificate Under 37 C.F.R. § 3.73(b)

Piccata Fund Limited Liability Company is the assignee of the entire right, title, and interest in these patents and applications by virtue of the chains of assignment shown in the attached Appendix, which are recorded in the records of the PTO. To the best of the undersigned's knowledge and belief, the titles are in the name of said assignee. The undersigned, whose title is supplied below, is empowered to sign this certificate on behalf of Piccata Fund Limited Liability Company.

Signed:  Date: 5/9/12
Name: Roger Bird
Title: Authorized Person for Piccata Fund Limited Liability Company

APPENDIX: DETAILS OF LISTED APPLICATIONS

Application No.: 11/556,249

Confirmation No.: 8301

Patent No.: N/A

Filing Date: 11/3/2006

First Named Inventor: Michael Yuen

Title: Pre-Scan for Wireless Channel Selection

Attorney Docket No.: 27592-01389-US

Chain of Title: Assignment from Inventor to Autocell Laboratories, Inc., recorded at Reel 018477/Frame 0054; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/102,954

Confirmation No.: 6350

Patent No.: N/A

Filing Date: 4/11/2005

First Named Inventor: Roger Durand

Title: Interference Counter-Measures for Wireless LANs

Attorney Docket No.: 27592-01397-US2

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 016464/Frame 0646; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/102,997

Confirmation No.: 6096

Patent No.: N/A

Filing Date: 4/11/2005

First Named Inventor: David R. Hill

Title: WLAN Background Scanning

Attorney Docket No.: 27592-01397-US3

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 016466/Frame 0145; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/103,401

Confirmation No.: 8697

Patent No.: N/A

Filing Date: 4/11/2005

First Named Inventor: Lawrence V. Stefani

Title: Access Point Channel Forecasting for Seamless Station Association Transition

Attorney Docket No.: 27592-01397-US4

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 016472/Frame 0917; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/103,410

Confirmation No.: 7592

Patent No.: N/A

Filing Date: 4/11/2005

First Named Inventor: Roger Durand

Title: Interference Source Recognition for Wireless LANs

Attorney Docket No.: 27592-01397-US1

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 016466/Frame 0502; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 10/780,838

Confirmation No.: 3757

Patent No.: N/A

Filing Date: 2/18/2004

First Named Inventor: Floyd Backes

Title: Wireless Access Point Protocol Program

Attorney Docket No.: 27592-01403-US7

Chain of Title: Assignment from Inventor to Propagate Networks, Inc., recorded at Reel 015010/Frame 0361; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 10/781,204

Confirmation No.: 1946

Patent No.: N/A

Filing Date: 2/18/2004

First Named Inventor: Floyd Backes

Title: Apparatus for Adjusting Channel Interference Between Devices in a Wireless Network

Attorney Docket No.: 27592-01380-US11

Chain of Title: Assignment from Inventors to Propagate Networks, Inc., recorded at Reel 015006/Frame 0954; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel

027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 10/780,838

Confirmation No.: 3757

Patent No.: N/A

Filing Date: 2/18/2004

First Named Inventor: Floyd Backes

Title: Wireless Access Point Protocol Program

Attorney Docket No.: 27592-01403-US7

Chain of Title: Assignment from Inventor to Propagate Networks, Inc., recorded at Reel 015010/Frame 0361; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502, Reel 027781/Frame 0447, and Reel 027851/Frame 0628; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 10/807,005

Confirmation No.: 2816

Patent No.: N/A

Filing Date: 3/23/2004

First Named Inventor: Gary Vacon

Title: Method and Apparatus for Securing Communication Between Wireless Devices

Attorney Docket No.: 27592-01423-US

Chain of Title: Assignment from Inventors to Propagate Networks, Inc., recorded at Reel 015136/Frame 0197 (correction to recordation cover sheet recorded at Reel 028070/Frame 0287); change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502 and/or Reel 027781/Frame 0447; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 10/855,178

Confirmation No.: 7577

Patent No.: N/A

Filing Date: 5/27/2004

First Named Inventor: Roger Pfister

Title: System and Method for Generating Conjoined Display Objects Representing Devices Having Multiple Radio Frequency Capabilities in a Wireless Communication Network Management System

Attorney Docket No.: 27592-01420-US

Chain of Title: Assignment from Inventor to Propagate Networks, Inc., recorded at Reel 015373/Frame 0805; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; release of security agreement by Albert A. Holman, III (agent for lenders) to Autocell Laboratories, Inc., recorded at Reel 017382/Frame 0502 and/or

Reel 027781/Frame 0447; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/050,568

Confirmation No.: 3031

Patent No.: N/A

Filing Date: 2/3/2005

First Named Inventor: Floyd Backes

Title: Exception Processing for Wireless Roaming

Attorney Docket No.: 27592-01426-US

Chain of Title: Assignment from Inventors to Propagate Networks, Inc., recorded at Reel 016254/Frame 0757; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 015743/Frame 0534; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 12/359,683

Confirmation No.: 4880

Patent No.: N/A

Filing Date: 1/26/2009

First Named Inventor: Floyd Backes

Title: Program for Selecting an Optimum Access Point in a Wireless Network

Attorney Docket No.: 27592-01403-US22

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 022433/Frame 0644; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 12/359,782

Confirmation No.: 5067

Patent No.: N/A

Filing Date: 1/26/2009

First Named Inventor: Floyd Backes

Title: VLAN Tagging in WLANs

Attorney Docket No.: 27592-01378-US1

Chain of Title: Assignment from Inventor to Autocell Laboratories, Inc., recorded at Reel 028068/Frame 0226; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 12/356,232

Confirmation No.: 8440

Patent No.: N/A

Filing Date: 1/20/2009

First Named Inventor: Floyd Backes

Title: Wireless Mesh Architecture

Attorney Docket No.: 27592-01396-US1

Chain of Title: Assignment from Inventor to Propagate Networks, Inc., recorded at Reel 028068/Frame 0350; change of name from Propagate Networks, Inc., to Autocell Laboratories,

Inc., recorded at Reel 028070/Frame 0486; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 11/676,542

Confirmation No.: 8386

Patent No.: N/A

Filing Date: 2/20/2007

First Named Inventor: Floyd Backes

Title: Program for Distributed Channel Selection, Power Adjustment and Load Balancing Decisions in a Wireless Network

Attorney Docket No.: 27592-01381-US1

Chain of Title: Assignment from Inventors to Propagate Networks, Inc., recorded at Reel 028068/Frame 0386; change of name from Propagate Networks, Inc., to Autocell Laboratories, Inc., recorded at Reel 028070/Frame 0486; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 12/652,146

Confirmation No.: 1578

Patent No.: N/A

Filing Date: 1/5/2010

First Named Inventor: Floyd Backes

Title: Program for Adjusting Channel Interference Between Access Points in a Wireless Network

Attorney Docket No.: 27592-01380-US26

Chain of Title: Assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

Application No.: 12/359,545

Confirmation No.: 4617

Patent No.: N/A

Filing Date: 1/26/2009

First Named Inventor: Floyd Backes

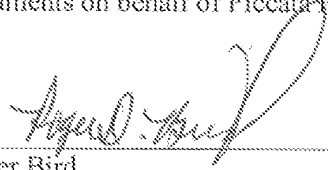
Title: Method for Selecting an Optimum Access Point in a Wireless Network on a Common Channel

Attorney Docket No.: 27592-01403-US21

Chain of Title: Assignment from Inventors to Autocell Laboratories, Inc., recorded at Reel 022434/Frame 0245; assignment from Autocell Laboratories, Inc., to Piccata Fund Limited Liability Company, recorded at Reel 027852/Frame 0201.

DECLARATION REGARDING AUTHORITY TO SIGN
ON BEHALF OF A LEGAL ENTITY
37 C.F.R. 3.73(b)(2)(i)

I, Roger Bird (whose title is supplied below), hereby declare that I am authorized to sign documents on behalf of Piccata Fund Limited Liability Company.



Roger Bird
Authorized Person for Piccata Fund Limited Liability Company

5/9/12

Date

Electronic Acknowledgement Receipt	
EFS ID:	12747059
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	34845
Filer:	Burton A. Amernick/Valerie Williams
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	160-125
Receipt Date:	10-MAY-2012
Filing Date:	05-JAN-2010
Time Stamp:	12:51:07
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	AutocellRevocation_PoA_Pt1_Signed.pdf	2766583 87db52caed4552dbc5cc03e6a855a498d02d8e95	no	9
Warnings:					
Information:					

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26

CONFIRMATION NO. 1578

POA ACCEPTANCE LETTER

30678
CONNOLLY BOVE LODGE & HUTZ LLP
1875 EYE STREET, N.W.
SUITE 1100
WASHINGTON, DC 20006



Date Mailed: 05/17/2012

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 05/10/2012.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/erimando/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/652,146	01/05/2010	Floyd Backes	160-125

34845
Anderson Gorecki & Manaras LLP
33 NAGOG PARK
ACTON, MA 01720

CONFIRMATION NO. 1578
POWER OF ATTORNEY NOTICE



Date Mailed: 05/17/2012

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 05/10/2012.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/erimando/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578
30678 7590 06/25/2012 CONNOLLY BOVE LODGE & HUTZ LLP 1875 EYE STREET, N.W. SUITE 1100 WASHINGTON, DC 20006			EXAMINER BEAMER, TEMICA M	
			ART UNIT 2617	PAPER NUMBER
			MAIL DATE 06/25/2012	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments filed 2/6/2012 have been fully considered but they are not persuasive. Applicant argues that instructing another device to adjust power to increase system performance is not equivalent to instructing another device to adjust transmit power in order reduce undesirable interference and therefore the examiner cannot reasonably maintain that Gilhousen teaches one device instructing another device to adjust transmit power in order to reduce undesirable interference by sending instructions to increase system performance because Gilhousen specifically teaches increasing system performance by increasing interference in col. 7, lines 63-68).

At the outset, the examiner used Gilhousen as a secondary reference to show that mobile devices are repeatedly instructed to adjust their power in order to reduce undesirable interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

Although Gilhousen teaches that increased power can lead to increased interference, Gilhousen further discloses wherein interference can be compensated for by allowing neighbor cells an increase in inbound power (col. 8, lines 1-11).

Therefore, the examiner maintains that Olberholtzer, the primary reference, and Gilhousen are reasonably combinable to teach the invention as presently claimed. The rejections to the claims are set forth below.

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

3. Claims 1-6 are rejected under 35 U.S.C. 103(a) as being unpatentable over Oberholtzer et al (Oberholtzer), U.S. Patent No. 5,465,399 in view of Gilhousen et al (Gilhousen), U.S. Patent No. 5,257,283.

Regarding claims 1 and 4, Oberholtzer discloses an apparatus/method for use in a wireless network, comprising: control circuitry; and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level (col. 7, lines 15-26), and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set (col. 7, lines 35-47, col. 7, lines 49-62).

Oberholtzer further discloses wherein each member station reports reception quality of received signals and if the received signals are of poor quality, the transmit power level is adjusted (col. 2, line 66-col. 3, line 11).

