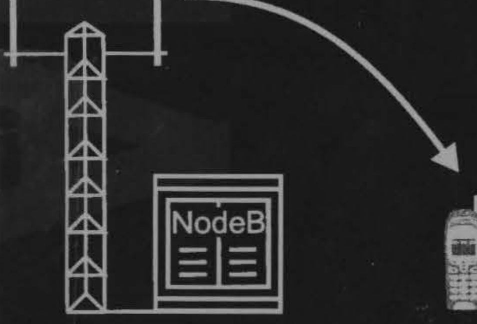
Andrew Richardson

WCDMA
Design Handbook



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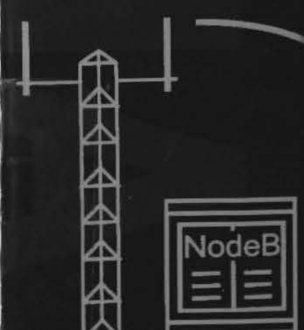

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Andrew Richardson has many years of experience in digital communication systems, having worked for Philips, Nokia and Simoco on both second- and third-generation cellular phone systems. Since 1999 he has run his own consultancy, Imagicom Ltd, offering design and training services in telecommunication systems technology.

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Contents

Abbreviations

2G	second generation
3G	third generation
3G-MSC/VLR	third generation mobile switching centre/visitor location register
3GPP	3rd Generation Partnership Project
3G-SGSN	third generation serving GPRS support node
AC	access class
ACK	acknowledgement
ACLR	adjacent channel leakage ratio
ACS	adjacent channel selectivity
ADC	analogue to digital converter
ADF	application dedicated files
AGC	automatic gain control
AI	acquisition indicator
AICH	acquisition indication channel
AID	application identifier
AK	anonymity key
AM	acknowledged mode
AMD	acknowledged mode data
AMF	authentication and key management field
AMR	adaptive multirate
AP	access preamble
APN	access point name
ARQ	automatic repeat request
AS	access stratum
ASC	access service class
ASIC	application specific integrated circuit
ATM	asynchronous transfer mode
ATT	AICH transmission timing
ATT	attach flag
AUTN	authentication token
AV	authentication vector

/visitor location register

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AWGN	additive white Gaussian noise
BBF	baseband filter
BC	broadcast control
BCCH	broadcast control channel
BCD	binary coded decimal
BCFE	broadcast channel functional entity
BCH	broadcast channel
BER	bit error rate
BGCF	breakout gateway control function
BLER	block error rate
BMC	broadcast and multicast control protocol
BO	buffer occupancy
BPF	band pass filter
BPSK	binary phase shift keyed
BS	base station
BSC	base station controller
BSS	base station system
BTS	base transceiver station
C/I	carrier to interference ratio
C/T	control/traffic
CA	channel assignment
CAI	channel assignment indicator
CAMEL	customised application for mobile network enhanced logic
CBC	cell broadcast centre
CBS	cell broadcast service
CC	call control
CCC	CPCH control channel
CCCH	common control channel
CCDF	complementary cumulative distribution function
CCTrCH	coded composite transport channel
CD	collision detection
CD/CA-ICH	collision detection/channel assignment indicator channel
CDMA	code division multiple access
CFN	connection frame number
CID	context identifier
CK	cipher key
CKSN	cipher key sequence number
CLI	calling line identification
CLIR	calling line identification restriction
CM	connection management
CN	core network

CP	control protocol
CPBCCH	compact packet BCCH
CPCH	common packet channel
CPICH	common pilot channel
CRC	cyclic redundancy check
CRNC	controlling radio network controller
c-RNTI	cell radio network temporary identifier
CS	circuit switched
CSCF	call session control function
CSICH	CPCH status indication channel
CTCH	common traffic channel
CTFC	calculated transport format combination
CTS	cordless telephony system
CW	continuous wave
D/C	data/control
DAC	digital to analogue converter
DC	dedicated control
DCCH	dedicated control channel
DCF	digital channel filter
DCFE	dedicated control functional entity
DCH	dedicated transport channel
DCS1800	digital cellular network at 1800MHz
DC-SAP	dedicated control SAP
DECT	digital enhanced cordless telecommunications
DF	dedicated files
DPCCH	dedicated physical control channel
DPCH	dedicated physical channel
DPDCH	dedicated physical data channel
DRAC	dynamic resource allocation control
DRNC	drift radio network controller
DRNS	drift radio network subsystem
DRX	discontinuous reception
DSCH	downlink shared transport channel
DSP	digital signal processor
DTCH	dedicated traffic channel
DTX	discontinuous transmission
EDGE	enhanced data rates for GSM evolution
EF	elementary file
EGC	efficient Golay correlator
EIR	equipment identity register
e-MLPP	enhanced multilevel precedence and preemption

EMS	extended message service
EOT	end of transmission
EPC	estimated PDU counter
ETSI	European Telecommunications Standards Institute
EVM	error vector magnitude
FACH	forward access channel
FBI	feedback mode indicator
FCT	frame count transmitted
FDD	frequency division duplex
FDMA	frequency division multiple access
FER	frame error rate
FFT	fast Fourier transform
FHT	fast Hadamard transform
FIR	finite impulse response
G3	Group 3
GC	general control
GERAN	GSM/EDGE radio access network
GGSN	gateway GPRS support node
GMM	GPRS mobility management
GMMAS-SAP	GPRS mobility management SAP
GMSC	gateway mobile switching centre
GPRS	general packet radio service
GSM	global system for mobile communications
GSMS	GPRS short message service
GTP	GPRS tunnelling protocol
HC	header compression
HCS	hierarchical cell structures
HE/AuC	home environment/authentication centre
HFN	hyper frame number
HLR	home location register
HPLMN	home PLMN
HPSK	hybrid PSK
HSDPA	high speed downlink packet access
HSS	home subscriber server
HTTP	hypertext transfer protocol
I-CSCF	interrogating call session control function
IE	information element
IK	integrity key
IMEI	international mobile equipment identity
IMS	internet protocol multimedia subsystem
IMSI	international mobile subscriber identity

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IMT2000	International Mobile Telecommunications 2000
IP	internet protocol
IPDL	idle period on the downlink
ISDN	integrated services digital network
ITU	International Telecommunication Union
KSI	key set identifier
LA	location area
LAC	location area code
LAI	location area identifier
LAPP	log *a-posteriori* probability
LAU	location area update
LI	length indicator
LLC	logical link control
LLR	log likelihood ratio
LNA	low noise amplifier
LO	local oscillator
LR	location registration
LSB	least significant bit
MAC	message authentication code
MAC	medium access control
MAC-b	MAC – broadcast
MAC-c/sh	MAC – common or shared
MAC-d	MAC – dedicated
MAC-hs	MAC – high speed
MAP	maximum a-posteriori probability
MASF	minimum available spreading factor
MCC	mobile country code
ME	mobile equipment
MF	master file
MGCF	media gateway control function
MGW	media gateway
MIB	master information block
MLSE	maximum likelihood sequence estimation
MM	mobility management
MN	mobile network
MNC	mobile network code
MO	mobile originated
MRC	maximum ratio combining
MRF	media resource function
MRFC	media resource function controller
MRFP	media resource function processor

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MRW	move receive window
MS	mobile station
MSB	most significant bit
MSC	mobile switching centre
MSE	mean square error
MSIN	mobile subscriber identifier number
MT	mobile terminated
MUX	multiplex
NACK	negative acknowledgement
NAS	non-access stratum
NSAPI	network service access point identifier
NW	network
OCQPSK	orthogonal complex QPSK
OSI	open systems interconnection
OTDOA	observed time difference of arrival
OVSF	orthogonal variable spreading factor
PCCC	parallel concatenated convolutional code
PCCH	paging control channel
PCCPCH	primary common control physical channel
PCDE	peak code domain error
PCF	policy control function
PCH	paging channel
PCPCH	physical common packet channel
P-CPICH	primary common pilot channel
PCs	personal communication system
P-CSCF	proxy call session control function
PD	protocol discriminator
PDC	personal digital cellular
PDCP	packet data convergence protocol
PDN	packet data network
PDP	packet data protocol
PDSCH	physical downlink shared channel
PDU	protocol data unit
PI	paging indicator
PICH	paging indication channel
PID	packet identifier
PIN	personal identification number
PLMN	public land mobile network
PMM	PS mobility management
PN	pseudo-noise
PNFE	paging and notification functional entity

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PRA	PCPCH resource availability
PRACH	physical random access channel
PS	packet switched
PSC	primary synchronisation code
P-SCH	primary synchronisation channel
PSK	phase shift keying
PSTN	public switched telephone network
PTM	point to multipoint
P-TMSI	packet temporary mobile subscriber identity
PTP	point to point
QoS	quality of service
QPSK	quadrature phase shift keying
R4	Release 4
R5	Release 5
R6	Release 6
R99	Release 99
RA	routing area
RAB	radio access bearer
RABM	radio access bearer manager
RAC	radio access capability
RACH	random access channel
RAI	routing area identifier
RAT	radio access technology
RAU	routing area update
RB	radio bearer
RES	response
RL	radio link
RLC	radio link control
RLS	radio link set
RLS	recursive least squares
RM	rate match
RNC	radio network controller
RNS	radio network subsystem
RNTI	radio network temporary identifier
ROHC	robust header compression
RPLMN	registered PLMN
RRC	radio resource control
RRC	root raised cosine
RR-SAP	radio resource SAP
RSCP	receive signal code power

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RTT	round trip time
S/P	serial to parallel
SAP	service access point
SCCPCH	secondary common control physical channel
SCH	synchronisation channel
S-CPICH	secondary common pilot channel
SCR	source controlled rate
S-CSCF	serving call session control function
SDP	session description protocol
SDU	service data unit
SF	spreading factor
SFN	system frame number
SGSN	serving GPRS support node
SHCCH	shared channel control channel
SI	status indicator
SI	stream identifier
SIB	system information block
SIBn	system information broadcast type n ($n = 1, \ldots, 18$)
SID	silence descriptor
SIP	session initiation protocol
SIR	signal to interference ratio
SISO	soft in soft out
SLF	subscription location function
SM	session management
SMC-CS	short message control – circuit switched
SMC-GP	short message control – GPRS protocol
SM-RL	short message relay layer
SMS	short message service
SMSMM	SMS mobility management
SM-TL	short message transfer layer
SNR	signal to noise ratio
SOVA	soft output Viterbi algorithm
SQN	sequence number
SRB	signalling radio bearer
SRNS	serving radio network subsystem
s-RNTI	serving radio network temporary identifier
SS	supplementary service
S-SCH	secondary synchronisation channel
SSDT	site selection diversity transmission
STTD	space time transmit diversity

SUFI	super fields
TACS	total access communications system
TAF	terminal adaptation function
TCP	transmission control protocol
TCTF	target channel type field
TCTV	traffic channel transport volume
TDD	time division duplex
TDMA	time division multiple access
TE	terminal equipment
TF	transport format
TFC	transport format combination
TFCI	transport format combination indicator
TFCS	transport format combination set
TFS	transport format selection
TFT	traffic flow template
TG8/1	Task Group 8/1
TGMP	transmission gap sequence measurement purpose
TI	transaction identifier
TIA	Telecommunications Industry Association
TM	transparent mode
TMD	transport mode data
TMSI	temporary mobile subscriber identity
ToS	type of service
TPC	transmit power control
TTI	transmission time interval
TVM	traffic volume measurement
Tx	transmit
UARFCN	UTRA absolute radio frequency channel number
UDP	user datagram protocol
UE	user equipment
UICC	universal integrated circuit card
UM	unacknowledged mode
UMTS	Universal Mobile Telecommunications System C304
URA	UTRAN registration area
URL	uniform resource locator
u-RNTI	UTRAN radio network temporary identifier
US	update status
USAT	USIM application toolkit
USCH	uplink shared channel
USIM	universal subscriber identity module
UTRAN	UMTS terrestrial radio access network

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VAD	voice activity detection
VCAM	versatile channel assignment mode
VGCS	voice group call service
VLR	visitor location register
WCDMA	wideband code division multiple access
XMAC	expected message suthentication code
XRES	expected response

11 Layer 3 – RRC

11.1 Introduction

In this chapter we examine the structure and the operation of the RRC protocol. The RRC protocol is the main AS control protocol. It is responsible for the configuration and control of all of the different layers that create the radio connection between the UE and the UTRAN. It is a large and complex protocol and consequently, in this chapter, we consider only some key aspects of its operation, leaving the interested reader to consult the relevant specification [24] for a more thorough description.

We start this chapter with a review of the RRC protocol architecture before considering specific key elements of its operation.

11.1.1 Architecture and messages

The RRC protocol architecture is illustrated (from the perspective of the UE) in Figure 11.1. The key functions of the architecture are the dedicated control functional entity (DCFE), the paging and notification functional entity (PNFE) and the broadcast control functional entity (BCFE).

The RRC messages are passed between the UE and the UTRAN. They are used to configure and control the RRC connection between the UE and the UTRAN. The RRC messages can be loosely grouped into four categories: RRC connection management messages; RB control messages; RRC connection mobility messages and RRC measurement messages.

In Tables 11.1–11.4, we review the basic message types. It should be noted that in these tables we are not considering the individual messages, but rather a generic type of message. For instance, in Table 11.1 we look at an RRC CONNECTION message type. In fact, there are a number of such messages: RRC CONNECTION REQUEST; RRC CONNECTION SETUP; RRC CONNECTION SETUP COPMPLETE and RRC CONNECTION RELEASE. By considering just the message types, we can compactly represent the different messages in the tables.

The first category of messages is the RRC connection management messages, which are responsible for establishing and maintaining the RRC connection in whatever form

Table 11.1. *RRC connection management messages*

Generic RRC message	Comment
RRC CONNECTION	Messages to establish, release and reject the creation of an RRC connection including the creation of SRBs.
SECURITY MODE	Messages to start, reconfigure confirm and indicate failure in the establishment of ciphering and integrity protection procedures.
COUNTER CHECK	Messages to request by UTRAN a check and provide a response to the current COUNT-C used for encryption and ciphering.
xx DIRECT TRANSFER	Messages to create a CN signalling connection (xx=INITIAL), send NAS PDUs on uplink (xx=UPLINK) and receive NAS PDUs on downlink (xx=DOWNLINK).
PAGING	Messages to send paging on common channels (Type 1) or using in-band dedicated channels (Type 2).
UE CAPABILITY	Messages to allow UTRAN to request and respond with the capabilities of the UE.
SYSTEM INFORMATION	Messages to carry from UTRAN system information and to indicate changes to it.
SIGNALLING CONNECTION	Messages to notify UE or UTRAN that signalling connection to CN is released.

