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(54) Title: INSTANTANEOUS JOINT TRANSMIT POWER CONTROL AND LINK ADAPTATION FOR RTS/CTS BASED CHANNEL ACCESS

(57) Abstract: A method for closed loop link adjustment based on a Request To Send-Clear To Send (RTS-CTS) channel access scheme includes the following steps. Designating a station as an originating station. Transmitting a RTS frame with predetermined transmit power from an originating station, prior to an intended DATA transmission, sounding the channel such that reception characteristics can be evaluated at a designated receiving station. Transmitting, in response to the originating station, a CTS frame with a predetermined transmit power from the receiving station with directives of link adjustments. Transmitting a DATA frame from the originating station to the receiving station frame complying with link adjustment directives to the extent of the originating stations capabilities. And, transmitting an acknowledge (ACK) frame in response to the originating stations from the receiving station indicating result of DATA frame reception.

INSTANTANEOUS JOINT TRANSMIT POWER CONTROL AND LINK ADAPTATION FOR RTS/CTS BASED CHANNEL ACCESS

This application claims priority from U.S. Provisional Application No. 60/282,191, filed on 09 April 2001 in the English language, which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the field of wireless communications, in particular to transmit power control and link adaptation techniques and mechanisms.

2. Background Information

The IEEE 802.11 is a wireless LAN (Local Area Network) standard that has been standardized by IEEE (Institute of Electrical & Electronics Engineers). The IEEE 802.11 wireless LAN standard is currently undergoing a process of extending the standard with QoS (Quality of Service) features. The objective is to enable, for example, computers or multimedia devices to communicate under QoS constraints. This standard extension goes under the name IEEE 802.11e and is managed by the so-called task group e, TGe.

Recently, the IEEE 802.11 standard was also extended with a new physical layer allowing higher data rates than the previous physical layer. Various data rates are enabled through several code rates and signal constellations. The purpose is to allow link adaptation depending on the channel quality. The high rate PHY (physical layer) on the so-called 5 GHz band is called IEEE 802.11a and is based on OFDM (Orthogonal Frequency Division Multiplexing). The corresponding so-called 2.4 GHz band PHY is called IEEE 802.11b and uses single carrier modulation schemes.

IEEE 802.11 operates either in a DCF (Distributed Coordination Function) or a PCF (Point Coordination Function) mode. The former is for distributed operation and the latter for centralized control from an access point, AP. So far the PCF mode has not been ratified by implementers as the complexity is consider to high, instead DCF is used both for the distributed operation as well as with the AP.

The origin of IEEE 802.11 access scheme is traced back to BTMA (Busy Tone Multiple Access) which was the first proposed method for distributed control of channel access avoiding the well known hidden terminal problem.

In MACA (Multiple Access with Collision Avoidance), proposed by Phil Karn in 1980, the introduction of a Request To Send (RTS) and Clear To Send (CTS), handshake phase prior data transmission solved the idea of distributed reservation. This presented a more feasible basis to build a practical system upon as it did not divide the frequency band in a channel for data and busy tones, as in the BTMA scheme. Also the idea of random exponential back off, that was later used in IEEE 802.11, was introduced in MACA.

In MACAW (Multiple Access with Collision Avoidance for Wireless), the basic mechanism of MACA was refined. Among other things, a link acknowledgment, ACK, scheme was introduced. The access scheme of IEEE 802.11 is now based to a great extent on principles developed in MACAW.

Other ongoing standardization activities in IEEE 802.11 include the so-called TGh (Task Group h, *i.e.*, an IEEE task group for IEEE 802.11h) that has the objective of designing and including transmit power control (TPC), as well as distributed frequency selection (DFS), in IEEE 802.11a. The purpose of power control from a standardization point of view is primarily to enable IEEE 802.11a stations, STAs, to conform to European regulatory requirements.

As background information, the basic access principles for IEEE 802.11 will now be described. For more detailed information the reader is referred to the standard IEEE 802.11-1999 (which replaces IEEE 802.11-1997), the standard IEEE 802.11a-1999 (High data rate on the 5 GHz Band), and the standard IEEE 802.11b-1999 (High data rate on the 2.4 GHz Band). Good and simple overviews may also be found in a) "Smart Antenna Systems and Wireless LANs", authored by Garret T. Okamoto and published by Kluwer academic publishers (ISBN 0-7923-8335-4), and "IEEE 802.11 Handbook, A Designers Companion", authored by Bob O'Hara and Al Patrick (ISBN 0-7381-1855-9).

There are two modes of channel access scheme operation in the Distributed Co-ordination Function (DCF), one based on CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) and one based on CSMA/CA including RTS-CTS message exchange. A MIB (Management Information Base) attribute "dot11RTSThreshold" is used to differentiate the use of the two. MPDUs (MAC Protocol Data Units, where "MAC" stands for Medium Access Control) shorter than the threshold is sent without RTS-CTSs, whereas longer MPDUs are sent with RTS-CTSs. The focus here is the RTS-CTS based CSMA/CA mechanism that enables mitigation of hidden stations and hence in general provides a more efficient use of the wireless medium.

Figures 1A-1D show a communication procedure between a station T and a station R, and related effects on nearby stations E, F, G, H. In Fig. 1A, station T transmits an RTS (Request to Send) signal to the station R. The transmit range 102 of the station T encompasses the stations R, E and F, but not the stations H, G. Thus the stations R, E and F receive or overhear the RTS signal, but the stations H, G do not. In a next step shown in Figure 1B, in reply to the RTS signal, the station R sends a CTS (Cleared to Send) reply signal to the station T. As shown in Figure 1B, the transmit range 104 of the station R encompasses the station F, H but not the stations E, G. After receiving the CTS signal, in

Figure 1C the station T transmits a DATA signal to the station R, and then in Figure 1D the station R acknowledges receipt of the DATA signal by sending an ACK signal or message to the station T.

Since the station H is a hidden station with respect to the station T, it is informed of the intention of station T to transmit via the reply CTS message sent by the station R (since station H is not hidden from the station R, i.e., it is within the transmit range 104 of the station R). As a consequence, the station H will not transmit and disturb ongoing reception by the station R. Stations E and F will in a similar manner defer channel access to the stations T and R, after overhearing the RTS from the station T and/or the CTS from the station R. As shown in Figures 1A-1D, station G is hidden from both stations T and R, and therefore will likely not overhear the RTS or CTS, and therefore it may transmit.

Figure 2 illustrates frame formats used in IEEE 802.11, where the numbers above the boxes indicate the size of the information in the box. Note, Address 4 in the DATA and MANAGEMENT frame exists only for DATA frames in a wireless DS (Distribution System), and does not exist in MANAGEMENT frames.

Figure 3 illustrates the frame exchange including RTS and CTS. When frames are received by stations other than those intended to receive the frames, a so called NAV (Network Allocation Vector) is set according to a duration value indicated in a field of the frame. This provides an additional collision avoidance mechanism to the physical channel access sensing and is therefore called virtual channel sensing. As long as either the physical or virtual channel sense indicates activities on the channel, a station must remain silent When the channel becomes free, stations start contending for the channel according to the channel access principles defined in the IEEE 802.11-1999 standard. In general, the NAV can only be extended if new frames are received.

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