Oberholtzer, however, fails to disclose wherein the selected power is repeatedly adjusted in order to reduce undesirable interference. In a similar field of endeavor, Gilhousen discloses a spread spectrum transmitter power control method and system. Gilhousen further discloses wherein multiple mobile stations in the system repeatedly adjust transmission power in order to reduce undesirable system interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

At the time of invention, it would have been obvious to a person of ordinary skill in the art to modify Oberholtzer with the teachings of Gilhousen for the purpose of increasing system quality for improved communication.

Regarding claims 2 and 5, the combination of Oberholtzer and Gilhousen discloses a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device , and wherein the control circuitry is operative to store the information in a memory (Oberholtzer, col. 7, lines 35-47, col. 7, lines 49-67).

Regarding claims 3 and 6, the combination of Oberholtzer and Gilhousen discloses wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device (Oberholtzer, col. 15, lines 22-27).

Conclusion

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is

(571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TEMICA M. BEAMER/

Primary Examiner, Art Unit 2617

Application/Control Number: 12/652,146
Art Unit: 2617

Page 6

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB
	updated search	8/29/2011	TMB
	updated search	6/16/2012	TMB

SEARCH NOTES			
Search Notes		Date	Examiner
WEST text search		10/23/2010	TMB
WEST text search		5/23/2011	TMB
updated search		8/29/2011	TMB
updated search		6/16/2012	TMB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47			
CLAIM		DATE							
Final	Original	10/23/2010	05/23/2011	08/29/2011	06/16/2012				
	1	✓	✓	✓	✓				
	2	✓	✓	✓	✓				
	3	✓	✓	✓	✓				
	4	✓	✓	✓	✓				
	5	✓	✓	✓	✓				
	6	✓	✓	✓	✓				

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM

Examiner: T. M. Beamer

RESPONSE UNDER 37 C.F.R. 1.116 (FINAL OFFICE ACTION)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This is in response to the final Office Action mailed June 25, 2012 in the above-captioned case.

Amendments to the Claims are reflected in the Listing of Claims which begins on page 2 of this paper.

Remarks begin on page 4 of this paper.

AMENDMENTS TO THE CLAIMS

This Listing of Claims will replace all prior versions and listings of claims in this application.

Listing of Claims:

1. (Previously Presented) Apparatus, comprising:
 - control circuitry; and
 - a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference.
2. (Previously Presented) The apparatus of claim 1 further including a receiver operative to receive, from the associated device, a signal with information indicative of the power level adopted by the associated device, and wherein the control circuitry is operative to store the information in a memory.
3. (Previously Presented) The apparatus of claim 1 wherein the control circuitry is further operative to communicate with the associated device to select a power level for another device.
4. (Previously Presented) A method, comprising:
 - selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference;
 - causing the first device to transmit communication signals at the selected power level;
 - and
 - causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

5. (Previously Presented) The method of claim 4 including the further step of receiving, from the second device, a signal with information indicative of the power level of the second device, and storing the information in a memory.

6. (Previously Presented) The method of claim 4 including the further step of communicating with the second device to select a power level for another device.

REMARKS

Applicants thank the Examiner for the careful consideration given to this application. Reconsideration is now respectfully requested in view of the amendments above and the remarks provided below. Claims 1-6 are pending in the application. By this Amendment, no claims are amended. No new matter has been added.

Applicants initially note that the instant application has been acquired by new owners and is being prosecuted by new counsel.

Upon review of the earlier prosecution, there is some confusion as to the status of the claims.

Claims 1-6, of which claims 1 and 4 are independent, are rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. 5,465,399 to Oberholtzer et al. (hereinafter “Oberholtzer”) in view of U.S. 5,257,283 to Gilhousen et al. (hereinafter “Gilhousen”). Applicants respectfully traverse the rejection.

Claim 1 recites: “a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference.” These features are neither taught nor suggested by the applied art.

With respect to the “to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference,” the Office Action does not identify where this claim language is found, particularly the “to reduce undesirable interference” language. The Office Action refers to several portions of Oberholtzer at column 7 for teaching a transmit power, but nowhere does this disclosure relate to reduction of interference.

The Office Action additionally cites to Oberholtzer for such teachings at 2:66-3:11, for which the Office Action states:

Oberholtzer further discloses wherein each member station reports reception quality of received signals and if the received signals are of poor quality, the transmit power level is adjusted (col. 2, line 66-col. 3, line 11).

Applicants submit that this rationale misstates and misapplies the teachings of Oberholtzer.

Specifically, Oberholtzer discloses at 4:57-5:20 and 5:34-39:

In the preferred form of the invention, all radio transmissions by any member stations 10 are intended to be made at a transmit power level sufficient to reach and communicate effectively with all of the member stations (if possible), even though the actual message may be intended for only one of the member stations. By using the minimum required power to reach all member stations, any member station transmitting a message to one or more other member stations avoids using an excessive transmitter power level. The method and system used to establish a minimum transmit power level for effective communication with each member station in network 12, automatically and without operator intervention, thus represents a principal object of the present invention. . . .

Each member station adjusts its transmit power level in communicating with other member stations so as to ensure viable communications by maintaining a prescribed power margin above a predefined threshold reported by the member station with the lowest signal-to-noise ratio (SNR).

The above disclosure relates to how the system harmonizes the power level by setting the power level for all member stations based on the stations that have the lowest SNR. To the extent that the signal with the lowest SNR is considered by the Office Action to be a signal of “poor quality”, then the power level of that signal **is not adjusted at all**. Rather, other signals – as understood of superior SNR – will have their power level lowered to match; such an adjustment for these higher SNR signals is for harmonization purposes, but has nothing to do with interference adjustment. Thus, none of the signals of the reference are configured where “the selected power level” is “adjusted in order to reduce undesirable interference.”

Oberholtzer thus does not stand for the proposition for which it has been cited. On this basis alone, the rejection of claim 1 cannot be maintained.

With respect to the “wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference” language, the Office Action turns to Gilhousen, as follows:

Gilhousen further discloses wherein multiple mobile stations in the system repeatedly adjust transmission power in order to reduce undesirable system interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

Gilhousen does not stand for the proposition for which it has been cited. The citation at 2:5-18 refers to changes in power due to movement, and has no discussion of interference. The citation at 7:59-8:11 refers to increasing power that results in an increase in interference, this is the exact opposite of reducing undesirable interference as recited in claim 1. The citation at 8:33-42 does relate to decreasing interference, but provides no teaching or suggestion of “repeatedly” adjusting power. On this independent basis, claim 1 is distinct from Gillhousen.

Claim 1 is therefore patentably distinct over the applied art. Withdrawal of the rejection and allowance of the claim are therefore requested.

Independent claim 4 recites similar language to claim 1. While claim 4 is of its own scope, claim 4 is nonetheless patentably distinct for the reasons discussed with respect to claim 1. Withdrawal of the rejection and allowance of the same are therefore requested.

The various dependent claims are patentably distinct for at least the reasons discussed with respect to the independent claims. Withdrawal of the rejection of the dependent claims and allowance of the same are therefore requested.

In view of the above, consideration and allowance are respectfully solicited.

Application No.: 12/652,146

Docket No.: 27592-01380-US26

In the event the Examiner believes an interview might serve in any way to advance the prosecution of this application, the undersigned is available at the telephone number noted below.

The Office is authorized to charge any necessary fees to Deposit Account No. 22-0185.

Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 22-0185, under Order No. 27592-01380-US26 from which the undersigned is authorized to draw.

Dated: August 24, 2012

Respectfully submitted,

Electronic signature: /Scott Watkins/
Scott Watkins
Registration No.: 36,715
CONNOLLY BOVE LODGE & HUTZ LLP
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(202) 293-6229 (Fax)
Attorney for Applicant

Electronic Acknowledgement Receipt	
EFS ID:	13582930
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/David Jump
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	24-AUG-2012
Filing Date:	05-JAN-2010
Time Stamp:	14:44:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		08-24-12_Response.pdf	119183	yes	7
			56dc3ba4be1a4d981c31bee075e871a03af5782e		

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment After Final	1	1
	Claims	2	3
	Applicant Arguments/Remarks Made in an Amendment	4	7
Warnings:			
Information:			
Total Files Size (in bytes):		119183	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed			
APPLICATION AS FILED – PART I												
(Column 1)			(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY			
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)		
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$	=	X \$	=	X \$	=	X \$	=		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$	=	X \$	=	X \$	=	X \$	=		
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).											
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))												
* If the difference in column 1 is less than zero, enter "0" in column 2.												
APPLICATION AS AMENDED – PART II												
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	08/24/2012	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 6	Minus	** 20	= 0	X \$	=	X \$60=	0	X \$	=	0
	Independent (37 CFR 1.16(h))	* 2	Minus	***3	= 0	X \$	=	X \$250=	0	X \$	=	0
	☐ Application Size Fee (37 CFR 1.16(s))											
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0			
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$	=	X \$	=	X \$	=	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$	=	X \$	=	X \$	=	
	☐ Application Size Fee (37 CFR 1.16(s))											
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE				
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.												

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578
30678 7590 09/27/2012 CONNOLLY BOVE LODGE & HUTZ LLP 1875 EYE STREET, N.W. SUITE 1100 WASHINGTON, DC 20006			EXAMINER BEAMER, TEMICA M	
			ART UNIT 2617	PAPER NUMBER
			NOTIFICATION DATE 09/27/2012	DELIVERY MODE ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

patent@cblh.com

Advisory Action Before the Filing of an Appeal Brief	Application No. 12/652,146	Applicant(s) BACKES ET AL.
	Examiner TEMICA M. BEAMER	Art Unit 2617

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED _____ FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.
NO NOTICE OF APPEAL FILED

1. ☒ The reply was filed after a final rejection. No Notice of Appeal has been filed. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114 if this is a utility or plant application. Note that RCEs are not permitted in design applications. The reply must be filed within one of the following time periods:

a) ☐ The period for reply expires _____ months from the mailing date of the final rejection.

b) ☒ The period for reply expires on: (1) the mailing date of this Advisory Action; or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.

c) ☐ A prior Advisory Action was mailed more than 3 months after the mailing date of the final rejection in response to a first after-final reply filed within 2 months of the mailing date of the final rejection. The current period for reply expires _____ months from the mailing date of the prior Advisory Action or SIX MONTHS from the mailing date of the final rejection, whichever is earlier.

Examiner Note: If box 1 is checked, check either box (a), (b) or (c). ONLY CHECK BOX (b) WHEN THIS ADVISORY ACTION IS THE FIRST RESPONSE TO APPLICANT'S FIRST AFTER-FINAL REPLY WHICH WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. ONLY CHECK BOX (c) IN THE LIMITED SITUATION SET FORTH UNDER BOX (c). See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) or (c) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. ☐ The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. ☐ The proposed amendments filed after a final rejection, but prior to the date of filing a brief, will not be entered because:

a) ☐ They raise new issues that would require further consideration and/or search (see NOTE below);

b) ☐ They raise the issue of new matter (see NOTE below);

c) ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or

d) ☐ They present additional claims without canceling a corresponding number of finally rejected claims.

NOTE: _____. (See 37 CFR 1.116 and 41.33(a)).