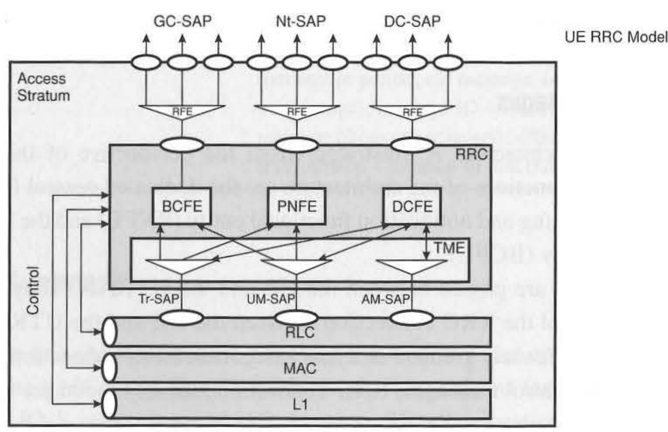

Figure 11.1 RRC protocol architecture.

it may take. The messages include the RRC connection messages, security control messages, and system information broadcast messages, as well as messages for NAS data transfer. The DIRECT TRANSFER messages are considered in Section 11.4 when we examine the direct transfer procedure. The RRC CONNECTION establishment messages are considered in Section 11.5 when we look at the establishment of an RRC connection. The SECURITY MODE messages are considered in Sections 2.6 and the SYSTEM INFORMATION messages are considered in the next section.

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Table 11.2. *RB control messages*

Generic RRC message	Comment
RADIO BEARER	Messages to establish, modify and release RBs and hence RABs.
PHYSICAL CHANNEL RECONFIGURATION	Messages used to assign, replace or release a set of physical channels.
TRANSPORT CHANNEL RECONFIGURATION	Messages to reconfigure a transport channel including the physical channels.
TRANSPORT FORMAT COMBINATION CONTROL	Messages to control the uplink TFC.
PUSCH CAPACITY REQUEST	[TDD] UE requesting uplink capacity on PUSCH.
UPLINK PHYSICAL CHANNEL CONTROL	[TDD] Message from UTRAN to transfer uplink physical channel information.

Table 11.3. *RRC connection mobility messages*

Generic RRC message	Comment
ACTIVE SET UPDATE	[FDD] To add, replace or delete radio links from the active set.
CELL CHANGE ORDER FROM UTRAN	Message from UTRAN to request cell change to another RAT cell.
CELL UPDATE	Messages to perform the cell update.
HANDOVER TO UTRAN	Message sent via another RAT to cause a handover to the UTRAN.
HANDOVER FROM UTRAN	Messages from UTRAN to cause handover to another RAT (e.g. GSM).
INTER-RAT HANDOVER INFO	Information from UE to UTRAN sent via another RAT prior to handover to UTRAN.
URA UPDATE	Messages to perform the URA update.
UTRAN MOBILITY INFORMATION	Messages used by UTRAN to allocate a new RNTI + other mobility information.

The RB control messages shown in Table 11.2 are concerned with the establishment, modification and release of various aspects of the RBs and RABs created in the network. This set of messages can be used to configure all or individual layers of an RB. The RADIO BEARER control messages are considered in Section 11.6 when we review the RB establishment procedures, and the PHYSICAL CHANNEL RECONFIGURATION set of messages are covered in Section 11.7 when we consider some of the handover aspects.

The RRC connection mobility messages shown in Table 11.3 are concerned with the mobility aspects of the connection between the UE and the UTRAN. These messages include the soft-handover control messages (ACTIVE SET UPDATE) and handover

Table 11.4. *RRC measurement messages*

Generic RRC message	Comment
ASSISTANCE DATA DELIVERY	Message from UTRAN to provide UE positioning assistance data.
MEASUREMENT CONTROL	Message from UTRAN to setup, modify or release a measurement.
MEASUREMENT REPORT	Message from UE to deliver measurement reports.

messages to and from the UTRAN, as well as messages such as CELL and URA update. The procedures associated with handover are considered in more detail in Section 11.7 for both soft- and hard-handover.

The final categories of messages are the measurement control and measurement reporting messages that are shown in Table 11.4. The measurement messages are concerned with the controlling and reporting of the various measurements made by the UE and reported to the UTRAN. The subject of measurements is a large and complex issue and for these reasons it is addressed separately (Chapter 12).

11.2 System information broadcasting

We start looking at the design and operation of the RRC, beginning with system information broadcast messages. The system information broadcast messages are normally carried via the PCCPCH and the SCCPCH in the case of broadcast information used for DRAC. In this section we focus on the PCCPCH case.

11.2.1 Structure of broadcast system information

SIBs are system information that is transmitted from the UTRAN to the UE. The UE needs to locate and read the system information prior to establishing any radio connection to the UTRAN. One of the design problems associated with the SIBs is that the information comes in a variety of types. Some information is updated frequently (such as estimates of uplink interference levels as measured at the Node B) and some information does not need regular updating (cell and system IDs for instance). In addition, the messages can be long and also of varying lengths. The structure of the broadcast channels is designed, therefore, to cope with these differing constraints.

Before examining the structure and architecture of the broadcast channels, it is useful to examine the lower layers of the physical channels that carry the SIBs. The method of transporting the SIBs is via a common physical channel known as the PCCPCH. This physical channel is broadcast with a constant data rate and constant TF, so that it is easy for the UE to detect and decode the information that is carried by that specific channel.

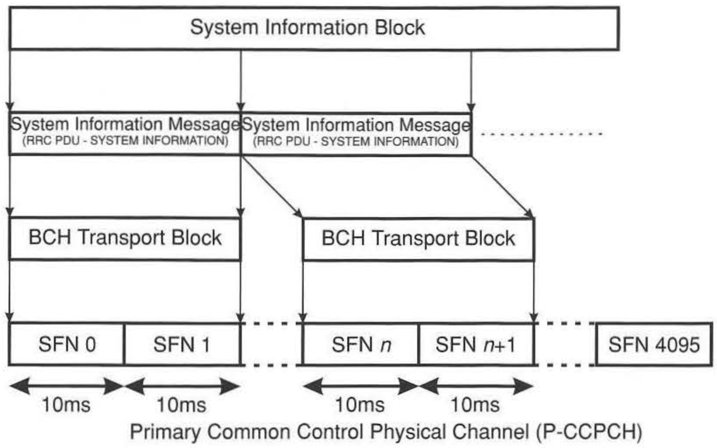

Figure 11.2 Basic transmission structure of SIBs.

For the broadcast information, a specific transport channel is defined (the BCH). For the BCH, the TTI is fixed by the standard as being 20 ms, i.e. a transport block is delivered across the radio interface using two 10 ms radio frames. Figure 11.2 illustrates the basic transmission of the SIB messages and their relationship to the transport blocks and hence the PCCPCH. The radio interface has a frame structure that is based on a 10 ms frame with a cell SFN that counts the number of frames up to a total length of 4096. The SFN is used as the basis of the scheduling of the SIB information, as illustrated in the diagram.

System information message

The SIBs are segmented and concatenated into system information messages with each system information message fitting into a BCH transport block. From Figure 11.2 it can be seen that an SIB is segmented into a number of system information messages, each of which becomes an RRC SYSTEM INFORMATION PDU. SIBs of different types can be concatenated into the same system information message. The scheduling of the system information messages is defined by information that is contained in a special broadcast message known as the master information block (MIB).

11.2.2 Example hierarchy of broadcast blocks

System information is organised with a tree-like hierarchy. Figure 11.3 illustrates an example of the hierarchy for the system information. At the top level, there is the MIB. The MIB, as the name implies, is the main controlling block that the UE needs to locate. The MIB contains either scheduling information for the SIBs directly, or

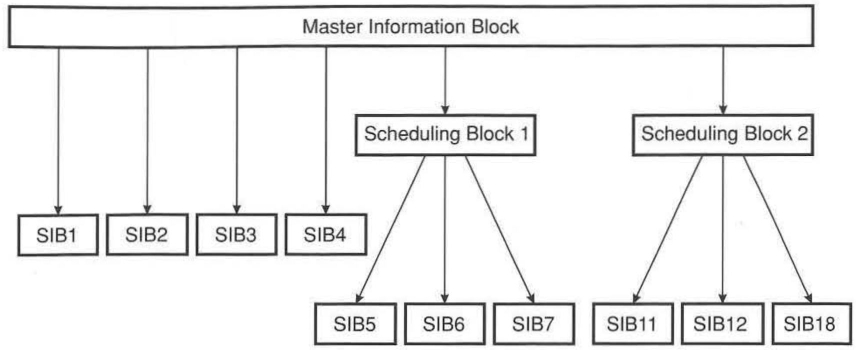

Figure 11.3 Hierarchy of broadcast blocks.

scheduling information for up to two scheduling blocks which themselves define the scheduling for the SIBs. Only the MIB or the scheduling blocks can contain scheduling information.

The UE needs first to locate the MIB and from this it can locate the scheduling blocks (assuming any are being used). From the MIB and the scheduling blocks, the UE can identify the scheduling information for all of the SIBs. Each SIB is scheduled independently to allow different transmission rates for the SIBs.

11.2.3 Segmentation and concatenation of SIBs

In general, the SIBs are too large for the BCH transport blocks (the BCH transport block has a fixed size of 246 bits) and so segmentation and concatenation of the SIBs is required as shown in Figure 11.2. The SIBs are broken into system information messages, and each system information message is transported in an RRC SYSTEM INFORMATION PDU.

The segmentation and concatenation procedure is done at the RRC layer, and to facilitate the segmentation process a number of different segment types are defined:

- first segment,
- subsequent segment,
- last segment,
- complete.

In addition, the UTRAN can concatenate a number of segments from different SIBs if there is sufficient space within the system information message. For each segment type, there is header information as well as the data. The header information indicates the number of segments for a specific SIB and the subsequent and last segments contain a segment index to identify where they are within the segment for use when the reassembly of the segments is performed in the receiver.

Table 11.5. *Parameters used in the segmentation of SIBs*

Parameter	Usage
SEG_COUNT	Defines the number of segments for a specific SIB. For no segmentation it equals 1. Values in the range 1, . . . , 16.
SIB_REP	Defines the SIB repetition period, i.e. how many radio frames before the SIB is retransmitted. Only specific values allowed (4, 8, 16, 32, . . . , 4096).
SIB_POS	Defines the SIB position within the SFN. Due to segmentation, this parameter can take multiple values for the same SIB. Must be a multiple of 2 (this is due to 20 ms transport block size and 10 ms frame size).
SIB_OFF	Defines the offset for subsequent segments of a segmented SIB. Must be a multiple of 2 for the same reason as above. SIB_OFF can be an array of elements, consequently the SIB offset can be variable.

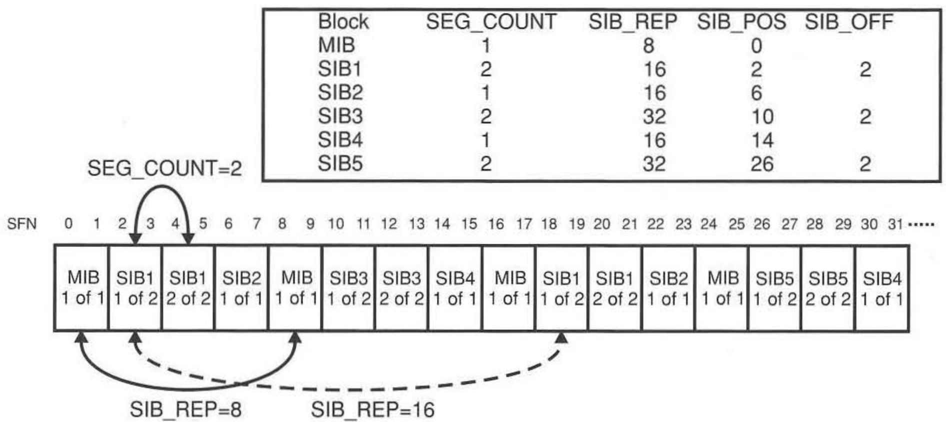

Figure 11.4 Example of SIB and MIB segmentation and scheduling.

11.2.4 Scheduling of system information

To define the scheduling of the SIBs a number of parameters are used as defined in Table 11.5, and illustrated in Figure 11.4. For the MIB, some of the parameters are fixed: $SIB\_POS = 0$ (i.e. it starts at the beginning of the SFN); $SIB\_OFF = 2$ frames (i.e. adjacent segments). The MIB repetition period (*SIB_REP*) is 8 frames for the FDD mode and could be 8,16 or 32 frames for the TDD mode. For the TDD mode the UE must attempt to determine the SIB_REP as no signalling information is used to indicate the value. In general, the segmented SIBs can be multiplexed together in the same SYSTEM INFORMATION message using the different message combinations considered in the following section.

The parameter *SIB_POS* defines the position of the first segment in the system frame, and *SIB_OFF*(i) is an array of offsets applied consecutively to define the location of subsequent segments (this is illustrated in the equation presented below). The number of segments is defined by the parameter SEG_COUNT.

$$SIB\_POS(i) = SIB\_POS(i-1) + SIB\_OFF(i) \text{ for } i = 1, 2, \ldots, SEG\_COUNT\ 1$$

The MIB may be segmented and so the UE needs to read the contents of the first segment of the MIB to determine the parameter SEG_COUNT and consequently how many segments the MIB is in.

Figure 11.4 illustrates example parameters and scheduling of an MIB and some SIBs. In this example it is assumed that the MIB is not segmented ($SEG\_COUNT = 1$), and that the SIBs are transmitted individually, one per BCH transport block (per 20 ms). In reality, however, the MIB may be segmented (in which case the segments are sent in adjacent SYSTEM INFORMATION messages ($SIB\_OFF = 2$)). Also, SIBs are segmented and multiplexed together with different SIBs sent in the same SYSTEM INFORMATION message. In Figure 11.4 the scheduling information for the SIBs has been obtained from the MIB. The MIB and the scheduling information blocks contain a number of elements known as value tags, the purpose of which is to allow the UE to observe the value tag and decide whether the information in the corresponding SIBs has changed. Using this procedure, the UE does not need to read all of the SIBs constantly and, as a consequence, can employ DRX procedures, periodically waking to read the MIB and the scheduling blocks. The PAGING TYPE1 message also contains the value tag for the MIB. This allows the UE to ascertain whether the MIB (and hence any SIBs) has changed whilst waking to read a paging message. This procedure enhances the power saving capability of the UE.

11.2.5 Structure of RRC SYSTEM INFORMATION PDU

The UTRAN has the facility to segment and concatenate SIBs before transporting them via the BCH and PCCPCH to the UE. To achieve this a number of different combinations of segments have been defined. Table 11.6 identifies the different segments combinations, and their use. The structures for some of the different combinations of the RRC SYSTEM INFORMATION PDU are outlined in Figure 11.5. In all cases, the SYSTEM INFORMATION PDU must fit the BCH transport block size of 246 bits.

Figure 11.5 illustrates the structure of data that will become the transport block. The data include what is called the SFNPrime, which is the SFN with the least significant bit removed. The SFNPrime with 0 appended defines the SFN of the first radio frame used to carry the transport block, and SFNPrime with 1 appended defines the SFN of the second radio frame used to carry the transport block.