4. ☐ The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).

5. ☐ Applicant's reply has overcome the following rejection(s): _____.

6. ☐ Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).

7. ☐ For purposes of appeal, the proposed amendment(s): (a) ☐ will not be entered, or (b) ☐ will be entered, and an explanation of how the new or amended claims would be rejected is provided below or appended.

AFFIDAVIT OR OTHER EVIDENCE

8. ☐ The affidavit or other evidence filed after final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).

9. ☐ The affidavit or other evidence filed after the date of filing the Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing of good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).

10. ☐ The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. ☒ The request for reconsideration has been considered but does NOT place the application in condition for allowance because:
The examiner maintains the rejections as set forth in the final rejection as explained in the remarks section. The examiner believes that the combination of Oberholtzer and Gilhousen discloses the invention as presently claimed. The power transmitted in these systems are increased or decreased in an effort to ensure that interference is minimized.

12. ☐ Note the attached Information *Disclosure Statement*(s). (PTO/SB/08) Paper No(s). _____

13. ☐ Other: _____.

STATUS OF CLAIMS

14. The status of the claim(s) is (or will be) as follows:

Claim(s) allowed: _____

Claim(s) objected to: _____

Claim(s) rejected: 1-6.

	/TEMICA M. BEAMER/ Primary Examiner, Art Unit 2617

DO NOT ENTER: /T.B./

09/24/2012

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM

Examiner: T. M. Beamer

RESPONSE UNDER 37 C.F.R. 1.116 (FINAL OFFICE ACTION)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This is in response to the final Office Action mailed June 25, 2012 in the above-captioned case.

Amendments to the Claims are reflected in the Listing of Claims which begins on page 2 of this paper.

Remarks begin on page 4 of this paper.

Request for Continued Examination (RCE) Transmittal Address to: Mail Stop RCE Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450	Application Number	12/652,146-Conf. #1578
	Filing Date	January 5, 2010
	First Named Inventor	Floyd Backes
	Art Unit	2617
	Examiner Name	T. M. Beamer
	Attorney Docket Number	27592-01380-US26

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.

Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. **Submission required under 37 CFR 1.114** Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).
 - a. ☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.
 - i. ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
 - ii. ☐ Other _____
 - b. ☒ Enclosed
 - i. ☒ Amendment/Reply
 - ii. ☐ Affidavit(s)/Declaration(s)
 - iii. ☐ Information Disclosure Statement (IDS)
 - iv. ☐ Other _____
2. **Miscellaneous**
 - a. ☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of _____ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)
 - b. ☐ Other _____
3. **Fees** The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.
 - a. ☐ The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any Overpayments, to Deposit Account No. 22-0185.
 - i. ☒ RCE fee required under 37 CFR 1.17(e)
 - ii. ☒ Extension of time fee (37 CFR 1.136 and 1.17)
 - iii. ☐ Other _____
 - b. ☐ Check in the amount of \$ _____ enclosed
 - c. ☒ Payment by credit card

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED			
Signature	/Scott Watkins/	Date	October 25, 2012
Name (Print/Type)	Scott Watkins	Registration No.	36,715

Electronic Patent Application Fee Transmittal				
Application Number:		12652146		
Filing Date:		05-Jan-2010		
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd Backes		
Filer:		Burton A. Amernick/Shawwna White		
Attorney Docket Number:		27592-01380-US26		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 1 month with \$0 paid	1251	1	150	150

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Request for continued examination	1801	1	930	930
Total in USD (\$)				1080

Electronic Acknowledgement Receipt	
EFS ID:	14077028
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/Shawwna White
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	25-OCT-2012
Filing Date:	05-JAN-2010
Time Stamp:	15:49:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$1080
RAM confirmation Number	2454
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Amendment Submitted/Entered with Filing of CPA/RCE	10-25-12_Amendment.pdf	123382 6c4ae8090d0dcecf6f3712eb2f7223500f6bcd3a6	no	9
Warnings:					
Information:					
2	Request for Continued Examination (RCE)	10-25-12_RCE_Transmittal.pdf	25179 c687da2735f76c122b86429904133b95e4455bee	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	32379 efdb51c433e0ccabe387d54eac39a4735cffe03	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			180940		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM

Examiner: T. M. Beamer

AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This follows the final Office Action mailed June 25, 2012 in the above-captioned case.

Amendments to the Claims are reflected in the Listing of Claims which begins on page 2 of this paper.

Remarks begin on page 6 of this paper.

AMENDMENTS TO THE CLAIMS

This Listing of Claims will replace all prior versions and listings of claims in this application.

Listing of Claims:

1. (Currently Amended) Apparatus, comprising:

control circuitry; and

a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level,

wherein the selected power level is repeatedly adjusted in order to reduce ~~undesirable~~ interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce ~~undesirable~~ interference.

2-3. (Cancelled)

4. (Currently Amended) A method, comprising:

selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce ~~undesirable~~ interference;

causing the first device to transmit communication signals at the selected power level;

and

causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

5-6. (Cancelled).

7. (New) The apparatus of claim 1, wherein the apparatus is operable to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

8. (New) The apparatus of claim 7, wherein the selected power level is lower than the maximum power level.

9. (New) The apparatus of claim 1, wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device.

10. (New) The apparatus of claim 9, wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

11. (New) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power.

12. (New) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the highest deviation.

13. (New) The method of claim 4, further comprising causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

14. (New) The method of claim 13, wherein the selected power level is lower than the maximum power level.

15. (New) The method of claim 4, further comprising setting the selected power level to a value below the nearest associated device on a same channel.

16. (New) The method of claim 15, wherein the setting the selected power level comprises:
initially setting the selected power level to the maximum power level, and
subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

17. (New) The method of claim 4, further comprising:
maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device;
and
wherein the selecting a power level comprises selecting the power level of one of the associated devices with the lowest transmission power.

18. (New) The method of claim 4, further comprising:
maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and
wherein the selecting a power level comprises selecting the power level of one of the associated devices with the highest deviation.

19. (New) A computer product including code stored on a non-transitory computer readable medium, the code comprising:
code for selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce interference;
code for causing the first device to transmit communication signals at the selected power level; and

code for causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

20. (New) The computer product of claim 19, further comprising code for causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

21. (New) The computer product of claim 20, wherein the selected power level is lower than the maximum power level.

22. (New) The computer product of claim 19, further comprising code for setting the selected power level to a value below the nearest associated device on a same channel.

23. (New) The computer product of claim 22, wherein the code for setting the selected power level comprises:

code for initially setting the selected power level to the maximum power level, and
code for subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

24. (New) The computer product of claim 19, further comprising:

code for maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the code for selecting a power level comprises code for selecting the power level of one of the associated devices with the lowest transmission power.

REMARKS

Applicants thank the Examiner for the careful consideration given to this application. Reconsideration is now respectfully requested in view of the amendments above and the remarks provided below. Claims 1, 4, and 7-24 are pending in the application. By this Amendment, no claims are amended, claims 7-24 are added, and claims 2, 3, 5 and 6 are cancelled. No new matter has been added.

The Advisory Action for the instant application indicates that Applicants arguments in the prior after Final response were not persuasive. Applicants would like to conduct an interview with the Examiner to discuss the same, such that Applicants resubmit the most recent arguments via RCE for that purpose.

Claims 1-6, of which claims 1 and 4 are independent and remain pending, are rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. 5,465,399 to Oberholtzer et al. (hereinafter “Oberholtzer”) in view of U.S. 5,257,283 to Gilhousen et al. (hereinafter “Gilhousen”). Applicants respectfully traverse the rejection.

Claim 1 recites: “a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference.” These features are neither taught nor suggested by the applied art.

With respect to the “to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce undesirable interference,” the Office Action does not identify where this claim language is found, particularly the “to reduce undesirable interference” language. The Office Action refers to several portions of Oberholtzer at column 7 for teaching a transmit power, but nowhere does this disclosure relate to reduction of interference.

The Office Action additionally cites to Oberholtzer for such teachings at 2:66-3:11, for which the Office Action states:

Oberholtzer further discloses wherein each member station reports reception quality of received signals and if the received signals are of poor quality, the transmit power level is adjusted (col. 2, line 66-col. 3, line 11).

Applicants submit that this rationale misstates and misapplies the teachings of Oberholtzer.

Specifically, Oberholtzer discloses at 4:57-5:20 and 5:34-39:

In the preferred form of the invention, all radio transmissions by any member stations 10 are intended to be made at a transmit power level sufficient to reach and communicate effectively with all of the member stations (if possible), even though the actual message may be intended for only one of the member stations. By using the minimum required power to reach all member stations, any member station transmitting a message to one or more other member stations avoids using an excessive transmitter power level. The method and system used to establish a minimum transmit power level for effective communication with each member station in network 12, automatically and without operator intervention, thus represents a principal object of the present invention. . . .

Each member station adjusts its transmit power level in communicating with other member stations so as to ensure viable communications by maintaining a prescribed power margin above a predefined threshold reported by the member station with the lowest signal-to-noise ratio (SNR).

The above disclosure relates to how the system harmonizes the power level by setting the power level for all member stations based on the stations that have the lowest SNR. To the extent that the signal with the lowest SNR is considered by the Office Action to be a signal of “poor quality”, then the power level of that signal **is not adjusted at all**. Rather, other signals – as understood of superior SNR – will have their power level lowered to match; such an adjustment for these higher SNR signals is for harmonization purposes, but has nothing to do with interference adjustment. Thus, none of the signals of the reference are configured where “the selected power level” is “adjusted in order to reduce undesirable interference.”

Oberholtzer thus does not stand for the proposition for which it has been cited. On this basis alone, the rejection of claim 1 cannot be maintained.

With respect to the “wherein the selected power level is repeatedly adjusted in order to reduce undesirable interference” language, the Office Action turns to Gilhousen, as follows:

Gilhousen further discloses wherein multiple mobile stations in the system repeatedly adjust transmission power in order to reduce undesirable system interference (col. 2, lines 5-18, col. 7, line 59-col. 8, line 11, col. 8, lines 33-42).

Gilhousen does not stand for the proposition for which it has been cited. The citation at 2:5-18 refers to changes in power due to movement, and has no discussion of interference. The citation at 7:59-8:11 refers to increasing power that results in an increase in interference, this is the exact opposite of reducing undesirable interference as recited in claim 1. The citation at 8:33-42 does relate to decreasing interference, but provides no teaching or suggestion of “repeatedly” adjusting power. On this independent basis, claim 1 is distinct from Gillhousen.

Claim 1 is therefore patentably distinct over the applied art. Withdrawal of the rejection and allowance of the claim are therefore requested.

Independent claim 4 recites similar language to claim 1. While claim 4 is of its own scope, claim 4 is nonetheless patentably distinct for the reasons discussed with respect to claim 1. Withdrawal of the rejection and allowance of the same are therefore requested.

Claims 7-25 have been added to further define the invention. No new matter has been added. Favorable consideration of new claims 7-25 are therefore respectfully requested.

In view of the above, consideration and allowance are respectfully solicited.

Application No.: 12/652,146

Docket No.: 27592-01380-US26

In the event the Examiner believes an interview might serve in any way to advance the prosecution of this application, the undersigned is available at the telephone number noted below.

The Office is authorized to charge any necessary fees to Deposit Account No. 22-0185.

Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 22-0185, under Order No. 27592-01380-US26 from which the undersigned is authorized to draw.

Dated: October 25, 2012

Respectfully submitted,

Electronic signature: /Scott Watkins/
Scott Watkins
Registration No.: 36,715
CONNOLLY BOVE LODGE & HUTZ LLP
1875 Eye Street, NW
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Washington, DC 20006
(202) 331-7111
(202) 293-6229 (Fax)
Attorney for Applicant

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed	
APPLICATION AS FILED – PART I										
(Column 1)			(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)				
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A		N/A					
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A		N/A					
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A		N/A					
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$ =		X \$ =					
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$ =		X \$ =					
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).									
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL		TOTAL					
APPLICATION AS AMENDED – PART II										
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY	
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)			
	Total (37 CFR 1.16(i))	*	Minus **	=	X \$ =	OR	X \$ =			
	Independent (37 CFR 1.16(h))	*	Minus ***	=	X \$ =	OR	X \$ =			
	☐ Application Size Fee (37 CFR 1.16(s))					OR				
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					OR				
				TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE			
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY	
AMENDMENT	10/25/2012	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(i))	* 20	Minus **	20 = 0	X \$ =	OR	X \$62 =	0		
	Independent (37 CFR 1.16(h))	* 2	Minus ***	3 = 0	X \$ =	OR	X \$250 =	0		
	☐ Application Size Fee (37 CFR 1.16(s))					OR				
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					OR				
				TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0		
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578
30678 7590 12/28/2012 CONNOLLY BOVE LODGE & HUTZ LLP 1875 EYE STREET, N.W. SUITE 1100 WASHINGTON, DC 20006			EXAMINER BEAMER, TEMICA M	
			ART UNIT 2646	PAPER NUMBER
			MAIL DATE 12/28/2012	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 12/652,146	Applicant(s) BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2646	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

- 1) ☒ Responsive to communication(s) filed on 25 October 2012.
- 2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.
- 3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.
- 4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

- 5) ☒ Claim(s) 1, 4 and 7-24 is/are pending in the application.
- 5a) Of the above claim(s) ____ is/are withdrawn from consideration.
- 6) ☐ Claim(s) ____ is/are allowed.
- 7) ☒ Claim(s) 1, 4 and 7-24 is/are rejected.
- 8) ☐ Claim(s) ____ is/are objected to.
- 9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

- 10) ☐ The specification is objected to by the Examiner.
- 11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

- 12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
- a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

- 1) ☒ Notice of References Cited (PTO-892)
- 2) ☐ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date ____.
- 3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date ____.
- 4) ☐ Other: ____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments with respect to claims 1 and 4 have been considered but are moot because the arguments do not apply to any of the references being used in the current rejection.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

3. Claims 1, 4, 7-10, 13-16 and 19-23 are rejected under 35 U.S.C. 102(e) as being anticipated by Dean, U.S. Patent Pub. No. 2011/0305172.

Regarding claims 1, 4 and 19, Dean discloses an apparatus/method, comprising: control circuitry; and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power

level at which a variable power transmitter of an associated device should be set in order to reduce interference.

Regarding claims 7, 13 and 20, Dean discloses wherein the apparatus/method is operable to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level (0139).

Regarding claims 8, 14 and 21, Dean discloses wherein the selected power level is lower than the maximum power level (0139).

Regarding claims 9, 15 and 22, Dean discloses wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device (0161).

Regarding claims 10, 16 and 23, Dean discloses wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel (0161).

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

5. Claims 11, 12, 17, 18 and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dean.

Regarding claims 11, 12, 17, 18 and 24, Dean discloses the apparatus/method/code of claims 1, 4 and a9 as described. Dean further inherently discloses a library or database of some sort that maintains a power level of associated devices since power adjustments are made based on the transmission power the device (0048, 0049).

Dean, however, fails to disclose wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power or wherein the power level is set to a power level of one of the associated devices with the highest deviation.

The examiner contends, however, that such adjustments would be based on design preference since Dean shows that power adjustments are increased or decreased in a manner to reduce interference (0051).

At the time of invention, it would have been obvious to a person of ordinary skill in the art to modify Dean for the purpose of increasing system performance.

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Butovitsch, U.S. Patent No. 6,708,041, discloses base station transmit power control in a CDMA cellular telephone system.

Kim et al., U.S. Patent No. 6,418,322, discloses a method for forward power control in a cellular system.

Lysejko, U.S. Patent No. 5,745,496, discloses an apparatus and method of establishing a downlink communication path in a wireless telecommunications system.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is (571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TEMICA M. BEAMER/
Primary Examiner, Art Unit 2646

Notice of References Cited	Application/Control No. 12/652,146		Applicant(s)/Patent Under Reexamination BACKES ET AL.	
	Examiner TEMICA M. BEAMER		Art Unit 2646	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2011/0305172	12-2011	Dean, Richard F.	370/279
*	B	US-6,708,041	03-2004	Butovitsch et al.	455/522
*	C	US-6,418,322	07-2002	Kim et al.	455/522
*	D	US-5,745,496	04-1998	Lysejko, Martin	370/515
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47			
CLAIM		DATE							
Final	Original	10/23/2010	05/23/2011	08/29/2011	06/16/2012	12/17/2012			
	1	✓	✓	✓	✓	✓			
	2	✓	✓	✓	✓	-			
	3	✓	✓	✓	✓	-			
	4	✓	✓	✓	✓	✓			
	5	✓	✓	✓	✓	-			
	6	✓	✓	✓	✓	-			
	7					✓			
	8					✓			
	9					✓			
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	19					✓			
	20					✓			
	21					✓			
	22					✓			
	23					✓			
	24					✓			

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB
	updated search	8/29/2011	TMB
	updated search	6/16/2012	TMB
	updated search	12/17/2012	TMB

SEARCH NOTES			
Search Notes		Date	Examiner
WEST text search		10/23/2010	TMB
WEST text search		5/23/2011	TMB
updated search		8/29/2011	TMB
updated search		6/16/2012	TMB
updated search		12/17/2012	TMB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

.....
In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM
.....

Examiner: T. M. Beamer

RESPONSE TO NON-FINAL OFFICE ACTION

Mail Stop AMENDMENT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This is in response to the non-final Office Action mailed December 26, 2012, in the above-captioned case.

5137614

AMENDMENTS TO THE CLAIMS

This Listing of Claims will replace all prior versions and listings of claims in this application.

Listing of Claims:

1. (Previously Presented) Apparatus, comprising:
 - control circuitry; and
 - a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce interference.
- 2-3. (Cancelled)
4. (Previously Presented) A method, comprising:
 - selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce interference;
 - causing the first device to transmit communication signals at the selected power level;
 - and
 - causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.
- 5-6. (Cancelled).
7. (Previously Presented) The apparatus of claim 1, wherein the apparatus is operable to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

8. (Previously Presented) The apparatus of claim 7, wherein the selected power level is lower than the maximum power level.

9. (Previously Presented) The apparatus of claim 1, wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device.

10. (Previously Presented) The apparatus of claim 9, wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

11. (Previously Presented) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power.

12. (Previously Presented) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the highest deviation.

13. (Previously Presented) The method of claim 4, further comprising causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

14. (Previously Presented) The method of claim 13, wherein the selected power level is lower than the maximum power level.

15. (Previously Presented) The method of claim 4, further comprising setting the selected power level to a value below the nearest associated device on a same channel.

16. (Previously Presented) The method of claim 15, wherein the setting the selected power level comprises:

- initially setting the selected power level to the maximum power level, and
- subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

17. (Previously Presented) The method of claim 4, further comprising:

- maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device;
- and

- wherein the selecting a power level comprises selecting the power level of one of the associated devices with the lowest transmission power.

18. (Previously Presented) The method of claim 4, further comprising:

- maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

- wherein the selecting a power level comprises selecting the power level of one of the associated devices with the highest deviation.

19. (Previously Presented) A computer product including code stored on a non-transitory computer readable medium, the code comprising:

- code for selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce interference;

- code for causing the first device to transmit communication signals at the selected power level; and

code for causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

20. (Previously Presented) The computer product of claim 19, further comprising code for causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

21. (Previously Presented) The computer product of claim 20, wherein the selected power level is lower than the maximum power level.

22. (Previously Presented) The computer product of claim 19, further comprising code for setting the selected power level to a value below the nearest associated device on a same channel.

23. (Previously Presented) The computer product of claim 22, wherein the code for setting the selected power level comprises:

code for initially setting the selected power level to the maximum power level, and
code for subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

24. (Previously Presented) The computer product of claim 19, further comprising:

code for maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the code for selecting a power level comprises code for selecting the power level of one of the associated devices with the lowest transmission power.

REMARKS

Applicants thank the Examiner for the careful consideration given to this application. Reconsideration is now respectfully requested in view of the amendment above and the following remarks.

Claims 1, 4 and 7-24 are pending in this application. Claims 1, 4 and 19 are independent claims. Claims 2, 3, 5 and 6 were previously cancelled without prejudice or disclaimer. No claims are herein amended, added or cancelled. Reconsideration and allowance of the presented application are respectfully requested.

Applicants requested a telephone interview for the instant application. The interview agenda as submitted by email was as follows:

Applicants would like to discuss the following:

- The Office Action does not provide supporting rationale for the rejection of claim 4. Applicants seek clarification as to what teachings in Dean are being applied against this claim.
- The Office Action cites to Dean 139 against claim 7, but Applicants do not understand how this is the case. Clarification is requested.
- The Office Action cites to Dean 161 against claim 9, but again Applicants do not understand how this is the case. Clarification is requested.
- Also with respect to claim 7 and 9, it is unclear how the supporting rationale dovetails with the rejection of claim 1. Specifically, 139 and 161 of Dean relate to actions of the Dean repeater. Since the Office Action does not provide any citation to support the rejection of claim 1, it is unclear whether the rejection of claim 1 is similarly based on the repeater, or other element such as the Dean base station. Clarification on the nature of the specific basis for the rejection of claim 1 is therefore needed.

The Examiner replied by email, as follows:

I apologize for such short notice, but I am unable to have our interview scheduled for 1pm today. However, I have already reviewed your comments, the Dean reference and the rejection. Dean does lack support for some of the limitations claimed, therefore, if you file a response to the office action stating your concerns, I will complete another non-final action (or possible allowance depending on the search). I will submit an interview summary which will summarize this discussion in this e-mail.

Pursuant to the above, Applicants respond to the Office Action as follows.

Independent claim 1, and claims 7-10, stand rejected under 35 U.S.C. § 102(e) as being anticipated by Dean, US Publication 2011/0305172. Applicants respectfully traverse the rejection. The Office Action does not provide any rationale or citation for the rejection of claim 1, which precludes meaningful response. Further, Applicants cannot discern how the citations applied against claims 7 and 9 are considered disclose the subject matter of these dependent claims.