The UE initially does not know which of the two possible frames is the start of the 20-ms TTI that carries the BCH transport block. To locate the start of the 20-ms below). The number

contents of the first
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MIB and some SIBs.
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e start of the 20-ms

Table 11.6. *List of possible combinations of SIBs in SYSTEM INFORMATION PDU*

Combination	Description	Usage
Combination 1	No data	
Combination 2	First segment	Used to carry the first part of a segmented SIB.
Combination 3	Subsequent segment	Used to carry subsequent segments of a segmented SIB.
Combination 4	Last segment	Used to carry the last (short) segment of a segmented SIB.
Combination 5	Last segment First segment	Used to carry the last (short) segment of a segmented SIB followed by the first segment of a following segmented SIB.
Combination 6	Last segment Complete SIBs	Used to carry the last (short) segment of a segmented SIB followed by a number of complete (unsegmented) SIBs.
Combination 7	Last segment Complete SIBs First segment	Used to carry the last (short) segment of a segmented SIB followed by a number of complete (unsegmented) SIBs followed by the first segment of a segmented SIB.
Combination 8	Complete SIBs	Used to carry a number of complete (unsegmented) SIBs.
Combination 9	Complete SIBs First segment	Used to carry a number of complete (unsegmented) SIBs followed by the first segment of a segmented SIB.
Combination 10	Complete SIBs	Used to carry complete SIB of size 215–226 bits.
Combination 11	Last segment	Used to carry the last segment of a segmented SIB of size 215–222 bits.

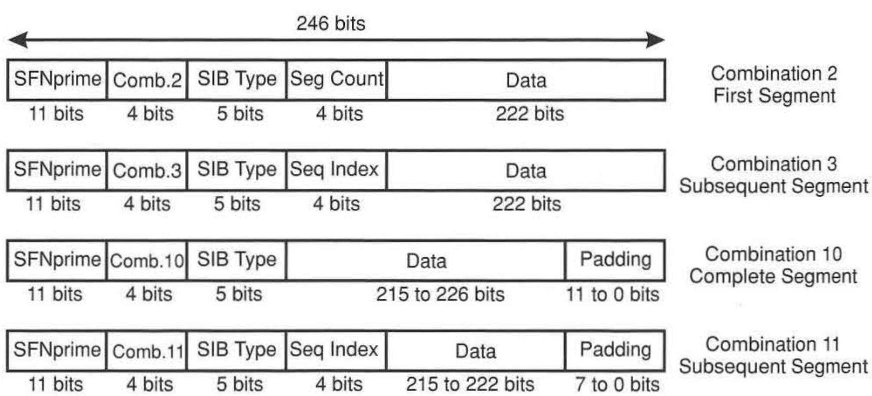

Figure 11.5 Examples of SYSTEM INFORMATION PDU.

transport block, the UE uses the CRC bits that are attached to the transport block during the creation of the CCTrCH.

The UE attempts to decode the CRC bits for two possible start locations. One of the start locations is correct (CRC check passes), and the other is incorrect (CRC check fails). In this way, the UE can detect the start of the BCH transport channel and, from this, read the SFNPrime, which can be passed to the RRC via the MAC and RLC along with the contents of the transport block.

11.2.6 Purpose of SIBs

Table 11.7 defines the purpose of the different SIBs that are present in the system. All of the SIBs (except for SIB 10) are sent via the BCH and the PCCPCH. SIB 10 is used only in the FDD mode for dynamic resource control and is sent via the FACH and the SCCPCH.

11.3 Paging and DRX

11.3.1 DRX

DRX is used in systems such as UMTS to allow a UE to periodically move into a sleep mode. Whilst in this sleep mode, the UE is able to power down many of its normally operational functions, thus conserving battery power and prolonging the standby time.

One problem that is associated with the use of DRX is that the UE must be able to receive paging messages from either the UTRAN or the CN. If the UE is using DRX, this means that the paging messages need to be co-ordinated with the sleep cycle of the UE. In this next section we outline the principles of the DRX cycle and in Section 11.3.3, look at how it impacts on the paging process.

11.3.2 DRX procedure

Initially we must define three quantities: first a PI, second a DRX cycle and finally a paging occasion.

PI

A PI is used to define a short indicator that is transmitted on the PICH to indicate to a UE that there is a paging message on an associated paging channel carried by the SCCPCH.

For the FDD mode, the number of PIs per radio frame (N_p) (of 10 ms) can be 18, 36, 72 or 144. For the TDD mode the number of PIs per radio frame depends on a number of parameters (see [40]). The advantage in using the PI is that the detection in the UE is both easy and relatively fast. The following expression defines in the UE which PIs it should monitor (note there is also an additional layer 1 equation that defines which bits in the PICH the UE should monitor for a specific PI in a specific SFN – see Chapter 4):

$$\text{PI} = \text{DRX Index mod } N_p$$

the MAC and RLC

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on that defines which
a specific SFN – see

Table 11.7. *Definitions for different SIB types*

Name	Purpose
MIB	Main index for system information. Contains scheduling information on SIBs and up to two scheduling blocks.
Scheduling block 1	Optional block used to provide scheduling information on SIBs.
Scheduling block 2	Optional block used to provide scheduling information on SIBs.
SIB1	Contains NAS information (CN specific information) as well as information on timers for use in idle or connected mode.
SIB2	Contains information on the URAs that are available. There can be up to eight URAs in a cell.
SIB3	Contains information on the cell selection and reselection parameters that the UE should use whilst in idle mode. If SIB4 is not present it can also be used for UEs in connected mode.
SIB4	Contains information on the cell selection and reselection parameters that the UE should use whilst in connected mode. If SIB4 is not present the UE should use SIB3.
SIB5	Contains information on the common physical channels in the cell (PICH, AICH, P-CCPCH, PRACH, SCCPCH) for a UE in idle mode. If SIB6 is not present it can also be used for UEs in connected mode.
SIB6	Contains information on the common physical channels in the cell (PICH, AICH, P-CCPCH, PRACH, SCCPCH) for a UE in connected mode. If SIB6 is not present the UE should use SIB5.
SIB7	Contains information on fast changing cell parameters such as the uplink interference levels (used for open loop power control for the PRACH) and the dynamic persistence value (also used for PRACH).
SIB8	For FDD mode only. Contains static information for CPCH.
SIB9	For FDD mode only. Contains dynamic information for CPCH.
SIB10	For FDD mode only. Sent via FACH, contains information relevant to the DRAC procedures.
SIB11	Contains measurement control information for a UE in idle mode. If SIB12 not present it can also be used for UEs in connected mode.
SIB12	Contains measurement control information for a UE in connected mode. If SIB12 not present the UEs can use SIB11.
SIB13–13.4	Contains information on ANSI-41 parameters used with ANSI-41 core networks.
SIB14	For TDD mode only. Contains outer loop power control information applied to dedicated and common physical channels.
SIB15–SIB15.4	Contains information to be used for UE positioning methods such as GPS or OTDOA.
SIB16	Contains information on channel configuration (physical, transport and RB) to be stored in the UE for use during handover to UTRAN.
SIB17	For TDD mode only. Contains information on shared common channels to be used in connected mode.
SIB18	Contains PLMN identities for neighbouring cells to be considered for use by a UE that is in either idle or connected mode.

where

DRX Index = IMSI div 8192

DRX cycle

The DRX cycle defines the periodicity of the DRX process (Table 11.8). The longer the DRX cycle, the longer the UE is in a sleep state, and the longer the delay before the UE can respond to a paging message. The DRX cycle length is defined by the DRX cycle length coefficient (k) thus:

DRX cycle length $= 2^k$ frames for FDD mode

There can be a number of values for k depending upon the current state of the UE. For the CN, each of the CN domains can have a different value for k. If the UE is attached to multiple CN domains, each with different DRX cycle lengths, then the UE selects the shortest cycle length. Similarly, there is also a DRX cycle length defined for the UTRAN.

Paging occasion

The paging occasion defines the SFN of the frame of which the UE must monitor the PICH to see whether a paging message is being sent to that UE. If the PI bits are set (i.e. equal to binary 1) in that paging occasion, the UE reads the paging message on the PCH transmitted on the associated SCCPCH. The paging occasion for the FDD mode is defined by:

$$\text{paging occasion (SFN)} = (\text{IMSI div } K) \bmod (\text{DRX cycle length}) + n^*\text{DRX cycle length} \quad (11.1)$$

where n can take the values 0,1,2, . . . up to a maximum such that the SFN is valid (i.e. < 4096) and K is the number of SCCPCHs that carry a PCH. The paging occasion for the TDD mode is defined using a formula with slight modifications and defined in [40].

11.3.3 Example

Let us consider an example, in which we illustrate how a UE can estimate the paging occasion, the DRX cycle length and which PIs to look for. As we saw in Section 11.3.2, the information that the UE calculates is based in part on information received from broadcast messages, and also information that is calculated based on the IMSI. In this example we are assuming that there are four SCCPCHs ($K = 4$) that are carrying PCHs. First, the UE needs to ascertain which of the SCCPCHs it is using and to do this it uses the expression (IMSI mod K). The example shown in Figure 11.6 uses a specific IMSI and from this we find that the UE should be using SCCPCH1 from the four available (SCCPCH0–SCCPCH3).

(Table 11.8). The longer
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Table 11.8. *Values for DRX cycle coefficient*

Parameter	Values	Cycle length
'UTRAN DRX cycle length coefficient'	3–9	80 ms–5.12 s
'CN domain specific DRX cycle length coefficient'	6–9	640 ms–5.12 s

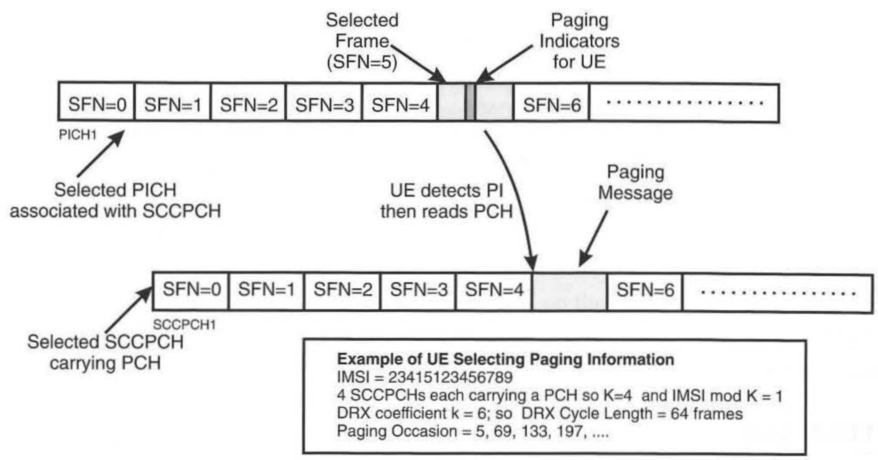


Figure 11.6 Example of PI.

Next, the UE needs to calculate the DRX duty cycle and then the paging occasion. The DRX duty cycle is estimated using the expression presented earlier and in our example the DRX duty cycle coefficient k is 6, which corresponds to a duty cycle of 64 frames. The paging occasion is calculated using the IMSI, K and the DRX duty cycle using (11.1). In this example we find the paging occasion occurs on frame numbers 5, 69, 133 etc. and every 64th frame up to the maximum frame count of 4095.

The final thing that the UE needs to calculate is the PI from which it can calculate which part of the PICH to detect for a possible paging message. In this example, using the equation in Section 11.3.2, the PI is calculated as being 13.

Now, with all of this information, the UE can check whether the appropriate bits in $SFN = 5$ of the PICH are set. In this example (as shown in Figure 11.6) the PI bits are set and so the UE should read the paging message that will be transmitted on SCCPCH1 in the following frame.

The offset between the PICH and the SCCPCH is so defined to allow the UE to receive the PICH and then have time to read the paging message. For the FDD mode the TTI is 10 ms and for the TDD mode the TTI is 20 ms. This means that for the FDD mode the paging message is sent using a single radio frame.

Table 11.9. *Contents of paging message*

Field	Comment
Paging record list	A list of paging records (1, . . . 8).
Paging record	Details of each paging record in the list includes: UTRAN originated: • u-RNTI; • CN-ORIGINATEDPAGE-CONNECTEDMODE-UE; • Paging cause (terminating: conversational; streaming; interactive; background; high priority signalling; low priority signalling; cause unknown); • CN domain identity (CS or PS domain); • Paging record type ID [IMSI, TMSI, P-TMSI] CN originated: • Paging cause (as above); • CN domain identity (as above); • CN paged UE identities (IMSI, TMSI, P-TMSI + value for identity type selected).
BCCH	MIB value tag – defines if MIB has changed.
Modification information	BCCH modification time – time for changes to apply.

11.3.4 Paging message

The contents of the paging message are illustrated in Table 11.9. The paging message can include up to eight paging records. The paging message is from the CN, but could come via the UTRAN if the UE is in the CELL_PCH or URA_PCH states. In either case, the paging record defines the reason for the paging message (some type of mobile terminated transaction as shown in Table 11.9), and also the identity type and in the case of CN paging it also includes the identity itself.

11.4 RRC connection establishment

The next aspect of the RRC procedures that we consider is the establishment of an RRC connection. Figure 11.7 illustrates the basic RRC connection request procedure initiated at the request of higher layers and which is the first stage in establishing a signalling connection to the CN. At the start the UE is in the idle mode. In the following we examine the procedure outlined in Figure 11.7 in greater detail.

11.4.1 RRC CONNECTION REQUEST

This first message in the opening sequence is sent by the UE to the UTRAN using a CCCH logical channel, the RACH transport channel and the PRACH. The structure

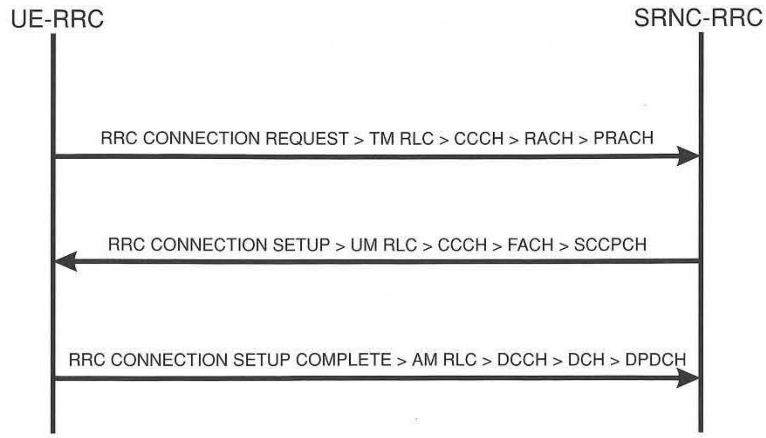


Figure 11.7 RRC connection request procedure.

for these channels is part of SRB0 used by the UE on the uplink, and defined by the contents of the SIB5 broadcast message.