Claims 11 and 12, which depend from claim 1, stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Dean. As noted above, the absence of rationale with respect to claim 1 precludes a meaningful response. Further, the sole basis of rejection of claim 11 is inherency and claim 12 is design choice. No evidence is provided in favor of either rationale. To the extent that the Examiner maintains the rejection, Applicants request that the Examiner provide supporting evidence of the same in the next communication.

Independent claim 4, and claims 13, 15 and 16 that depend therefrom, stand rejected under 35 U.S.C. § 102(e) as being anticipated by Dean, and dependent claims 17 and 18 that depend from claim 4 stand rejected as obvious over Dean. The Office Action does not analyze claim 4, which precludes any meaningful response by Applicants. Also, to the extent that the rejection of claims 17 and 18 are based on inherency or design choice, Applicants request evidence of the same.

Independent claim 19, and claims 20-23 that depend therefrom, stand rejected under 35 U.S.C. § 102(e) as being anticipated by Dean, and dependent claim 24 that depends from claim 19 stand rejected as obvious over Dean. The Office Action does not analyze claim 19, which precludes any meaningful response by Applicants. Also, to the extent that the rejection of claims 24 is based on inherency or design choice, Applicants request evidence of the same.

For the foregoing reasons, Applicants request that the Examiner “complete another non-final action (or possible allowance depending on the search)” as set forth in the email exchange with Applicants.

Disclaimer

Applicants may not have presented all possible arguments or have refuted the characterizations of either the claims or the prior art as found in the Office Action. However, the lack of such arguments or refutations is not intended to act as a waiver of such arguments or as concurrence with such characterizations.

CONCLUSION

In view of the above, reconsideration and allowance are respectfully solicited.

In the event the Examiner believes an interview might serve in any way to advance the prosecution of this application, the undersigned is available at the telephone number noted below.

The Office is authorized to charge any necessary fees to Deposit Account No. 22-0185.

Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 22-0185, under Order No. 27592-01380-US26 from which the undersigned is authorized to draw.

Dated: February 25, 2013

Respectfully submitted,

Electronic signature: /Scott Watkins/

Scott Watkins

Registration No.: 36,715

NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP

1875 Eye Street, NW

11TH Floor

Washington, DC 20006

(202) 331-7111

(202) 293-6229 (Fax)

Attorney for Applicant

Electronic Acknowledgement Receipt	
EFS ID:	15035191
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/Valerie Williams
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	25-FEB-2013
Filing Date:	05-JAN-2010
Time Stamp:	10:30:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		RespNFOA_dtd_12_26_12.pdf	1392983 b944fb12d3afc6e13f97cfa0c6a590b8d014deb2	yes	8

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	5
	Applicant Arguments/Remarks Made in an Amendment	6	8
Warnings:			
Information:			
Total Files Size (in bytes):		1392983	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed			
APPLICATION AS FILED – PART I												
(Column 1)			(Column 2)		SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY			
FOR	NUMBER FILED	NUMBER EXTRA	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)	RATE (\$)	FEE (\$)		
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X \$	=	X \$	=	X \$	=	X \$	=		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X \$	=	X \$	=	X \$	=	X \$	=		
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$250 (\$125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).											
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))												
* If the difference in column 1 is less than zero, enter "0" in column 2.												
APPLICATION AS AMENDED – PART II												
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	02/25/2013	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$	=	X \$62=	0	X \$	=	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$	=	X \$250=	0	X \$	=	0
	☐ Application Size Fee (37 CFR 1.16(s))											
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0			
(Column 1)			(Column 2)		(Column 3)		SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$	=	X \$	=	X \$	=	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$	=	X \$	=	X \$	=	
	☐ Application Size Fee (37 CFR 1.16(s))											
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))											
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE				
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.												

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.



UNITED STATES PATENT AND TRADEMARK OFFICE

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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578
30678 7590 06/18/2013 NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP 1875 EYE STREET, N.W. SUITE 1100 WASHINGTON, DC 20006			EXAMINER BEAMER, TEMICA M	
			ART UNIT 2646	PAPER NUMBER
			MAIL DATE 06/18/2013	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 12/652,146	Applicant(s) BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2646	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 25 February 2013.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ____.

2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5) ☒ Claim(s) 1,4 and 7-24 is/are pending in the application.
5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) ____ is/are allowed.

7) ☒ Claim(s) 1,4,7-11,13-17 and 19-24 is/are rejected.

8) ☒ Claim(s) 12 and 18 is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some * c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. ____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Interim copies:

a) ☐ All b) ☐ Some c) ☐ None of the: Interim copies of the priority documents have been received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08)
Paper No(s)/Mail Date ____.

3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. ____.

4) ☐ Other: ____.

DETAILED ACTION

Response to Arguments

1. Applicant's arguments with respect to the present claims have been considered but are moot because the arguments do not apply to any of the references being used in the current rejection.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

3. Claims 1, 4, 7-10, 13-16 and 19-23 are rejected under 35 U.S.C. 102(b) as being anticipated by Dent, U.S. Patent No. 5,579,306.

Regarding claim 1, Dent discloses an apparatus (base station site 41), comprising: control circuitry (col. 4, lines 50-67; figure 4); and a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level, wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce interference (col. 2, lines 30-55, col. 4, lines 3-20, col. 5, lines 1-9).

Regarding claims 4 and 19, Dent discloses a method/code comprising selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce interference; causing the first device to transmit communication signals at the selected power level; and causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts to the selected power level (col. 2, lines 30-55, col. 4, lines 3-20, col. 5, lines 1-9).

Regarding claims 7 and 20, Dent discloses wherein the apparatus is operable to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level (col. 3, lines 21-40).

Regarding claims 8 and 21, Dent discloses wherein the selected power level is lower than the maximum power level (col. 3, line 60-col. 4, line 2).

Regarding claims 9 and 22, Dent discloses wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device (col. 4, lines 3-31).

Regarding claims 10 and 23, Dent discloses wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel (col. 4, lines 32-49).

Regarding claims 11 and 24, Dent discloses the apparatus further comprising a library of (1) the associated devices and (2) for each associated device a corresponding

value representing a transmission power of the corresponding associated device; and wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power (col. 6, lines 35-47).

Regarding claim 13, Dent discloses the method of claim 4 further comprising the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level (col. 3, lines 21-40).

Regarding claim 14, Dent discloses the method of claim 13, wherein the selected power level is lower than the maximum power level (col. 3, line 62-col. 4, line 2).

Regarding claim 15, Dent discloses the method of claim 4, further comprising setting the selected power level to a value below the nearest associated device on a same channel (col. 4, lines 3-31).

Regarding claim 16, Dent discloses the method of claim 15, wherein the setting the selected power level comprises: initially setting the selected power level to the maximum power level, and subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel (col. 4, lines 32-49).

Regarding claim 17, Dent discloses the method of claim 4, further comprising maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power (col. 6, lines 35-47).

Allowable Subject Matter

4. Claims 12 and 18 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

5. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Won et al., U.S. Patent No. 5,991,636, discloses an adaptive power control method for a CDMA mobile radio telephone system.

Sawahashi et al., U.S. Patent No. 5,590,409, discloses a transmission power control method and transmission power control apparatus.

Gilhousen et al., U.S. Patent No. 5,485,486, discloses a method and apparatus for controlling transmission power in a CDMA cellular telephone system.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to TEMICA M. BEAMER whose telephone number is (571)272-7797. The examiner can normally be reached on Monday-Thursday (alternate Fridays) 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lester Kincaid can be reached on (571) 272-7922. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/TEMICA M. BEAMER/
Primary Examiner, Art Unit 2646

Notice of References Cited	Application/Control No. 12/652,146	Applicant(s)/Patent Under Reexamination BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2646	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-5,579,306	11-1996	Dent, Paul W.	370/330
*	B	US-5,991,636	11-1999	Won et al.	455/522
*	C	US-5,590,409	12-1996	Sawahashi et al.	455/69
*	D	US-5,485,486	01-1996	Gilhousen et al.	370/335
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47			
CLAIM		DATE							
Final	Original	10/23/2010	05/23/2011	08/29/2011	06/16/2012	12/17/2012	06/15/2013		
	1	✓	✓	✓	✓	✓	✓		
	2	✓	✓	✓	✓	-	-		
	3	✓	✓	✓	✓	-	-		
	4	✓	✓	✓	✓	✓	✓		
	5	✓	✓	✓	✓	-	-		
	6	✓	✓	✓	✓	-	-		
	7					✓	✓		
	8					✓	✓		
	9					✓	✓		
	10					✓	✓		
	11					✓	✓		
	12					✓	O		
	13					✓	✓		
	14					✓	✓		
	15					✓	✓		
	16					✓	✓		
	17					✓	✓		
	18					✓	O		
	19					✓	✓		
	20					✓	✓		
	21					✓	✓		
	22					✓	✓		
	23					✓	✓		
	24					✓	✓		

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB
	updated search	8/29/2011	TMB
	updated search	6/16/2012	TMB
	updated search	12/17/2012	TMB
	updated search	6/15/2013	TMB

SEARCH NOTES		
Search Notes	Date	Examiner
WEST text search	10/23/2010	TMB
WEST text search	5/23/2011	TMB
updated search	8/29/2011	TMB
updated search	6/16/2012	TMB
updated search	12/17/2012	TMB
updated search	6/15/2013	TMB

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM

Examiner: T. M. Beamer

RESPONSE TO NON-FINAL OFFICE ACTION

Mail Stop **AMENDMENT**
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This is in response to the non-final Office Action mailed June 18, 2013, in the above-captioned case.

5137614

AMENDMENTS TO THE CLAIMS

This Listing of Claims will replace all prior versions and listings of claims in this application.

Listing of Claims:

1. (Previously Presented) Apparatus, comprising:

control circuitry; and

a variable power transmitter operable in response to the control circuitry to transmit wireless communication signals at a selected power level up to a maximum power level,

wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce interference.

2-3. (Cancelled)

4. (Previously Presented) A method, comprising:

selecting a power level at which a first device is to transmit wireless signals, wherein the selected power level is repeatedly adjusted in order to reduce interference;

causing the first device to transmit communication signals at the selected power level;

and

causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

5-6. (Cancelled).

7. (Previously Presented) The apparatus of claim 1, wherein the apparatus is operable to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

8. (Previously Presented) The apparatus of claim 7, wherein the selected power level is lower than the maximum power level.

9. (Previously Presented) The apparatus of claim 1, wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device.

10. (Previously Presented) The apparatus of claim 9, wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

11. (Previously Presented) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the lowest transmission power.

12. (Previously Presented) The apparatus of claim 1, further comprising:

a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

wherein the selected power level is set to a power level of one of the associated devices with the highest deviation.

13. (Previously Presented) The method of claim 4, further comprising causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

14. (Previously Presented) The method of claim 13, wherein the selected power level is lower than the maximum power level.

15. (Previously Presented) The method of claim 4, further comprising setting the selected power level to a value below the nearest associated device on a same channel.

16. (Previously Presented) The method of claim 15, wherein the setting the selected power level comprises:

initially setting the selected power level to the maximum power level, and
subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

17. (Previously Presented) The method of claim 4, further comprising:

maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device;
and

wherein the selecting a power level comprises selecting the power level of one of the associated devices with the lowest transmission power.

18. (Previously Presented) The method of claim 4, further comprising:

maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

wherein the selecting a power level comprises selecting the power level of one of the associated devices with the highest deviation.

19. (Previously Presented) A computer product including code stored on a non-transitory computer readable medium, the code comprising:

code for selecting a power level at which a first device is to transmit wireless signals,
wherein the selected power level is repeatedly adjusted in order to reduce interference;

code for causing the first device to transmit communication signals at the selected power level; and

code for causing the first device to transmit a signal to a second device with information indicative of the selected power level such that the second device adopts the selected power level.

20. (Previously Presented) The computer product of claim 19, further comprising code for causing the first device to transmit at the maximum power level, regardless of the selected power level, the signal with information indicative of a power level.

21. (Previously Presented) The computer product of claim 20, wherein the selected power level is lower than the maximum power level.

22. (Previously Presented) The computer product of claim 19, further comprising code for setting the selected power level to a value below the nearest associated device on a same channel.

23. (Previously Presented) The computer product of claim 22, wherein the code for setting the selected power level comprises:

code for initially setting the selected power level to the maximum power level, and
code for subsequently reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.

24. (Previously Presented) The computer product of claim 19, further comprising:

code for maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a transmission power of the corresponding associated device; and

wherein the code for selecting a power level comprises code for selecting the power level of one of the associated devices with the lowest transmission power.

25. (New) The computer product of claim 19, further comprising:

code for maintaining a library of (1) the associated devices and (2) for each associated device a corresponding value representing a deviation from a maximum power of the transmission power of the corresponding associated device; and

wherein the code for selecting a power level comprises code for selecting a power level to a power level of one of the associated devices with the highest deviation.

REMARKS

Applicants thank the Examiner for the careful consideration given to this application. Reconsideration is now respectfully requested in view of the amendment above and the following remarks.

Claims 1, 4 and 7-25 are pending in this application. Claims 1, 4 and 19 are independent claims. Claims 2, 3, 5 and 6 were previously cancelled without prejudice or disclaimer. Claim 25 has been added. No other claims are herein amended, added or cancelled. Reconsideration and allowance of the presented application are respectfully requested.

Summary of Examiner Interview

Applicants thank the Examiner for the telephone interview to discuss the status of the pending application. Herein follows a summary of the interview.

The discussion focused on the claim 1 language: “wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce interference”. Applicants requested that the Examiner clarify what teachings in the Dent reference were considered to meet the “repeatedly” and “reduce interference”. The Examiner expressed that these concepts were perhaps not clearly shown in the reference and thus not a proper basis for anticipation, although the Examiner nonetheless felt that the teachings were obvious.

Claim Rejections Under 35 U.S.C. § 102

Claim 1, 4, 7-10, 13-16, and 19-2, of which claims 1, 4 and 19 are independent, are rejected under 35 U.S.C. § 102(b) as being anticipated by Dean, U.S. Patent No. 5,579,306. Applicants respectfully requested.

Claim 1 is representative of the independent claims. Claim 1 recites: “wherein the selected power level is repeatedly adjusted in order to reduce interference, and to transmit a signal with information indicative of a power level at which a variable power transmitter of an

associated device should be set in order to reduce interference.” These features are neither taught nor suggested by the Dent reference.

With respect to the language and “to transmit a signal with information indicative of a power level at which a variable power transmitter of an associated device should be set in order to reduce interference”, there is no corresponding teaching or suggestion in Dent. The only discussion of interference in Dent is that Dent selects “the frequency and time slot containing minimum interference.” Dent 3:56-60. There is no teaching or suggestion that Dent addresses interference at the power level. Indeed, Dent treats power issues as: “Commands are issued to the mobile station over the air to adjust its power level to a level sufficient for good received signal quality at the base.” Dent thus addresses interference by frequency and time selection; there is no basis to conclude that Dent addresses interference from the perspective of power level.

With respect to the “repeatedly” language, there is no teaching or suggestion of the same in Dent. The Examiner expressed a belief that the teachings of Dent power level settings occur continuously, but no disclosure in Dent states this. In view of the lack of support, continuous activity cannot be inferred.

Claim 1 is accordingly patentably distinct over the applied art. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

Independent claims 4 and 19 recite similar language to claim 1. While claims 4 and 19 are of their own scope, these claims are likewise patentably distinct over the applied art for at least the reasons discussed with respect to claim 1. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

Dependent claims 7, 13 and 20, which depend from claims 1, 4 and 19, respectively have been rejected on the same grounds as claim 1. Applicants respectfully traverse the rejection.

Claims 7, 13 and 20 are patentably distinct from the applied art for at least the reasons discussed with respect to claim 1 above. In addition, claim 7 recites: “wherein the apparatus is operable to transmit at the maximum power level, regardless of the selected power level, the

signal with information indicative of a power level”. Claims 13 and 20 recites similar language. This combination is neither taught nor suggested by the applied art.

The Office Action cites Dent at 3:21-40 for the corresponding teachings. However, the cited section refers to the prior art, not the Dent invention. Note Dent at 3:21 “FIGS. 1 and 2 illustrate *conventional* allocation scheme . . .”, and both Figs. 1 and 2 are labeled “prior art” in the figures. The figures show that the prior art is sending signals at maximum power, but does not teach that “the signal with information indicative of a power level” is sent at maximum power. Rather, Dent Fig.3 shows that the power levels of the frequency are determined by the phone needs. Nowhere does Dent teach or suggest that it transmits “the signal with information indicative of a power level” at max power regardless of the power level.

Claims 7, 13 and 20, and claims 8, 14 and 21 that depend therefrom, respectively, are accordingly patentably distinct over the applied art. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

Dependent claims 9, 15, and 22, which depend from claims 1, 4 and 19, respectively have been rejected on the same grounds as claim 1. Applicants respectfully traverse the rejection.

Claims 9, 15 and 22 are patentably distinct from the applied art for at least the reasons discussed with respect to claim 1 above. In addition, claim 9 recites: “wherein the apparatus is operable to set the selected power level to a value below a nearest associated device on a same channel to thereby avoid interference with the nearest associated device.” Claims 15 and 22 recite similar language. This combination is neither taught nor suggested by the applied art.

The Office Action cites Dent at 4:3-31 for the corresponding teachings. The cited section refers to power levels set as new mobile devices are added to the frequency. There is no disclosure of any kind in this section, or any part of Dent, as to a power level of a “nearest” associated device. Also, when the same channel is maintained, Dent adjusts the power level upward if need to accommodate the estimated power needs of the newly added device: “If the required power for the second mobile link level is, for example, 0 to 6 dB higher than that for the first mobile, the base smoothly increases the power transmitted to the higher level.” At no point is the power level set to a “value below” the “nearest” associated device as recited in claim 9.

Claims 9, 15 and 22, and claims 10, 16 and 23 that depend therefrom, respectively, are accordingly patentably distinct over the applied art. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

Dependent claims 10, 16 and 23, which depend from claims 9, 15 and 22 above, respectively, have been rejected on the same grounds as claim 1. Applicants respectfully traverse the rejection.

Claims 10, 16 and 23 are patentably distinct from the applied art for at least the reasons discussed with respect to claims 1 and 9 above. In addition, claim 10 recites: “wherein the selected power level is reached by initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device on a same channel.” Claims 16 and 23 recite similar language. This combination is neither taught nor suggested by the applied art.

The Office Action cites Dent at 4:32-41 for the corresponding teachings. However, the cited section refers states that when a new device is added “The mobile is then allocated a time slot on that frequency for which the transmit power is greater than but closest to the estimated power. . . the highest power transmission is smoothly increased to the estimated requirement for the new mobile, and the new mobile allocated an unused time slot on that frequency.” Dent thus raises the power level of the base from where it is to where it needs to be to accommodate the new device via the power being “smoothly increased” to the desired level. There is no teaching or suggestion of “initially setting the selected power level to the maximum power level, and then reducing the transmit power of the variable power transmitter to a level below the nearest associated device” as recited in claim 10.

Claims 10, 16 and 23 are accordingly patentably distinct over the applied art. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

The remaining dependent claims are patentably distinct over the applied art for at least the reasons discussed with respect to the independent claims. Withdrawal of the rejection and allowance of the same are therefore respectfully requested.

Applicants acknowledge with the thanks the indication of allowable subject matter in claims 12 and 18, which depend from claims 1 and 4, respectively. As Applicants believe claims 1 and 4 are patentable in their current form, Applicants have taken no further action with claims 12 and 18 at this time.

New claim 25 has been added to further define that which Applicants regard as their invention. Claim 25 is similar to claims 12 and 18, but is drafted to depend from claim 19. Favorable consideration of new claim 25 is respectfully requested.

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Applicants may not have presented all possible arguments or have refuted the characterizations of either the claims or the prior art as found in the Office Action. However, the lack of such arguments or refutations is not intended to act as a waiver of such arguments or as concurrence with such characterizations.

CONCLUSION

In view of the above, reconsideration and allowance are respectfully solicited.

In the event the Examiner believes an interview might serve in any way to advance the prosecution of this application, the undersigned is available at the telephone number noted below.

The Office is authorized to charge any necessary fees to Deposit Account No. 22-0185.

Applicant believes no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 22-0185, under Order No. 27592-01380-US26 from which the undersigned is authorized to draw.

Dated: September 17, 2013

Respectfully submitted,

Electronic signature: /Scott Watkins/
Scott Watkins

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Attorney for Applicant

Electronic Acknowledgement Receipt	
EFS ID:	16876433
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/Kathleen Peacock
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	17-SEP-2013
Filing Date:	05-JAN-2010
Time Stamp:	15:21:44
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		27592-01380-US26_RES_9-17-13.pdf	112242 7f71e3a166c626d0f578cf538bd9fb55043d1b33	yes	12

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	6
	Applicant Arguments/Remarks Made in an Amendment	7	12
Warnings:			
Information:			
Total Files Size (in bytes):		112242	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

REMARKS

Applicants thank the Examiner for the careful consideration given to this application. Reconsideration is now respectfully requested in view of the amendment above and the following remarks.

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Dated: September 17, 2013

Respectfully submitted,

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Scott Watkins

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Attorney for Applicant

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/652,146		Filing Date 01/05/2010		☐ To be Mailed	
ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
(Column 1)		(Column 2)							
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).							
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.						TOTAL			
APPLICATION AS AMENDED – PART II									
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT	09/17/2013		CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total (37 CFR 1.16(i))		* 21		Minus	** 20	= 1		
	Independent (37 CFR 1.16(h))		* 3		Minus	***3	= 0		
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						RATE (\$)		ADDITIONAL FEE (\$)	
						x \$80 =		80	
						x \$420 =		0	
						TOTAL ADD'L FEE		80	
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT			CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total (37 CFR 1.16(i))		*		Minus	**	=		
	Independent (37 CFR 1.16(h))		*		Minus	***	=		
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						RATE (\$)		ADDITIONAL FEE (\$)	
						X \$ =			
						X \$ =			
						TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.									