The UE sets the connection frame number (CFN) based on the SFN for the common channels as follows:

$$\text{CFN} = \text{SFN} \bmod 256$$

Next the UE maps the AC to ASC (this is considered in detail in Chapter 8) to facilitate PRACH parameter selection and performs the PRACH transmission procedure, sending the RRC CONNECTION REQUEST message.

The contents of the RRC CONNECTION REQUEST message are summarised in Table 11.10. One of the elements of the RRC CONNECTION REQUEST message is the establishment cause. The potential values for the establishment cause are presented in Table 11.11, it informs the UTRAN on the nature of the RRC connection required. Once the message is sent, the UE selects a SCCPCH carrying a FACH according to (initial UE identity mod K), where K is the number of SCCPCHs that carry FACH, excluding those that only carry PCHs. Once the SCCPCH is selected, the UE monitors the SCCPCH and FACHs for the response from the UTRAN.

11.4.2 RRC CONNECTION SETUP

The action by the UTRAN to the RRC CONNECTION REQUEST is to return an RRC CONNECTION SETUP message to the UE and establish an RRC connection whose characteristics are defined within the setup message. As a minimum, three SRBs (SRB1, SRB2 and SRB3) are established with an optional fourth (SRB4) possible.

Table 11.10. *Contents of RRC CONNECTION REQUEST message*

Message element	Description
Initial UE identity	The initial UE identity in priority order: • TMSI + LAI; • P-TMSI + RAI; • IMSI; • IMEI.
Establishment cause	Reason for RRC connection request (see Table 11.11).
Protocol error indication	True/false indicator to define whether a protocol error occurred.
Measured results on RACH	Measured results on current cell and six best serving cells. Information could be CPICH E_c/N_o, CPICH RSCP or path loss as well as the primary scramble code for the neighbour cells.

Table 11.11. *Establishment causes*

Signalling	MO call	MT call	Other
Originating HP Originating LP Terminating HP Terminating LP	Conversational Streaming Interactive Background Subscribed traffic	Conversational Streaming Interactive Background	Emergency call Inter-RAT cell reselection Inter-RAT cell change order Registration Detach Terminating – unknown Call Re-establishment

Table 11.12 defines the basic contents of the RRC CONNECTION SETUP message and their purposes. Table 11.13 defines the processing steps that the UE follows, and the following section defines the contents of the RRC CONNECTION SETUP message in more detail.

Selection of SCCPCH

Having transmitted the RRC CONNECTION REQUEST message, the UE needs to listen for the RRC CONNECTION SETUP message. First, the UE must identify the SCCPCH that is carrying the FACH that carries the CCCH that carries the SETUP message.

The UE will have listened to the SIB5 message that defines the structure of the common channels. Part of this message includes a list of the SCCPCHs present in the cell. The UE counts the number of SCCPCHs that carry a FACH (those SCCPCHs

Table 11.12. *Contents of RRC CONNECTION SETUP message*

Message element	Description
Initial UE identity	This should be the same as the one used by the UE. IE will look for this on selected SCCPCH/FACH.
RRC transaction identifier	An identifier (0–3) that is used to identify specific RRC messages.
Activation time	This defines the time (specified as the CFN) at which the parameters in the message will take effect.
New u-RNTI	UTRAN specific temporary identity allocated to the UE when entering connected mode.
New c-RNTI	Cell specific temporary identity allocated to the UE within a specific cell.
RRC state indicator	This defines which state the UE should enter. Only CELL_DCH and CELL_FACH are valid in the initial RRC connection setup message.
UTRAN DRX cycle length coefficient	The quantity '*k*' used to calculate the DRX cycle length. Value ranges from 3 to 9 for the UTRAN.
Capability update requirement	This defines whether the UE should supply FDD, TDD and other system (e.g. GSM) capability information.
Signalling RB information setup (multi 3–4)	This defines the three (optionally four) SRBs that need to be setup for the UE. The message also configures the RLC (uplink and downlink) and the mapping possible for the SRBs onto the different transport channels.
UL transport channel information common to all	This defines the transport channel information, TFSs and TFCs that are relevant to all transport channels on the uplink.
Added or reconfigured uplink transport channel information (multi nos. transport channels)	This defines information for transport channels that are being added (in this case). There is one message for each transport channel being defined.
DL transport channel information common to all	This defines common downlink transport channel information.
Added or reconfigured downlink transport channel information (multi nos. transport channels)	This defines downlink transport channel information for new/changed transport channels.
Frequency information	This defines UARFCN for uplink and downlink.
Maximum allowed uplink Tx power	This defines the maximum allowed uplink transmit power (–50 to 33 dBm).
Uplink DPCH information	This defines parameters for uplink DPCH such as scramble code type (short or long), scramble code number (0 to 16777215), (minimum) spreading factor.
CPCH set information	This defines the CPCH parameters if configured.
Downlink common for all RLs	This defines the physical channel parameters for the downlink RLs. Parameters include diversity type, compressed mode parameters, spreading factors.
Downlink information for each RL (multi)	This defines information specific to each RL in the active set. This also includes information for the PDSCH if that is also being allocated at the same time.

Table 11.13. *Processing stages for RRC CONNECTION SETUP message*

Step	Procedure
1	Process the 'activation time' information element. If it indicates that the time is 'now'; this means that the UE should activate the RRC connection on an appropriate TTI boundary. Alternatively, the 'activation time' could contain the CFN and hence the time that the UE should activate the connection.
2	Compute the DRX cycle length using the UTRAN DRX cycle length coefficient. This is used to define the paging occasions for the UE in connected mode.
3	UE selects state according to RRC state indicator.
4	Store the new c-RNTI received and use it for common channels (RACH, FACH and CPCH).
5	Store the new u-RNTI.
6	If requested compute the various capability information required for subsequent transmission to the UTRAN.
7	The UE establishes the different SRBs according to the information defined within the setup message. This information may also include multiplexing options that define which, and how, SRBs can be mapped onto the different possible transport channels (this can occur when moving from the CELL_DCH to CELL_FACH state and require different TFCs). In addition the MAC and RLC are configured, including the possibility that more than one logical channel is connected to the same transport channel (logical channel multiplexing).
8	The UE configures the TF set and TFCS according to the received messages.
9	The UE configures the physical layers according to the physical layer configuration messages.

carrying only a PCH are ignored). If there are K SCCPCHs carrying a FACH listed in the SIB5 message, the UE selects the SCCPCH according to:

Index of selected SCCPCH = Initial UE identity mod K

The index is a number in the range 0–($K - 1$) and identifies which of the SCCPCHs the UE should use. The first SCCPCH in the SIB5 list is index 0, the second index 1 and so forth.

The initial UE identity is the identity that the UE used in the RRC CONNECTION REQUEST message. The identity could be the IMSI, TMSI, P-TMSI, IMEI or DS-41 based identities. The UE converts the identity into an integer value prior to estimating the required index.

Initial UE identity

Once the UE has identified the SCCPCH, it can listen for the RRC CONNECTION SETUP message that is intended for that UE. To do this, the UE has to decode each message on the selected SCCPCH and extract the initial UE identity contained within the message (note: the MAC UE identity field is not used for the CCCH carried by the FACH).

The initial UE identity is the identity that was used by the UE in the uplink and is used by the UTRAN in the downlink. This initial identity is only needed for the first exchange of information to allow the network to identify the UE prior to the allocation of the temporary UTRAN identity that will be used for subsequent messages.

RRC transaction identifier

The RRC transaction identifier is an integer in the range 0–3. The identifier is used to identify the different downlink procedures to allow multiple procedures. The UE uses the identifier for error trapping, such as the repeat transmission of the same message, or the transmission of a second RRC CONNECTION SETUP message.

Activation time

This is an integer between 0 and 255 that defines the CFN in which the changes specified in the remainder of the message should take effect. The activation time that is selected depends upon the CFN and the TTI boundary for all of the transport channels that are part of the CCTrCH. The CFN that is used for defining the activation time depends on whether the UE is being put into the CELL_FACH state or the CELL_DCH state.

In the CELL_FACH state the CFN is the same as that defined above. For the CELL_DCH state the CFN for calculating the activation time is given by:

$$\text{CFN} = ((\text{SFN}^{*}38400 - \text{DOFF}) \text{ div } 38400) \text{ mod } 256 \qquad \text{FDD mode}$$

where DOFF is the default DPCH offset in steps of 512 chips for the FDD mode or

$$\text{CFN} = (\text{SFN} - \text{DOFF}) \text{ mod } 256 \qquad \text{TDD mode}$$

where DOFF is the default offset in frames for the TDD mode. DOFF is defined in the part of the RRC CONNECTION SETUP 'downlink information common to all radio links'.

The activation time has a default value, and that default value is 'now'. A default of 'now' requires the UE to choose an activation time as soon as possible, which is short enough to allow the UE to respond to the RRC CONNECTION SETUP within a time in the region of 100 ms (the actual time is defined, but depends on a number of factors such as the Node B DPCH start time).

New u-RNTI

The u-RNTI is the UTRAN identifier for a UE. The u-RNTI is a 32 bit bit-string consisting of two parts: the SRNC identity (12 bits) and the s-RNTI (20 bits). The UE stores the u-RNTI and it is used when the UE is required to uniquely identify itself within the UTRAN.

New c-RNTI

The c-RNTI is a 16 bit bit-string used to uniquely identify a UE within a cell. The c-RNTI is an optional part of the RRC CONNECTION SETUP message and is only needed if the UE is being put into the CELL_FACH state.

RRC state indicator

The RRC state indicator defines the state that the UE should move into after successfully completing the RRC CONNECTION REQUEST procedure. The UE is entering the connected state. There are only two valid states, i.e. the CELL_DCH state and the CELL_FACH state. The other two possible states (CELL_PCH and URA_PCH) are invalid states for a UE establishing an RRC connection and result in an error condition if received in the RRC CONNECTION SETUP message.

A UE that is put into the CELL_DCH state is assigned a dedicated physical channel on both the uplink and the downlink. The UE can use the resources of the channel as required. A UE that is put into the CELL_FACH state is assigned a common physical channel (SCCPCH on downlink and PRACH or PCPCH on uplink). In this state, the UE must share the resources on the uplink with the other UEs in the cell that use these common channels.

UTRAN DRX cycle length coefficient

The UTRAN DRX cycle length coefficient is an integer number in the range (3, . . . , 9) and is used by the UE to derive the length of the DRX period and the location of the paging occasions.

Capability update requirement

This field defines whether UE capability information is required. The default value is false, indicating that capability information is not required. A value of true indicates that the UE should provide capability information.

The capability update requirement can also request capability information on up to four other RATs, and for R99, GSM is defined as one of these RATs.

SRB information to setup

The SRB information defines the SRBs that are being established as part of the RRC connection establishment procedure. Three SRBs and an optional fourth SRB are established as part of this procedure. SRBs are used as follows:

SRB1: UM RLC used for RRC signalling;
SRB2: AM RLC used for RRC signalling;
SRB3: AM RLC used for NAS signalling – high priority;
SRB4: AM RLC used for NAS signalling – low priority (optional).

The contents of the SRB setup are as follows.

RB identity

The RB identity defines the identity of the RB that is being established. The value of the first SRB is defined to be 1, and the value is incremented by 1 for each additional SRB. For the initial RRC connection establishment, we expect to see either three or four RBs and so the RB identity should be 1–3 or 1–4 respectively.

For each RB, the information in the following subsections is defined.

Choice RLC info type

The 'choice RLC info type' defines the RLC information for the SRBs. The choice keyword indicates that there may be more than one selection to choose from. The first selection allows the explicit definition of the RLC information (see below), or alternatively the RLC information can be the same as that for another RB ('Same as RB' option defined below).

RLC info

This first option for the RLC info type choice defines the RLC information explicitly. The details of this field of information define the configuration of the RLC layer for the SRB to which it applies. Both the uplink and the downlink fields can be defined, as can the three different RLC modes (TrM, UM and AM). For the mode selected, the subsequent fields define all of the parameters that should be configured for that mode. The parameters and configuration of the RLC layer are considered in detail in Chapter 9.

Same as RB

This is the second option for the RLC info type field. If this option is selected for the specific SRB being configured, then the RLC information is copied from an existing RB, and the value in the field defines the RB identity to copy from.

RB mapping info

The RB mapping information defines how the RB is mapped onto different possible transport channels. The basic objective of the RB mapping information is to define how the RBs (SRBs in this example) can be mapped onto different transport channels (possibly due to a UE being in either the CELL_DCH state or the CELL_FACH state).

The RB mapping information IE relates to a set of logical channels, and defines the logical channel identity and RLC configuration for these logical channels. Next, it associates these logical channels with those associated with a specific TFS IE either defined within the RRC CONNECTION SETUP message (as is the case for the DCH transport channels) or alternatively defined elsewhere (e.g. within the SIB5 or SIB6 message for the RACH). The mapping information can therefore be used to switch transport channels (for instance due to a change of state from CELL_FACH to CELL_DCH when instructed by the UTRAN) but still maintain the same logical channel, albeit with different TFC options in the transport channel, and different effective QoS for the transport channels.

At this stage, we are considering the SRBs, and these could be mapped onto either a DCH transport channel in the uplink and the downlink, or alternatively a RACH transport channel in the uplink and a FACH transport channel in the downlink. This situation is summarised in Figure 11.8.

Number of uplink RLC logical channels

The number of uplink RLC logical channels defines how many logical channels there are per RLC entity. This situation is discussed in detail in Chapter 9. Essentially, when

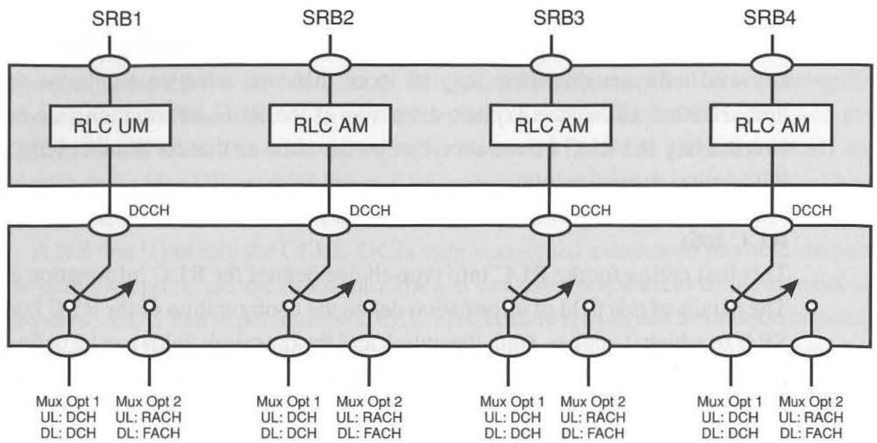


Figure 11.8 SRB multiplexing options.

operating in the AM, the RLC requires a signalling path to transfer the RLC control information (such as STATUS PDUs). This signalling path may use the same logical channel as the data path (one logical channel option) or it may have its own logical channel (two logical channels option). In the example we are considering here, each RLC entity uses only one logical channel.

Uplink transport channel type

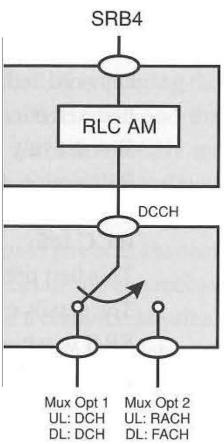
For each multiplexing option and for each RLC logical channel the uplink transport channel type is defined. In our example, there is only one logical channel per RLC entity and two mapping options. For the first mapping option the uplink transport channel type is set to DCH, and for the second mapping option, the uplink transport channel type is set to RACH.

Uplink transport channel identity

The uplink transport channel identity defines the identity of the transport channel that is being used if the transport channel is DCH or USCH (TDD mode only). If the transport channel is a RACH, this field is not present. In this situation, the UE has previously selected which of the available RACHs can be used, based on those available in the cell (defined in SIB6 or SIB5 if SIB6 does not contain the information) and the TTI usable with them. For these transport channels, the transport channel identity is defined in the appropriate SIB5/6 message for the RACH.

Logical channel identity

The logical channel identity is used to distinguish the logical channels that are mapped to the same transport channel by the MAC. The logical channel identity is a number in



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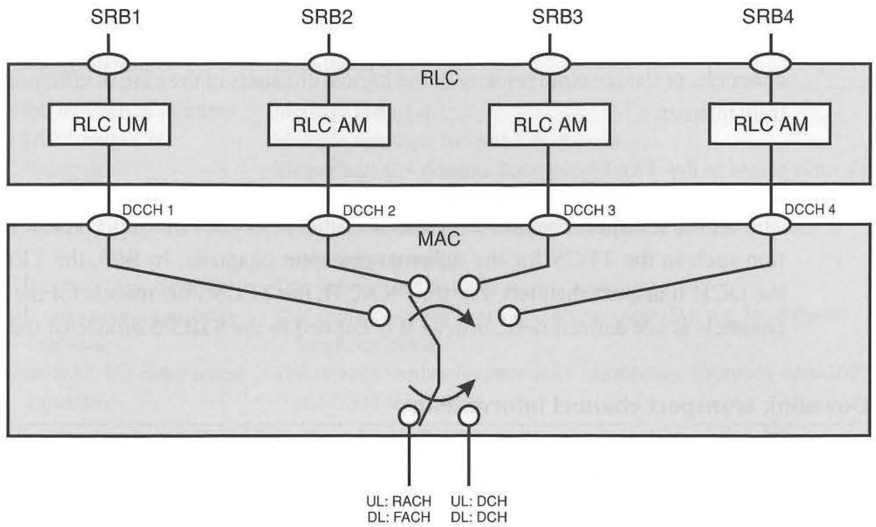

Figure 11.9 Combined logical channel and transport channel multiplexing.

the range 1–15, so up to 15 logical channels can be multiplexed by the MAC onto the same transport channel. In this example, we are considering three or four SRBs being multiplexed onto the same transport channel. The logical channel identity, therefore, is 1 for SRB1, 2 for SRB2, 3 for SRB3 and 4 for SRB4 if SRB4 is present. The combination of transport channel switching and logical channel multiplexing is illustrated in Figure 11.9.

Choice RLC size list

This field defines how the RLC sizes defined within the RB mapping field are related to the RLC sizes defined within the TFS for the specific transport channel that is being considered. If the transport channel is a DCH, the options are: 'all', 'configured', or 'explicit list'. 'All' means that all RLC sizes in the TFS defined for that specific transport channel are applicable for the logical channel. The option 'configured' means that the RLC sizes allowed are configured within the RRC CONNECTION SETUP message. The option 'explicit list' means that the RLC sizes are indexed within the RB mapping information IE, and the index relates to the TFS information defined for that transport channel. For the RACH transport channel, the only option is the 'explicit list'. The TFS parameters for the RACH transport channel are defined within the SIB6 message if available or else in the SIB5 message.

MAC logical channel priority

The MAC logical channel priority is an integer number in the range 1–8 and defines the priority of the logical channel entering the MAC. The highest priority is 1, and the lowest priority is 8. The MAC uses the logical channel priority information to define things such as the priority of the TF combining in the case of dedicated transport channels, or the absolute priority of the logical channels in the case of common channel transmission.

Uplink transport channel information

The uplink transport channel information common defines transport channel information such as the TFCS for the different transport channels. In R99, the TFCS is for the DCH transport channels. For the PRACH, the TFCS information for the transport channels is not defined here, instead it is defined in the SIB5/6 broadcast messages.

Downlink transport channel information

The downlink transport channel information, like the uplink information, defines the transport channel information (such as the TFCS) for the transport channels that are defined within the RRC CONNECTION SETUP message. In R99, the TFCS is for the DCH transport channels. For the SCCPCH, the TFCS information for the transport channels is not defined here, but is defined instead in the SIB5/6 broadcast messages.

Frequency information

The frequency information IE defines the UARFCN for the carrier that the UE is tuned to. The UE needs to know which channel it is using so that it can correctly change to different frequencies for measurement purposes that may lead to a handover.

Maximum allowed uplink Tx power

This IE indicates the maximum allowed uplink T_X power. The value is an integer in the range (−50, . . . , 33), where the integer value is defined in dBm.

Uplink DPCH information

This set of information defines aspects of the physical channel for the DPCH that the UE may have been assigned. The information within the IE relates to the physical channel and includes elements such as the minimum allowed spreading factor for the data part on the uplink, the scrambling code Id, the power control algorithm to use, the length of the power control preamble and the SRB delay.

The power control preamble and the SRB delay define the number of frames after the power control is activated for the DPCCH before the DPDCH and the SRBs, respectively, are transmitted.

CPCH set information

The CPCH set information contains the information required to establish the CPCH on the uplink (if required to do so by the UTRAN).

Table 11.14. *RRC CONNECTION SETUP COMPLETE message contents*

Message element	Description
RRC transaction identifier	Message identifier.
START multi CN	Multiple messages for each CN domain.
CN domain	This defines CN domains for which START will be sent to either the CS domain or PS domain.
START	Initialisation value of HFN used for each CN domain and used in security procedures.
UE radio access capability	This defines the UE radio access capability.
UE radio access capability extension	This defines extensions to radio access capability, e.g. for different frequency bands.
Inter-RAT UE radio access capability	This defines formats for inter-RAT capabilities. Currently cdma2000 and GSM are defined.

Downlink information

The downlink information defines all of the information that is required to establish the downlink physical channels. This includes information common to all radio links including elements such as:

- power control information including offset between pilot and DPDCH;
- spreading factor information, TFCI information for dedicated channels;
- compressed mode information and transmit diversity information.

There is also information that is specific to each radio link such as:

- the primary CPICH scrambling code number;
- information to configure the PDSCH (if present);
- DPCH configuration information (frame offset, spreading factor and code number, scrambling code number (if different to primary scrambling code in cell), power control information and transmit diversity information).

11.4.3 RRC CONNECTION SETUP COMPLETE

Upon completion of the setup procedures, the UE sends an RRC CONNECTION SETUP COMPLETE message to the UTRAN. The contents of this message are defined in Table 11.14. Once the UE has created the RRC CONNECTION SETUP COMPLETE message, it is transmitted to the UTRAN using the appropriate logical, transport and physical channels for the current mode of operation of the UE (i.e. CELL_DCH or CELL_FACH states within the connected mode). The flow of the message through the layers was illustrated in Figure 11.7.

11.4.4 Summary of RRC connection setup

Figure 11.10 summarises the structure of the protocol architecture after the establishment of the SRBs for the uplink. Only the CELL_DCH architecture is shown. If the

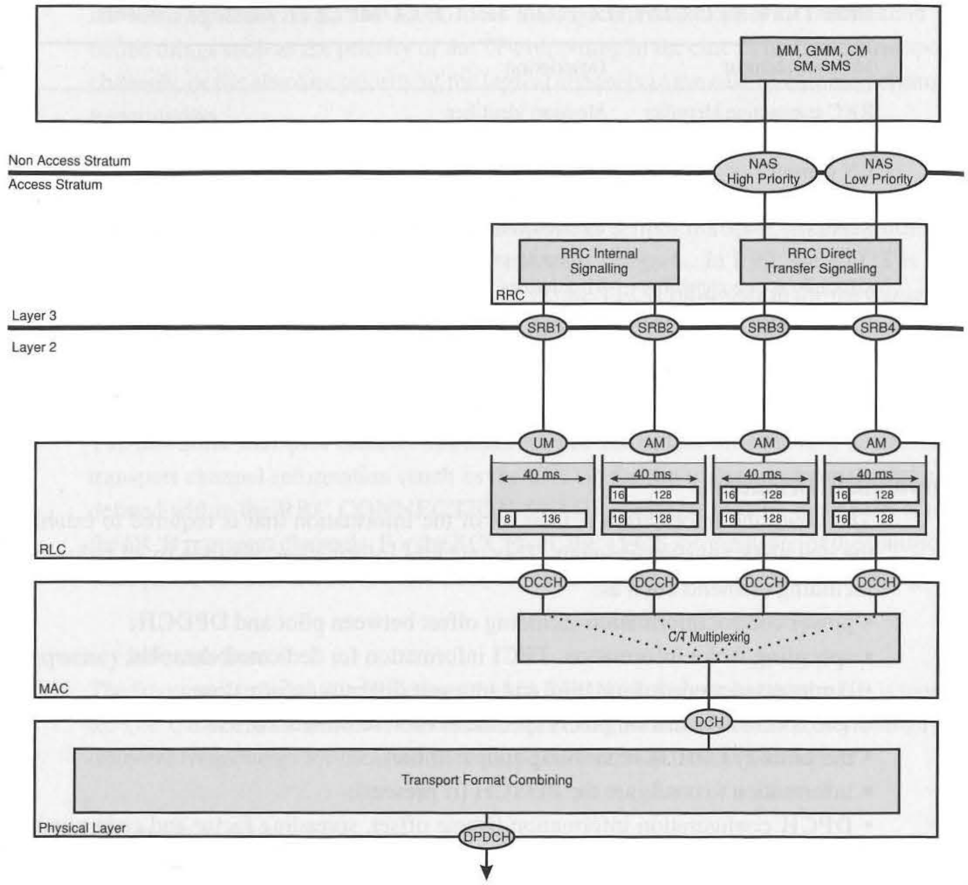

Figure 11.10 Protocol architecture after configuration of SRBs.

UE was configured to operate also in the CELL_FACH state, then there would be a comparable structure but only using the common transport and physical channels. Two of the RBs are used for RRC signalling and two are used for NAS signalling. The RRC CONNECTION SETUP message contained all the information that was needed by the UE to configure all the layers shown in the figure.

11.5 Direct transfer procedure

The next procedure that we consider is that used to transfer the NAS messages from the UE to the appropriate CN domain and the reverse operation. This procedure is referred to as direct transfer.

Direct transfer is the mechanism that allows a UE to send a receive NAS messages from the CN. There are a number of direct transfer messages used across the radio

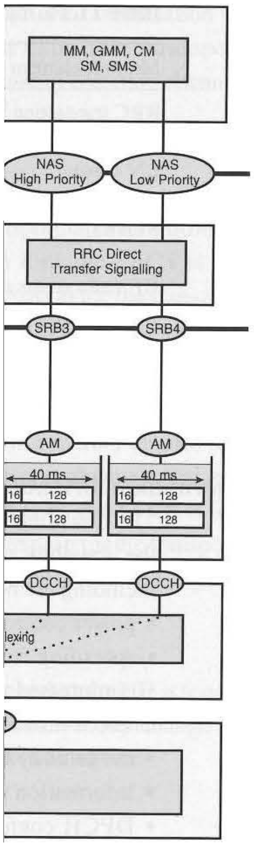

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Table 11.15. *Direct transfer messages*

Message	Direction	Description
INITIAL DIRECT TRANSFER	Uplink	Initial direct transfer message that also activates a signalling connection to a specific CN domain.
UPLINK DIRECT TRANSFER	Uplink	Subsequent direct transfer message on uplink.
DOWNLINK DIRECT TRANSFER	Downlink	Direct transfer on downlink using previously created signalling connection.

interface and these are outlined in Table 11.15. The direct transfer messages shown in Table 11.15 are used to establish signalling connections (INITIAL DIRECT TRANSFER) and to exchange NAS messages between the UE and the CN. The NAS messages are carried within the direct transfer message.

We start by considering an example of an initial direct transfer procedure. This could be used to carry an 'ATTACH REQUEST' NAS message or some alternative NAS message such as a location update message.

11.5.1 Initial direct transfer

If we assume that the NAS in the UE wishes to send a message to the NAS in the CN (e.g. an ATTACH REQUEST message to the PS domain), first, the NAS must request the AS to create an RRC connection as described in the previous section. Next the NAS can create the NAS message and pass it to the AS, which can then send the message to the appropriate CN domain using the INITIAL DIRECT TRANSFER message. This procedure is outlined in Figure 11.11, and the contents of the INITIAL DIRECT TRANSFER message are defined in Table 11.16. In this example, we are assuming that the NAS has requested the establishment of a PS connection to the PS-domain using the ATTACH REQUEST message (the use and contents of this message are considered in more detail in Chapter 13).

Before we can establish a PS connection, an RRC connection must be established. Figure 11.11 illustrates the sequence of messages required using the RRC primitives shown in Figure 11.11, the NAS can request the establishment of a GMM context and in the process a PS signalling connection. The primitives include the NAS message (ATATCH REQUEST) as well as the establishment cause, signalling channel priority (high or low), CN identity, UE identity and RAIs and LAIs.

The RRC layer first needs to establish an RRC connection using the procedures outlined previously (the establishment cause in the RRC CONNECTION REQUEST message is that received from the NAS). Once the RRC connection is available, the INITIAL DIRECT TRANSFER message is sent (via SRB3 assuming that the signalling channel priority flag was set to high) and includes the NAS message.

Table 11.16. *INITIAL DIRECT TRANSFER message*

Message element	Description
Integrity check information	Used to check the message integrity has not been violated.
CN domain identity	Identifies the CN domain that is the intended recipient of the initial direct transfer message.
Intradomain NAS node selector	Defines a 10 bit routing parameter based on a TMSI or IMSI that can be used to identify a specific connection between the UE and the CN domain.
NAS message	Contains the NAS message to be transmitted transparently through the UTRAN to the CN domain. The length of the message is between 1 and 4095 octets.
Measured results on RACH	Set of measurements made by the UE on the current cell and up to seven monitored cells.