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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30678 7590 01/03/2014
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EXAMINER

BEAMER, TEMICA M

ART UNIT

PAPER NUMBER

2646

DATE MAILED: 01/03/2014

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578

TITLE OF INVENTION: Program for Adjusting Channel Interference between Access Points in a Wireless Network

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960	\$0	\$0	\$960	04/03/2014

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

30678 7590 01/03/2014
NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP
1875 EYE STREET, N.W.
SUITE 1100
WASHINGTON, DC 20006

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578

TITLE OF INVENTION: Program for Adjusting Channel Interference between Access Points in a Wireless Network

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960	\$0	\$0	\$960	04/03/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
BEAMER, TEMICA M	2646	455-418000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
☐ Applicant asserting small entity status. See 37 CFR 1.27
☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578

30678	7590	01/03/2014
NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP		
1875 EYE STREET, N.W.		
SUITE 1100		
WASHINGTON, DC 20006		

EXAMINER	
BEAMER, TEMICA M	

ART UNIT	PAPER NUMBER
2646	

DATE MAILED: 01/03/2014

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

**Notices of Allowance and Fee(s) Due mailed between October 1, 2013 and
December 31, 2013**

(Addendum to PTOL-85)

If the "Notice of Allowance and Fee(s) Due" has a mailing date on or after October 1, 2013 and before January 1, 2014, the following information is applicable to this application.

If the issue fee is being timely paid on or after January 1, 2014, the amount due is the issue fee and publication fee in effect January 1, 2014. On January 1, 2014, the issue fees set forth in 37 CFR 1.18 decrease significantly and the publication fee set forth in 37 CFR 1.18(d)(1) decreases to \$0.

If an issue fee or publication fee has been previously paid in this application, applicant is not entitled to a refund of the difference between the amount paid and the amount in effect on January 1, 2014.

Notice of Allowability	Application No. 12/652,146	Applicant(s) BACKES ET AL.	
	Examiner TEMICA M. BEAMER	Art Unit 2646	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to amendment filed 9/17/2013.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1, 4 and 7-25 (renumbered as claims 1-21). As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:
a) ☐ All b) ☐ Some *c) ☐ None of the:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).
* Certified copies not received: _____.

Applicant has **THREE MONTHS FROM THE "MAILING DATE"** of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in **ABANDONMENT** of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)	5. ☐ Examiner's Amendment/Comment
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____	6. ☐ Examiner's Statement of Reasons for Allowance
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material	7. ☐ Other _____
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____	

/TEMICA M. BEAMER/ Primary Examiner, Art Unit 2646	

<i>Index of Claims</i> 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2646

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47				
CLAIM		DATE								
Final	Original	10/23/2010	05/23/2011	08/29/2011	06/16/2012	12/17/2012	06/15/2013	12/30/2013		
1	1	✓	✓	✓	✓	✓	✓	=		
-	2	✓	✓	✓	✓	-	-	-		
-	3	✓	✓	✓	✓	-	-	-		
2	4	✓	✓	✓	✓	✓	✓	=		
-	5	✓	✓	✓	✓	-	-	-		
-	6	✓	✓	✓	✓	-	-	-		
3	7					✓	✓	=		
4	8					✓	✓	=		
5	9					✓	✓	=		
6	10					✓	✓	=		
7	11					✓	✓	=		
8	12					✓	O	=		
9	13					✓	✓	=		
10	14					✓	✓	=		
11	15					✓	✓	=		
12	16					✓	✓	=		
13	17					✓	✓	=		
14	18					✓	O	=		
15	19					✓	✓	=		
16	20					✓	✓	=		
17	21					✓	✓	=		
18	22					✓	✓	=		
19	23					✓	✓	=		
20	24					✓	✓	=		
21	25							=		

Issue Classification 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2646

US ORIGINAL CLASSIFICATION						INTERNATIONAL CLASSIFICATION									
CLASS		SUBCLASS				CLAIMED						NON-CLAIMED			
455		418				H	O	4	M	3 / 00 (2006.01.01)					
CROSS REFERENCE(S)															
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)														
455	67.11	67.13	434	522											

NONE		Total Claims Allowed:	
		21	
(Assistant Examiner)	(Date)		
/TEMICA M BEAMER/ Primary Examiner.Art Unit 2646	12/30/2013	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	4

Issue Classification 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2646

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47															
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	13	17												
-	2	14	18												
-	3	15	19												
2	4	16	20												
-	5	17	21												
-	6	18	22												
3	7	19	23												
4	8	20	24												
5	9	21	25												
6	10														
7	11														
8	12														
9	13														
10	14														
11	15														
12	16														

NONE		Total Claims Allowed:	
		21	
(Assistant Examiner)	(Date)		
/TEMICA M BEAMER/ Primary Examiner.Art Unit 2646	12/30/2013	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	4

Search Notes 	Application/Control No. 12652146	Applicant(s)/Patent Under Reexamination BACKES ET AL.
	Examiner TEMICA M BEAMER	Art Unit 2617

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
455	522,67.11, 67.13, 434, 226.1	10/23/2010	TMB
	updated search	5/23/2011	TMB
	updated search	8/29/2011	TMB
	updated search	6/16/2012	TMB
	updated search	12/17/2012	TMB
	updated search	6/15/2013	TMB
	updated	12/30/2013	TMB

SEARCH NOTES		
Search Notes	Date	Examiner
WEST text search	10/23/2010	TMB
WEST text search	5/23/2011	TMB
updated search	8/29/2011	TMB
updated search	6/16/2012	TMB
updated search	12/17/2012	TMB
updated search	6/15/2013	TMB
updated	12/30/2013	TMB

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
455	418, 522, 434, 67.11, 67.13	12/30/2013	TMB
	PGPUB search	12/30/2013	TMB



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578
30678 7590 02/22/2014 NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP 1875 EYE STREET, N.W. SUITE 1100 WASHINGTON, DC 20006			EXAMINER BEAMER, TEMICA M	
			ART UNIT 2646	PAPER NUMBER
			MAIL DATE 02/22/2014	DELIVERY MODE PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.



UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Application No. : 12652146
Applicant : Backers
Filing Date : 01/05/2010
Date Mailed : 02/22/2014

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Notice of Allowance Mailed

This application has been accorded an Allowance Date and is being prepared for issuance. The application, however, is incomplete for the reasons below.

Applicant is given two (2) months from the mail date of this Notice within which to respond. This time period for reply is extendable under 37 CFR 1.136(a) for only TWO additional MONTHS.

The informalities requiring correction are indicated in the attachment(s). If the informality pertains to the abstract, specification (including claims) or drawings, the informality must be corrected with an amendment in compliance with 37 CFR 1.121 (or, if the application is a reissue application, 37 CFR 1.173). Such an amendment may be filed after payment of the issue fee if limited to correction of informalities noted herein. See Waiver of 37 CFR 1.312 for Documents Required by the Office of Patent Publication, 1280 Off. Gaz. Patent Office 918 (March 23, 2004). In addition, if the informality is not corrected until after payment of the issue fee, for purposes of 35 U.S.C. 154(b)(1)(iv), "all outstanding requirements" will be considered to have been satisfied when the informality has been corrected. A failure to respond within the above-identified time period will result in the application being ABANDONED.

See attachment(s).

*A copy of this notice **MUST** be returned with the reply. Please address response to
"Mail Stop Issue Fee, Commissioner for Patents,
P.O. Box 1450, Alexandria, VA 22313-1450".*

/Kam Sin/
Publication Branch
Office of Data Management
(571) 272-4200

IDENTIFICATION OF APPLICATION DEFICIENCIES

- ☐ Applicant must provide legible text for the following item(s).
- ☐ Specification filed , page(s) .
 - ☐ Claims filed , claim(s) .
 - ☐ Oath/declaration filed .
 - ☐ Other: .
- ☒ Applicant must provide missing information on the following page(s) of the specification by amending the specification to add the missing text. No new matter may be added. pages 64, 66, 68, 70 and 73 appear to have cut off text in the tables
- ☐ The specification refers to one or more applications by attorney docket number and does not show the U.S. application number(s). Applicant must supply the U.S. application number in place of each attorney docket number.
- ☐ Applicant must provide an Abstract of the Disclosure.
- ☐ Applicant has submitted a DECLARATION (37 CFR 1.63) FOR A UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76) (e.g., form PTO/SB/01A). The Application Data Sheet, however, is not present with the filed application. Applicant must submit an Application Data Sheet or file a new oath or declaration (e.g., PTO/SB/01) executed by the inventors and containing the information required in 37 CFR 1.63.
- ☐ Applicant must provide an executed declaration.
- ☐ Applicant must provide the missing page(s) of the oath/declaration or Application Data Sheet filed
- ☐ Applicant must provide a declaration signed by inventor(s) .
- ☐ The oath/declaration filed shows non-initialed and/or non-dated alterations. Applicant must file a new oath/declaration in compliance with 37 CFR 1.67(a).
- ☐ Applicant(s) in the latest-filed oath/declaration or Application Data Sheet (ADS) did not show the inventor's residence at all, or did not show both a city and state in the U.S. inventor's residence, or did not show both a city and country in the non-U.S. inventor's residence. Applicant must supply an oath/declaration or Application Data Sheet (ADS) that shows each U.S. inventor's city and state of residence and each non-U.S. inventor's city and country of residence.

Docket No.: 27592-01380-US26
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Floyd Backes et al.

Application No.: 12/652,146

Confirmation No.: 1578

Filed: January 5, 2010

Art Unit: 2617

For: SYSTEM, METHOD AND APPARATUS FOR
ASCERTAINING A DYNAMIC ATTRIBUTE
OF A SYSTEM

Examiner: T. M. Beamer

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

Mail Stop **AMENDMENT**
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

This is in response to the Notice to File Corrected Application Papers mailed February 22, 2014, in the above-captioned case.

5137614

AMENDMENTS TO THE SPECIFICATION

Please replace the table on page 64 of the application with the following:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-SENDDRCP.request

Please replace the table on page 66 of the application with the following:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-POWERMGMTFIB.request

Please replace the second table on page 68 of the application with the following:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME.PWRMGMTRESTORE.request

Please replace the table on page 70 of the application with the following:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME.PWRMGMTFIBCONTINUE.request

Please replace the table on page 73 of the application with the following:

Name	Type	Valid Range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-BEACONNOTIFY.request

REMARKS

The Notice to File Corrected Application Papers dated February 22, 2014 states that the tables on pages 64, 66, 68, 70 and 73 of the specification appear to have cut off text. The instant amendment replaces those tables with the ones above.

The amendments herein place the tables shown on the noted pages within the borders of the pages in their entirety. In some cases the word “request” was partially cut off in the original text. However, the paragraph following each table contains the full term, including the “request” language. As such, the amendments to the specification made in this filing do not introduce any new matter.

No fee is believed due with this filing. However, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 22-0185, under Order No. 27592-01380-US26.