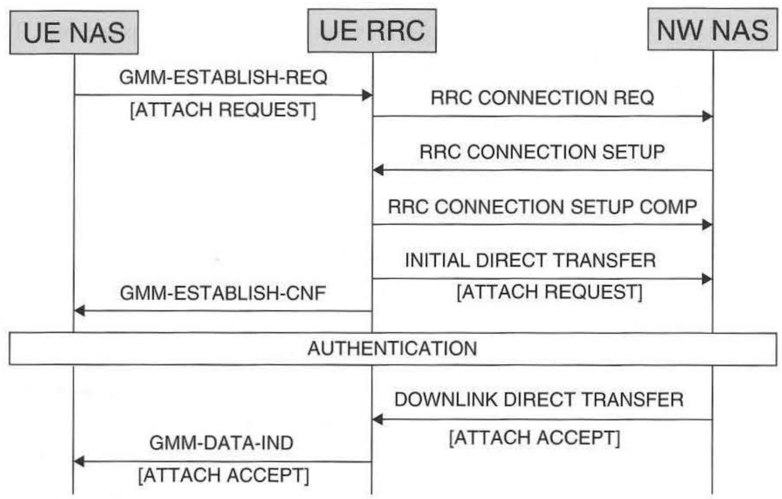

Figure 11.11 Example use of direct transfer to attach UE to network.

The RRC then confirms the creation of the signalling connection with the GMM-ESTABLISH-CNF primitive.

11.5.2 DOWNLINK DIRECT TRANSFER

If we assume that the UE sends an ATTACH REQUEST message, the response (ATTACH ACCEPT) is sent using the DOWNLINK DIRECT TRANSFER message. This part of the procedure is illustrated in the lower part of Figure 11.11. The contents of the DOWNLINK DIRECT TRANSFER message are illustrated in Table 11.17.

Table 11.17. *DOWNLINK DIRECT TRANSFER message*

Message element	Description
RRC transaction identifier	Identifier to track the RRC messages.
Integrity check information	This is used to check the message integrity has not been violated.
CN domain identity	This identifies the CN domain that is the intended recipient of the initial direct transfer message.
NAS message	This contains the NAS message to be transmitted transparently through the UTRAN from the CN domain. The message is between 1 and 4095 octets long.

11.6 RB setup

When the CN establishes a service to the UE, it has to create an RAB between the UE and the CN. The RAB in turn is composed of an RB and an Iu bearer. The relationship between the RAB and RB was illustrated in Chapter 2. The procedure that is performed to create a RAB is briefly outlined below:

- CN requests the RNC to create an RAB (RAB assignment request);
- RNC creates an Iu bearer between the RNC and the CN;
- RNC creates RLs between the Node B and the UE;
- RNC creates an RB between the RNC and the UE.

The last stage of this procedure creates the RB and involves the UE. The creation of the RB (and hence RAB) is achieved through two messages: RADIO BEARER SETUP from the UTRAN (SRNC) to the UE and in response the RADIO BEARER SETUP COMPLETE message from the UE to the UTRAN. To establish the RB the UTRAN sends the RADIO BEARER SETUP message to the UE, the contents of which are summarised in Table 11.18. Upon receipt of this message, the UE acts on the message appropriately and responds with the RADIO BEARER SETUP COMPLETE message.

The vast majority of the contents of the RADIO BEARER SETUP message are the same as the RRC CONNECTION REQUEST message and consequently we will not go through the details of these common areas here (please refer to Section 11.4). One specific area that differs (there are others such as the configuration of the PDCP layer and inclusion of DRAC information) is the RAB information that is included in the RADIO BEARER SETUP message.

The message RAB INFORMATION FOR SETUP is included below for reference.

RAB INFORMATION FOR SETUP

The RAB INFORMATION FOR SETUP message defines the RAB specific information. This information includes elements such as:

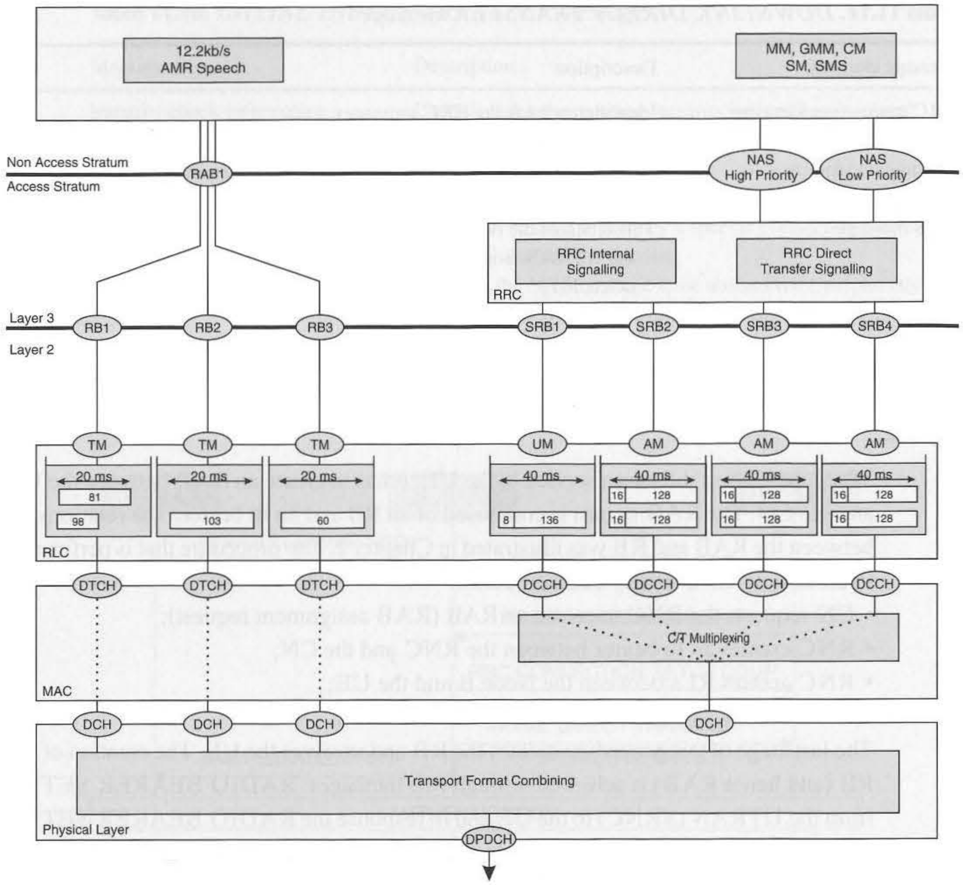

Figure 11.12 UE configuration after CS connection establishment.

- RAB identity: an 8 bit string that links the CN domain, bearer and UE; it comprises of an SI for the CS domain, and a NSAPI (numbered 5–15) for the PS domain.
- CN domain identity: this defines whether it is the CS domain or the PS domain.
- NAS synchronisation information: this is used by NAS for synchronising the bearer.

11.6.1 RAB setup for CS connection

Figure 11.12 illustrates the configuration of the UE after the establishment of an RAB for a CS speech connection. The RAB establishment procedure may be triggered in the UE by the request to establish a CS connection such as a speech call. This very example is considered in detail in Chapter 13.

Table 11.18. *RADIO BEARER SETUP message*

Message element	Description
RRC transaction identifier	Identifies individual RRC transactions per message type.
Integrity check information	Used to check the message integrity not violated.
Integrity protection mode information	Activates and configures the integrity protection.
Ciphering mode information	Activates and configures the ciphering mode for the different RBs.
Activation time	Defines when the changes in the setup message should be applied.
New u-RNTI	Defines a new u-RNTI if required, replaces any old value.
New c-RNTI	Defines a new c-RNTI if required, replaces any old value.
New DSCH-RNTI	Defines a new DSCH-RNTI if required, replaces any old value.
RRC SI	Defines the RRC state the UE is to move into (CELL_DCH, CELL_FACH, CELL_PCH, URA_PCH).
UTRAN DRX cycle length coefficient	Defines the DRX cycle length coefficient.
URA identity	Defines the URA identity to be stored and used in the URA_PCH state to activate a URA UPDATE procedure if it differs from values broadcast in SIB2.
CN information	Contains: PLMN identity; GSM NAS system information; up to four CN domains NAS system information.
SRB information setup list	Contains the information that defines the SRBs: SRB identity, RLC information and mapping information, logical channel information.
RAB information setup list	Contains the information that defines the RABs: RAB identity, one or more RB identity, PDCP information, RLC information and logical channel mapping information.
RB information affected list	Modifies the RB mapping information.
Downlink counter synchronisation information	Used to synchronise the downlink counters used for security procedures.
Uplink common transport channel information	Configuration information for the uplink common transport channels.
Uplink deleted transport channel information	List of uplink transport channels that are being deleted. List only allows DCH and USCH (TDD).
Uplink add/reconfigured transport channel information	List of transport channels and transport channel information for new transport channels or reconfigured transport channels.
Mode specific transport channel information	FDD mode transport channel information defining CPCH set identity (if applicable) and DRAC parameters (if applicable).
Downlink common transport channel information	List defining downlink transport channel information for common transport channels.
Downlink deleted transport channel information	List of downlink transport channels that are being deleted. List only allows DCH and DSCH.
Downlink add/reconfigured transport channel information	List of transport channels and transport channel information for new transport channels or reconfigured transport channels.
Frequency information	Uplink UARFCN and downlink UARFCN.
Maximum uplink Tx power	Defines the maximum uplink transmit power that the UE can use.
Uplink channel requirement	Defines the uplink DPCH or CPCH set information.
Mode specific physical channel information	Defines DSCH information for FDD mode.
Downlink common RL information	Defines the downlink RL information common to all RLs. For FDD mode this includes Tx diversity information and compressed mode information.
Downlink information per RL	Defines the RL information for all downlink RLs, including all of those in the active set. Includes elements such as scrambling code numbers, spreading code numbers.

Part of the RAB creation is the transmission of a RADIO BEARER SETUP message. The RADIO BEARER SETUP message includes all of the information that the UE requires for the AS part of the RAB creation process and is presented in Table 11.18; the contents of many of these fields were considered in Section 11.4. At the end of this procedure, the architecture of the UE is configured in a way similar to that presented in Figure 11.12. The details of the NAS part of the CS connection establishment (MO and MT) are considered in Chapter 13.

11.6.2 RAB setup for PS connection

We could assume that the next thing that the UE performs is the creation of a PS data connection (referred to as a PDP context). To do this, the UE performs a PDP CONTEXT ACTIVATION procedure, the details of which are considered in Chapter 13.

Part of the establishment of the PDP context is the creation of the RAB that supports the PDP context, and part of the establishment of the RAB is the creation of the RB using the RADIO BEARER SETUP message that we have just considered. The details of the NAS signalling and interlayer primitives between the NAS and AS are considered in Chapter 13 for this specific case.

On completion of this procedure, assuming that the CS call is still active, the NAS/AS architecture for the UE resembles that illustrated in Figure 11.13, which shows the simultaneous presence of the CS RAB and the PS RAB as well as the four SRBs used for the signalling messages between the UE and the network. The architecture shown is for the uplink and in the CELL_DCH case. There is an equivalent architecture for the downlink.

11.7 Handover

There are various forms of handover defined within the UMTS specifications. In this section we review the different forms of handover and then move on to explore some of the details associated with the different handover scenarios.

In general, before a handover can occur, the UE makes some signal measurements and reports them to the UTRAN. Based on the measurements, the UTRAN decides which type of handover to employ. The details of the various measurements that are made prior to a handover are considered in Chapter 12.

The types of handover considered in this section are soft-handover, hard-handover, handover to GSM and handover from GSM to UMTS. In addition we also consider cell change order, which is a cross between handover and cell reselection. Cell selection and reselection are considered in Chapter 12.

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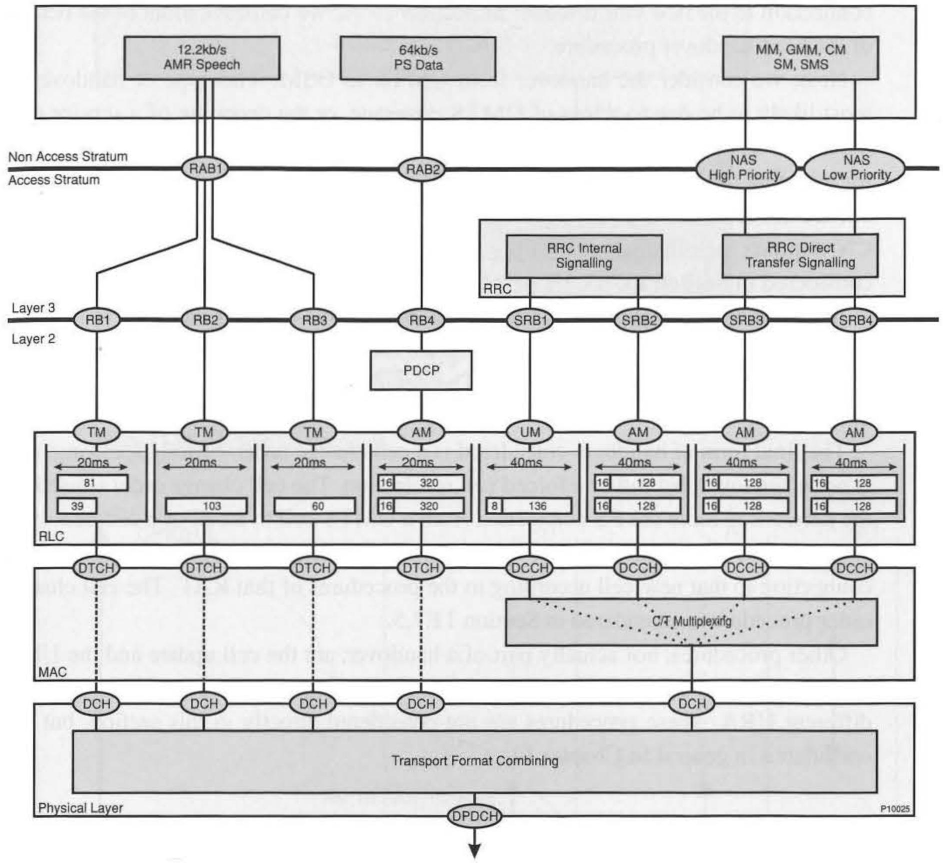

Figure 11.13 UE configuration after CS and PS connection establishment.

Soft-handover is a type of intrafrequency handover whereby the UE can be simultaneously connected to more than one cell and it is only applicable to the FDD mode of operation. In soft-handover we define something called the active set as being the set of RLs via which the UE is actively transmitting and receiving. The soft-handover procedure is referred to as the ACTIVE SET UPDATE and only applies to UEs that are in the CELL_DCH state. We consider the details of soft-handover in Section 11.7.1.

Hard-handover can be to a different cell on the same or a different frequency, to a TDD mode cell, or maybe to the same cell but using a different spreading code. The hard-handover procedure, like the soft-handover procedure, is activated by the UTRAN after the receipt of measurement reports from the UE. A hard-handover is a break-before-make handover, where the connection to the old cell is lost before the connection to the new cell is made. In Section 11.7.2 we consider some of the details of the hard-handover procedure.