Dated: March 10, 2014

Respectfully submitted,

Electronic signature: /Scott Watkins/
Scott Watkins
Registration No.: 36,715
NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP
1875 Eye Street, NW
11TH Floor
Washington, DC 20006
(202) 331-7111
(202) 293-6229 (Fax)
Attorney for Applicant

Electronic Acknowledgement Receipt	
EFS ID:	18416292
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/Kathleen Peacock
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	10-MAR-2014
Filing Date:	05-JAN-2010
Time Stamp:	13:19:05
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		27592-01380-US26_RES_3-10-14.pdf	30334 84240868575b410a7c3a59be429762a1e0a8952e	yes	4

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Applicant Response to Pre-Exam Formalities Notice	1	1
	Specification	2	3
	Applicant Arguments/Remarks Made in an Amendment	4	4
Warnings:			
Information:			
Total Files Size (in bytes):		30334	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571) 273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP
 1875 Eye Street, NW
 Suite 1100
 Washington, DC 20006

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

 (Depositor's name)

 (Signature)

 (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578

TITLE OF INVENTION: PROGRAM FOR ADJUSTING CHANNEL INTERFERENCE BETWEEN ACCESS POINT IN A WIRELESS NETWORK

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$960.00	\$0	\$0	\$960.00	04/03/2014
EXAMINER		ART UNIT	CLASS-SUBCLASS			
T. M. Beamer		2617	455-418000			

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached.
Use of a Customer Number is required.

2. For printing on the patent front page, list
 (1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
 (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Novak Druce Connolly Bove + Quigg LLP
 2 _____
 3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Piccata Fund Limited Liability Company

Wilmington, Delaware

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☒ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

☐ A check is enclosed.
☒ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 22-0185 (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29.
☐ Applicant asserts small entity status. See 37 CFR 1.27.
☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see form PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
 NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
 NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ /Scott Watkins/ Date _____ March 31, 2014
 Typed or printed name _____ Scott Watkins Registration No. _____ 36,715

Electronic Patent Application Fee Transmittal				
Application Number:		12652146		
Filing Date:		05-Jan-2010		
Title of Invention:		Program for Adjusting Channel Interference between Access Points in a Wireless Network		
First Named Inventor/Applicant Name:		Floyd Backes		
Filer:		Burton A. Amernick/Kathleen Peacock		
Attorney Docket Number:		27592-01380-US26		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	960	960
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Miscellaneous:				
Total in USD (\$)				960

Electronic Acknowledgement Receipt	
EFS ID:	18621736
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Burton A. Amernick/Kathleen Peacock
Filer Authorized By:	Burton A. Amernick
Attorney Docket Number:	27592-01380-US26
Receipt Date:	31-MAR-2014
Filing Date:	05-JAN-2010
Time Stamp:	09:35:29
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$960
RAM confirmation Number	8836
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Issue Fee Payment (PTO-85B)	27592-01380- US26_IFPF_3-31-14.pdf	36880 1657a5b6679757145dc00d7f7f605fce16044347	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30515 0eedc0a172ff6f602437e6f63257a99bcbff1b897	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			67395		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26	1578

30678 7590 04/01/2014
NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP
1875 EYE STREET, N.W.
SUITE 1100
WASHINGTON, DC 20006

EXAMINER

BEAMER, TEMICA M

ART UNIT	PAPER NUMBER

2646

MAIL DATE	DELIVERY MODE

04/01/2014

PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Response to Rule 312 Communication	Application No.	Applicant(s)
	12/652,146	FLOYD B.
	Examiner	Art Unit

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ The amendment filed on 10 March 2014 under 37 CFR 1.312 has been considered, and has been:

a) ☒ entered.

b) ☐ entered as directed to matters of form not affecting the scope of the invention.

c) ☐ disapproved because the amendment was filed after the payment of the issue fee.

Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

d) ☐ disapproved. See explanation below.

e) ☐ entered in part. See explanation below.

B.Crittenden

Publishing Division

Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT <i>(use as many sheets as necessary)</i>			Complete if Known	
			Application Number	12/652,146
			Filing Date	01/05/2010
			First Named Inventor	Backes
			Art Unit	2618
			Examiner Name	Unknown
			Attorney Docket Number	160-125
Sheet	7	of	10	

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No. ¹	Document Number	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		Number - Kind Code ² (if known)			
		US-2003/0236064	Dec. 2003	Shiohara et al.	
		US-2004/0001467	Jan. 2004	Cromer et al.	
		US-2004/0003285	Jan. 2004	Whelan et al.	
		US-2004/0008645	Jan. 2004	Janevski et al.	
		US-2004/0014422	Jan. 2004	Kallio	
		US-2004/0022219	Feb. 2004	Mangold et al.	
		US-2004/0023629	Feb. 2004	Klank	
		US-2004/0027284	Feb. 2004	Leeper et al.	
		US-2004/0037247	Feb. 2004	Ngo	
		US-2004/0038697	Feb. 2004	Attar et al.	
		US-2004/0039817	Feb. 2004	Lee et al.	
		US-2004/0047335	Mar. 2004	Proctor et al.	
		US-2004/0054767	Mar. 2004	Karaoguz et al.	
		~~US-2004/0054767~~	Mar. 2004	Karaoguz et al.	20040054767
		US-2004/0057507	Mar. 2004	Rotstein et al.	
		US-2004/0066759	Apr. 2004	Molteni et al.	
		US-2004/0071110	Apr. 2004	Guey et al.	
		US-2004/0095902	May 2004	Larola et al.	
		US-2004/0121749	Jun. 2004	Cui et al.	
		US-2004/0121765	Jun. 2004	Idnani et al.	

Change(s) applied
to document,
/D.D./
3/15/2014

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No. ¹	Foreign Patent Document	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T ⁶
		Country Code ³ - Number ⁴ - Kind Code ⁵ (if known)				

Examiner Signature	/Temica Beamer/	Date Considered	09/12/2010

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.
¹Applicant's unique citation designation number (optional). ²See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04.
³Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. ⁶Applicant is to place a check mark here if English language Translation is attached.
 Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.B./

Change(s) applied
to document,
/D.D./
3/15/2014

/D.D./
3/15/2014

Examiner Signature	/Temica Beamer/	Date Considered	09/12/2010

Considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04.

³Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. ⁶Applicant is to place a check mark here if English language Translation is attached.

comment under WFO Statement 31, if it is possible. Applicant is to place a check mark here if English language translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO:** Assistant Commissioner for Patents, Washington, DC 20231.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.B./

Change(s) applied
to document,
/D.D./
3/15/2014

[illegible]

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

¹Applicant's unique citation designation number (optional). ²See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04.

³Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. ⁶Applicant is to place a check mark here if English language Translation is attached.

Burden Hour Statement: This form is estimated to take 2.0 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /T.B./



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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/652,146	05/13/2014	8725132	27592-01380-US26	1578

30678 7590 04/23/2014
NOVAK DRUCE CONNOLLY BOVE + QUIGG LLP
1875 EYE STREET, N.W.
SUITE 1100
WASHINGTON, DC 20006

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

Floyd Backes, Sharon, NH;
Gary Vacon, East Falmouth, MA;
Paul Callahan, Carlisle, MA;
William Hawe, Hollis, NH;
Roger Durand, Amherst, NH;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☒ Practitioners associated with the Customer Number:**00570**

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☒ The address associated with Customer Number:**00570**

OR

☐ Firm or Individual Name

Address

City

State

Zip

Country

Telephone

Email

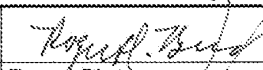
Assignee Name and Address:

Piccata Fund Limited Liability Company
 2711 Centerville Road
 Suite 400
 Wilmington, DE 19808

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

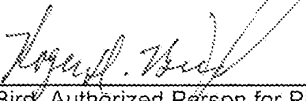
Signature		Date	11/25/14
Name	Roger Bird	Telephone	
Title	Authorized Person for Piccata Fund Limited Liability Company		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

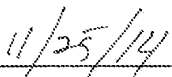
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2

DECLARATION REGARDING AUTHORITY TO SIGN ON BEHALF OF A LEGAL ENTITY
(37 C.F.R. 3.73(b)(2)(i))

I, Roger Bird (whose title is supplied below), hereby declare that I am authorized to sign on behalf of Piccata Fund Limited Liability Company.



Roger Bird, Authorized Person for Piccata Fund Limited Liability Company



Date

Electronic Acknowledgement Receipt	
EFS ID:	21247300
Application Number:	12652146
International Application Number:	
Confirmation Number:	1578
Title of Invention:	Program for Adjusting Channel Interference between Access Points in a Wireless Network
First Named Inventor/Applicant Name:	Floyd Backes
Customer Number:	30678
Filer:	Jeffrey W. Gluck/Denise Porreca
Filer Authorized By:	Jeffrey W. Gluck
Attorney Docket Number:	27592-01380-US26
Receipt Date:	21-JAN-2015
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Application Type:	Utility under 35 USC 111(a)

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Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Assignee showing of ownership per 37 CFR 3.73.	STATEMENT_UNDER_PRE_AIA_SECTION_373b_OR_POST_AIA_373c.PDF	451313 80663361f888d381514a02b74993cae83d45af6	no	1
Warnings:					
Information:					

2	Power of Attorney	Autocell_US_POA_SB80_and_Declaration_to_Sign_Panitch_signed.PDF	1104167 8dbb063c9d12544c91dceb80d230da2744a630a7	no	2
Warnings:					
Information:					
Total Files Size (in bytes):			1555480		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

STATEMENT UNDER PRE AIA SECTION 3.73(b) OR POST AIA 3.73(c)Piccata Fund Limited Liability CompanyApplication No./Patent No.: 8,725,132 Filed/Issue Date: May 13, 2014Titled: **PROGRAM FOR ADJUSTING CHANNEL INTERFERENCE BETWEEN ACCESS POINTS IN A WIRELESS NETWORK**Piccata Fund Limited Liability Company, a Limited Liability Company
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;
2. ☐ an assignee of less than the entire right, title, and interest in
(The extent (by percentage) of its ownership interest is _____ %); or
3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made) the patent application/patent identified above, by virtue of either:
- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy therefore is attached.

OR

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:
1. From: Backes et al. To: Propagate Networks Inc.
The document was recorded in the United States Patent and Trademark Office at Reel 014995, Frame 0425, or for which a copy thereof is attached.
2. From: Propagate Networks Inc. To: Autocell Laboratories, Inc.
The document was recorded in the United States Patent and Trademark Office at Reel 015743, Frame 0534, or for which a copy thereof is attached.
3. From: Autocell Laboratories, Inc. To: Piccata Fund Limited Liability Company
The document was recorded in the United States Patent and Trademark Office at Reel 027852, Frame 0201, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).☐ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Jeffrey W. Gluck/
SignatureJanuary 15, 2015
DateJeffrey W. Gluck, Ph.D.
Printed or Typed NameAttorney for Assignee
Title

JWG/kh



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26

CONFIRMATION NO. 1578

POWER OF ATTORNEY NOTICE

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Date Mailed: 02/06/2015

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/21/2015.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

/mteklelmichael/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/652,146	01/05/2010	Floyd Backes	27592-01380-US26

CONFIRMATION NO. 1578

POA ACCEPTANCE LETTER

570
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Date Mailed: 02/06/2015

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/21/2015.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/mtekle michael/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101