Next, we consider the handover from UMTS to GSM. This type of handover is most likely to be due to a loss of UMTS coverage, or the dropping of a service that requires UMTS specific bearer capabilities. In either case, the UTRAN is responsible for initiating the handover. Once again, measurements from the UE may be the trigger, but are not essential. The UTRAN requests a handover to GSM via the CN, and the CN requests the establishment of the GSM bearers. The details of this handover are considered in Section 11.7.3.

A related handover is the handover from GSM to UMTS. This handover may occur for service related reasons. The principles are the same as the handover from UMTS to GSM, but applied in reverse order. The details of this handover are considered in Section 11.7.4.

The final form of handover considered is a cell change order. Strictly speaking, this is not a handover, but rather a forced cell reselection. The cell change order is used by the network to force the PS connection from a UMTS cell to a cell of a different type of RAT. The UE needs to select the new cell using the new RAT and establishes a connection to that new cell according to the procedures of that RAT. The cell change order procedure is considered in Section 11.7.5.

Other procedures, not actually part of a handover, are the cell update and the URA update that occur as a consequence of a UE reselecting a different cell, or a cell in a different URA. These procedures are not considered directly in this section, but are considered in general in Chapter 14.

11.7.1 Soft-handover

An active set is defined in [41] as a 'set of radio links that are simultaneously involved in a specific communication service between an UE and a UTRAN access point'. Figure 11.14 illustrates this basic concept of an active set. The UE has a logical connection to the CN via the SRNS, but is in addition receiving signals from the DRNS. It is the responsibility of the UTRAN to ensure that the transmissions from each of the Nodes B arrive at the UE within the same nominal time window. The rake receiver in the UE assigns a 'finger' to each of the transmissions. The number of fingers that a UE contains is an implementation issue, but as [24] stipulates the maximum number of RLs in the active set is eight, this implies that up to eight fingers are required in the rake receiver. Each finger in the rake receiver may be set to collect energy from the specific Node B it is monitoring with the UE configured with the channelisation and scrambling codes used. On the uplink, the SRNS is responsible for the combining of the information flows received by the different cells. Selection diversity combining is the technique most likely to be used for this purpose.

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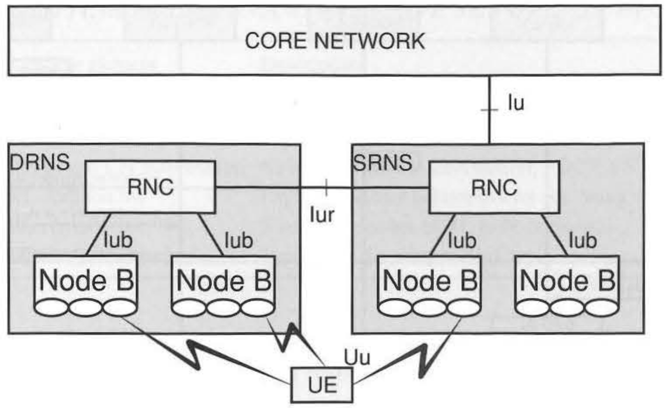

Figure 11.14 Active set operation.

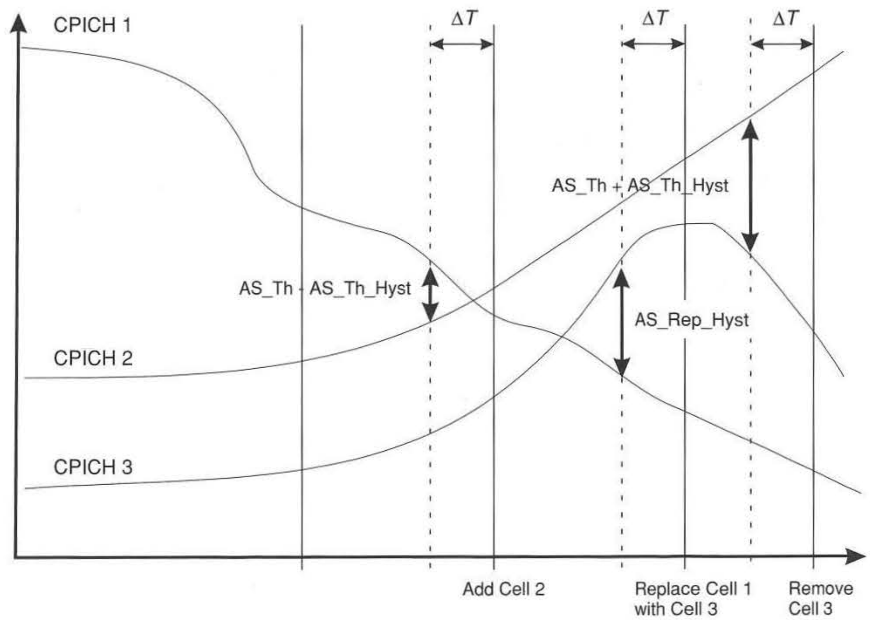

Figure 11.15 Typical active set measurements made by the UE.

Figure 11.15 shows an example of the measurement processes that need to be implemented to add and replace cells in the active set. The diagram represents the signal power that the UE is measuring from the primary pilot channels from a number of neighbouring cells. At the start, the UE is only connected to Cell 1 (whose power is indicated by CPICH 1). The power in Cell 2 increases and the difference between the

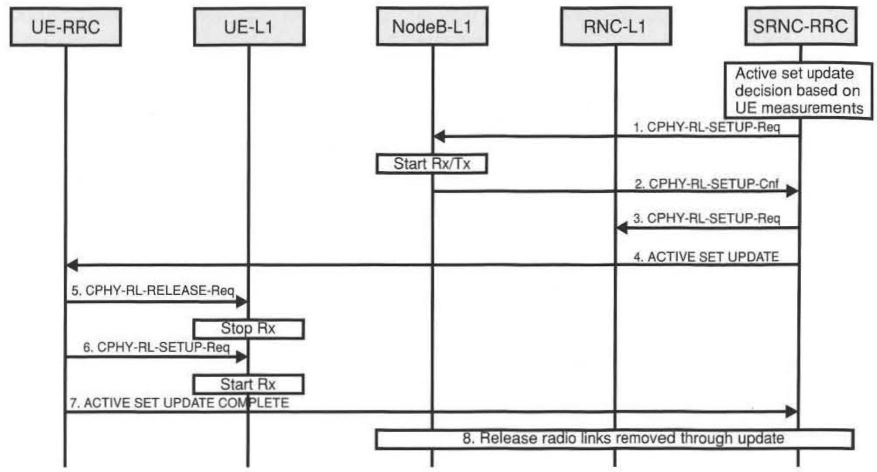

Figure 11.16 Active set update procedure message flows.

power Cell 1 and Cell 2 drops below the quantity shown in the diagram (soft-handover level minus some hysteresis amount), then after some time delay, Cell 2 is added to the active set. The next event occurs because the level in Cell 1 has dropped and that in Cell 3 increased, and the difference between Cell 1 and Cell 3 is such that Cell 3 replaces Cell 1 in the active set. The final event occurs because the signal level in Cell 3 has fallen below some differential level defined by the soft-handover level plus some hysteresis margin.

Figure 11.16 outlines the basic procedure associated with soft-handover. The procedure is referred to as the ACTIVE SET UPDATE procedure. Active set update is only relevant to the case where dedicated channels are being used (UE in CELL_DCH state). The ACTIVE SET UPDATE message is sent from the UTRAN to the UE via a DCCH channel. The message from the UTRAN may indicate either an add to the active set or a drop from the active set. If the command is to add to the active set, then the message includes the information necessary to achieve this (e.g. channelisation codes, scrambling codes etc.). Upon successful receipt and implementation of this message, the UE responds with an ACTIVE SET UPDATE COMPLETE message. The procedure starts with the UTRAN receiving measurements from the UE and deciding to change the active set.

1–3. The UTRAN configures the target cell resources assuming that RLs are being added to the active set.

4. The UTRAN sends the ACTIVE SET UPDATE message to the UE. The update message contains all of the necessary information on the RLs that are being added and removed.

5–6. The UE modifies the physical layer removing RLs as required and configuring the new RLs that are to be added.

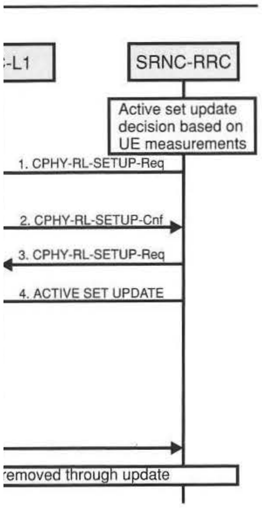

Table 11.19. *Message contents for ACTIVE SET UPDATE message*

Message element	Description
General elements	Transaction identifier, activation time, integrity protection information, ciphering information.
RNTI and CN information	New u-RNTI, CN information, PDCP SN information.
RL addition list	Physical channel parameters for RL being added.
RL removal list	Scrambling codes of RL to be removed.
Diversity information	Type of Tx diversity used if any.

7. The UE sends the ACTIVE SET UPDATE COMPLETE message.
8. The UTRAN frees any resources that are no longer used for the UE.

Table 11.19 outlines the basic contents of the ACTIVE SET UPDATE message. The message includes the general elements such as the activation time and ciphering and integrity protection information. The message also includes the physical channel information for the RLs that are to be added (if any) and the scrambling codes for the radio links to be deleted (if any). Diversity information is also included to indicate what transmit diversity is used, if any.

11.7.2 Hard-handover

Figure 11.17 outlines the hard-handover procedure. Hard-handover is implemented using the PHYSICAL CHANNEL RECONFIGURATION message (step 4, Figure 11.17) that changes some elements of the physical channel. This requires the UE to modify the physical channel (steps 5–8, Figure 11.17) before responding with the PHYSICAL CHANNEL RECONFIGURATION COMPLETE message (step 9, Figure 11.17).

Table 11.20 outlines the basic elements of the PHYSICAL CHANNEL RECONFIGURATION message. Many of the elements in Table 11.20 have been defined in Section 11.4 and Section 11.6 and consequently they are not considered in detail here.

On receipt of the PHYSICAL CHANNEL RECONFIGURATION message, the UE responds with the PHYSICAL CHANNEL RECONFIGURATION COMPLETE message; the elements of which are presented in Table 11.21. The PHYSICAL CHANNEL RECONFIGURATION COMPLETE defines mainly counters and timing elements. The elements include the START time used by ciphering and ciphering activation time, the PDCP sequence numbers used by lossless relocation, and the integrity protection configuration parameters.

11.7.3 Handover from UMTS to GSM

Handover from UMTS to GSM is possible even if no measurements are made on the target cell. The UE must be in the CELL_DCH state. Handover is possible with no

Table 11.20. *Contents of PHYSICAL CHANNEL RECONFIGURATION message used for hard-handover*

Message contents	Description
General information	Integrity protection, ciphering info, activation time, RNTI, RRC state, CN information, URA identity, DRX information.
Uplink channel requirement	Defines the uplink physical channels (FDD/TDD).
Downlink common information	Defines downlink physical channels (FDD/TDD).
Downlink information per RL	Defines physical channel information.

Table 11.21. *Contents of PHYSICAL CHANNEL RECONFIGURATION COMPLETE message used for hard-handover*

Message contents	Description
General information	Integrity protection, transaction identifier.
Integrity protection activation information	Defines the time when integrity protection should be activated.
Uplink counter synchronisation	START value for CN domains and PDCP sequence numbers.
Uplink RB cipher activation time	Defines timing of ciphering activation in terms of RLC sequence numbers.

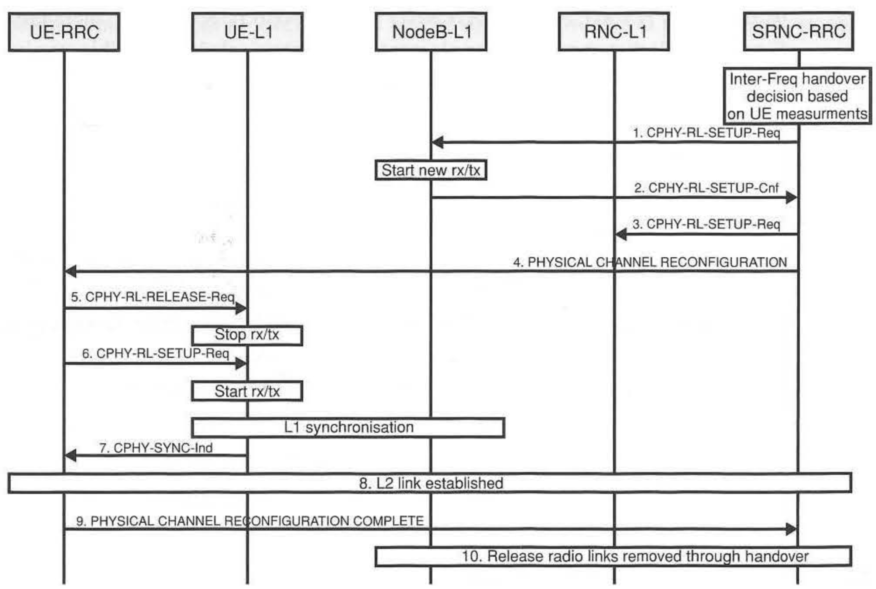

Figure 11.17 Hard-handover procedure.

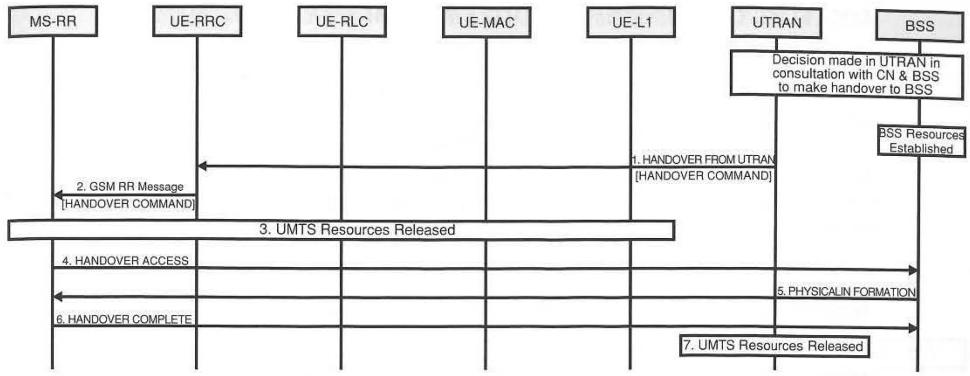

Figure 11.18 Handover from UMTS to GSM procedure.

RABs, CS RABs, CS and PS RABs. For R99, however, only one CS RAB can be handed over from UMTS to GSM. The network indicates the RAB identity (RAB Id) for the RAB that is to be handed over to GSM.

Figure 11.18 outlines the basic steps taken in the change from UMTS to GSM. This starts with a decision in the UTRAN that a change in RAT is required, based on measurements made by the UE, although the UE can be requested to handover without having made measurements. The numbered messages in Figure 11.18 are explained in the numbered clauses below.

1. The HANDOVER FROM UTRAN command is sent to the UE. This message also includes the GSM HANDOVER COMMAND message. The HANDOVER COMMAND includes all of the information that the MS needs to continue the connection in the GSM system.
2. The RRC in the UE sends the contents of the message to the GSM RR layer in the MS (GSM mode handset).
3. The UMTS radio resources are released by the UE.
4. The MS sends the GSM HANDOVER ACCESS access messages to the BSS as it would in GSM.
5. The BSS sends the PHYSICAL INFORMATION message including timing advance information.
6. The MS sends the HANDOVER COMPLETE message.
7. The UTRAN resources are released.

Table 11.22 presents the outline contents of the HANDOVER FROM UTRAN message. Moving from UMTS to GSM, multicall is not currently supported in GSM, and so only one of the CS RABs can be handed over to GSM. The RAB information defines which RAB should continue.

The details of the GSM part of the handover are contained in the GSM HANDOVER COMMAND, which is considered next. Table 11.23 presents the outline

Table 11.22. *Contents of the HANDOVER FROM UTRAN message*

Message element	Description
Integrity check information	Used to check the message integrity has not been violated.
Activation time	Defines CFN when changes apply.
RAB information	Defines which CS RAB is to be handed over – only 1.
GSM message	Includes GSM 'HANDOVER COMMAND' message.

Table 11.23. *GSM HANDOVER COMMAND message contents (abbreviated)*

Information	Description
Cell description	PLMN colour code, BS colour code, BCCH ARFCN.
Channel description	Defines the channel type, hopping information.
Handover reference	Defines a reference value used to identify the HO access.
Multislot configuration	Multislot configuration information.
Time information	Information on cell time offset and timing advance.
Codec information	Information on multirate codec.

contents of the GSM HANDOVER COMMAND message, which is included within the HANDOVER FROM UTRAN message. The HANDOVER COMMAND message provides information on the frequency and frequency hopping patterns, the channel configuration information and the bearer service configuration information that allows the UE to continue the call in the GSM system.

As part of the transfer of the radio connection to the GSM frequency, the MS (the name for the UE in the GSM system) continues by transmitting the GSM HANDOVER ACCESS message using the GSM RACH. The HANDOVER ACCESS message is sent a number of times for reliability and it also includes the handover reference value that the MS received in the HANDOVER COMMAND to identify the handover attempt.

The network responds with the PHYSICAL INFORMATION message, which is used to pass information on the timing advance to the MS and to stop the MS sending more HANDOVER ACCESS messages. The MS completes the procedure by sending the HANDOVER COMPLETE message, which includes an optional mobile observed time difference.

11.7.4 Handover from GSM to UMTS

Figure 11.19 outlines the basic steps taken in the change from GSM to UMTS; the meaning of the different messages is identified by the numbered clauses below. Similarly to the previous case, the handover is triggered by the source radio network (BSS) in

Table 11.24. *Contents of the INTER SYSTEM TO UTRAN HANDOVER COMMAND message*

Message element	Description
RR protocol disc	RR protocol discriminator.
Skip indicator	Skip indicator.
Message type	Defines INTERSYSTEM TO UTRAN HANDOVER command.
Handover to UTRAN	UMTS HANDOVER TO UTRAN message.

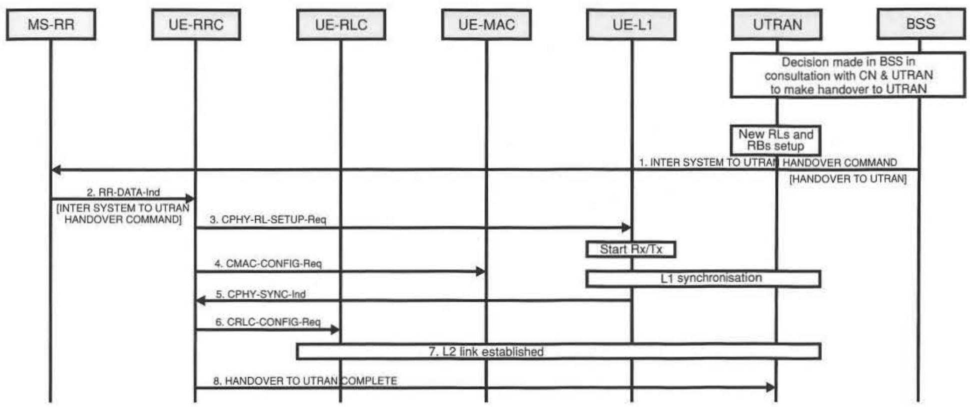

Figure 11.19 Handover from GSM to UMTS procedure.

consultation with the target radio network (UTRAN) (although not directly, rather via their respective CN elements).

1. The procedure starts with the MS receiving an INTER SYSTEM TO UTRAN HANDOVER COMMAND, which includes the UMTS HANDOVER TO UTRAN message.
2. The contents of this message are passed internally in the handset from the MS-RR to the UE-RRC layers.

3–7. The UE configures the L1 and L2 entities and synchronises with the L1 transmissions from the Node B.

8. The UE sends the HANDOVER TO UTRAN COMPLETE message when it has successfully moved to the target UMTS cell.

Table 11.24 outlines the basic contents of the INTER SYSTEM TO UTRAN HANDOVER COMMAND that the MS receives, including the UMTS RRC message: HANDOVER TO UTRAN.

The MS extracts the HANDOVER TO UTRAN part of the message, it changes to the UMTS mode of operation defined in the message and synchronises with the UMTS network. The response is sent and the connection continues via the UMTS network.

Table 11.25. *Contents of the HANDOVER TO UTRAN message*

Message element	Description
New U-RNTI	Allocates a new u-RNTI.
Ciphering algorithm	Defines which ciphering algorithm to use.
Specification mode	Complete specification – L2 explicitly defined. Predefined configuration – most of L2 defined by BSS. Default configuration – configuration Id defined in [24] for all L1 parameters defined.
Maximum allowed Tx power	Defines the uplink transmit power.

Table 11.26. *Default configurations for handover to UTRAN defined in [24]*

Configuration identity	Description
0	3.4-kb/s signalling
1	13.6-kb/s signalling
2	7.95-kb/s speech + 3.4-kb/s signalling
3	12.2-kb/s speech + 3.4-kb/s signalling
4	28.8-kb/s conversational class CS data + 3.4-kb/s signalling
5	32-kb/s conversational class CS data + 3.4-kb/s signalling
6	64-kb/s conversational class CS data + 3.4-kb/s signalling
7	14.4-kb/s streaming class CS data + 3.4-kb/s signalling
8	28.8-kb/s streaming class CS data + 3.4-kb/s signalling
9	57.6-kb/s streaming class CS data + 3.4-kb/s signalling
10	Multimode speech + 3.4-kb/s signalling

Table 11.25 outlines the basic contents of the HANDOVER TO UTRAN message. In addition to the typical message contents, the message includes the specification mode elements. The specification mode defines how the UE is told which of the UTRAN cell parameters it should use. Currently there are three options. This first is called complete specification, in which all of the details of L1 and L2 are specified within the message. The second option is a predefined configuration that the UE received from the original RAT (e.g. from the BSS in GSM) and which is identified using a tag value. The UE can be told to use one of these preconfigured configurations. The third option is to use a default configuration that is defined in [24] and also in Table 11.25. The default configurations list all of the necessary L2 and some L1 parameters that the UE needs to activate certain services. The default configurations are defined using a configuration identifier. Currently there are 11 default configurations, which are listed in Table 11.26.

Table 11.27. *Contents of the CELL CHANGE ORDER FROM UTRAN message*

Message contents	Description
General elements	Transaction identifier, activation time,
RAB information list	RAB Ids, CN domain, NAS synch indicator.
Inter RAT target cell desc	Defines target cell characteristics such as GSM, BSIC, frequency band, ARFCN.

11.7.5 Cell change order

The CELL CHANGE ORDER FROM UTRAN is used to change from a UTRAN cell to a cell in another RAT. It is a little like a handover, but it is intended for non-real-time services, and so is analogous to a forced cell reselection. It is applicable to the CELL_FACH state and the CELL_DCH state (PS connections only), and is used to allow UTRAN to force UEs not using the CS domain to use other RAT cells.

The contents of the CELL CHANGE ORDER FROM UTRAN message can be seen in the Table 11.27. In the reverse direction, it is possible that the other RAT may also cause a CELL CHANGE ORDER TO UTRAN. In this case the other RAT, through some means, encourages the UE to change to a UTRAN cell using information that is provided on that cell. When camped on the UTRAN cell, the UE performs an RRC connection establishment procedure with the establishment cause defined as 'Inter-RAT Cell Change Order'.

11.8 Miscellaneous RRC procedures

In this section we consider a number of associated RRC procedures, starting with the definition and calculation of the CTFC. Then we consider the dynamic resource allocation control (DRAC), which is used to dynamically change uplink data rates for the UEs in a cell in the CELL_DCH state.

11.8.1 CTFC calculation

The CTFC is used as an efficient method of signalling the TFC from the RNC to the UE. The definition and use of the TFC is considered in Chapter 8.

The TFCs are signalled to the UE using the CTFC. Here we examine the structure of the CTFC and how it is interpreted by the UE to form the TFC. The use of and operation of the CTFC are best considered via an example.

In the first instance, the quantity P_i is calculated for each of the transport channels in the TFCS from:

$$P_i = \prod_{j=0}^{i-1} L_j$$

Assume 3 transport channels $TFI_1 \in \{0, 1\}$, $TFI_2 \in \{0, 1, 2\}$, $_3TFI \in \{0, 1, 2, 3\}$

$$P_1 = L_0 = 1$$
$$P_2 = L_0 \times L_1 = 1 \times 2 = 2$$
$$P_3 = L_0 \times L_1 \times L_2 = 1 \times 2 \times 3 = 6$$

TFI_1	TFI_2	TFI_3	CTFC	TFCI
0	0	0	0x1 + 0x2 + 0x6 = 0	0
0	1	0	0x1 + 1x2 + 0x6 = 2	1
0	2	0	0x1 + 2x2 + 0x6 = 4	2
1	0	1	1x1 + 0x2 + 1x6 = 7	3
1	2	2	1x1 + 2x2 + 2x6 = 17	4
1	1	3	1x1 + 1x2 + 3x6 = 21	5
1	2	3	1x1 + 2x2 + 3x6 = 23	6
1	0	3	1x1 + 0x2 + 3x6 = 19	7

Figure 11.20 Calculation of CTFC.

where $j = 1, 2, \ldots, L$ and $L_0 = 1$. Next the CTFC for a specified transport channel format TFI_i is given by:

$$CTFC(TFI_1,\ TFI_2,\ TFI_3, TFI_4, \ldots TFI_I) = \sum_{i=1}^{I} TFI_i \cdot P_i$$

The example shown in Figure 11.20 illustrates the basic procedure associated with calculating the CTFC. Assume that there are three transport channels. The first has two TFs, the second has three TFs, and the third has four TFs. First we calculate the values for L_i, which is the number of TFs for transport channel i; L_0 is equal to 1. The values for P_i are calculated from the equations above and are illustrated in Figure 11.20, for different TFs. By using the equation presented earlier, it is possible to derive the CTFC for each combination.

The CTFC uniquely defines the specific TFC combination. It is the CTFC numbers that are signalled to the UE and which the UE uses when creating the TFCS.

11.8.2 DRAC procedure

DRAC of uplink DCH is used as a means to dynamically control the uplink load from one or several UEs. The use of the DRAC procedure is indicated to the UE by the presence of a static DRAC information element in the messages that establish or modify the dedicated channels. Part of the DRAC static information is the DRAC class that is assigned to the UE. The DRAC class is used as part of the selection of the TF in the operational phase of the DRAC procedure. The DRAC procedure is activated by the reception of a DRAC static information IE. This occurs during RB establishment, RB reconfiguration, RB release or transport channel reconfiguration.

Table 11.28. *Example TFCS table and the data rate calculation*

TFCI	DCH1	DCH2	DCH3	TOTAL	BIT RATE
0	0	0	0	0	0
1	0	100	0	100	10 kb/s
2	0	200	0	200	20 kb/s
3	200	0	200	400	40 kb/s
4	200	200	400	800	80 kb/s
5	200	100	800	1100	110 kb/s
6	200	200	800	1200	120 kb/s
7	200	0	800	1000	100 kb/s

DRAC is achieved by the UTRAN broadcasting a number of resource control parameters on the downlink SIB10 message transported using a SCCPCH. These parameters control how the uplink resources are allocated. The DRAC procedure is only valid for DCH transport channels configured to follow the DRAC procedures. In addition, it is only available to UEs that can support both a DPCH (physical channel that carries the DCH transport channels) and a SCCPCH (physical channel that transports the FACH transport channel).

The SIB10 message includes a TRANSMISSION_PROBABILITY parameter and a MAXIMUM_BIT_RATE parameter. TRANSMISSION_PROBABILITY has the range of 0.125–1 in steps of 0.125. MAXIMUM_BIT_RATE has a range of 0–512 kb/s with a step of 16 kb/s.

The DRAC procedure works as follows. The UE obtains a pair of parameters (transmission probability, maximum bit rate) from the SIB10 messages broadcast in each of the cells in the active set and selects the pair that has the lowest product. Having established the lowest set of quantities, this defines the transmission probability and the maximum bit rate to use for the remainder of the procedure.

In the next stage, the UE reduces the set of available TFCs. Only the TFCs whose data rate (summed over all DCHs contributing to the peak data rate) is less than the selected maximum bit rate will be included in the new set. Consider an example of the three DCHs defined in the previous section where we considered the CTFC, each with TTI of 10 ms:

- DCH1: {0, 200} bits per TTI
- DCH2: {0, 100, 200} bits per TTI
- DCH3: {0, 200, 400, 800} bits per TTI

Assume the same TFCS as per the CTFC example previously, and assume that the maximum bit rate is set at 96 kb/s. The peak bit rate is calculated for each TFC as shown in Table 11.28. As the maximum bit rate is set at 96 kb/s, TFCI1–TFCI4 are allowed in the new TFCS, but TFCI5–TFCI7 are not.

The dynamic part of the DRAC procedure proceeds as follows. It commences as soon as the SIB10 message is received by the UE. At the start of the next TTI, the UE randomly selects a parameter p from the range $\{0,1\}$. If p is less than the TRANSMISSION_PROBABILITY, then the UE can transmit with a TFC obtained from the new set of TFs. The transmission will occur for $T_{validity}$ frames, after which the process is repeated – starting with the selection of the random number. If the random number is greater than the transmission probability, the UE waits for a period of T_{retry} frames before starting the process again.

11.9 Summary

The RRC protocol is a large and complex protocol that provides for the configuration and control of the radio connections between the UE and the UTRAN. In this chapter we have reviewed some of the key aspects of the RRC protocol starting with the receipt of the initial system broadcast information, the establishment of RRC connections and RABS, and then moving on to look at issues such as handover.