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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

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1 Scope

The present document specifies the E-UTRA MAC protocol.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer Procedures".

[3] 3GPP TS 36.322: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification'.

[4] 3GPP TS 36.323: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) Specification'.

[5] 3GPP TS 36.212: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding'.

[6] 3GPP TS 36.214: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements'.

[7] 3GPP TS 36.211: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation'.

[8] 3GPP TS 36.331: 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification'.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

Active Time: time during which the UE monitors the PDCCH for a PDCCH-subframe. Section 5.7 defines the conditions for which a subframe is included as part of Active Time.

Contention Resolution Timer: Specifies the number of consecutive PDCCH-subframe(s) during which the UE shall monitor the PDCCH after the uplink message containing the C-RNTI MAC control element or the uplink message associated with UE Contention Resolution Identity submitted from higher layer is transmitted.

DRX Cycle: Specifies the periodic repetition of the On Duration followed by a possible period of inactivity (see figure 3.1-1 below).

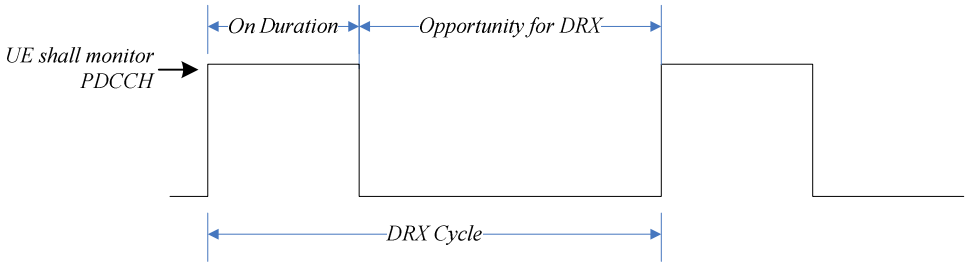

Figure 3.1-1: DRX Cycle

DRX Inactivity Timer: Specifies the number of consecutive PDCCH-subframe(s) after successfully decoding a PDCCH indicating an initial UL or DL user data transmission for this UE.

DRX Retransmission Timer: Specifies the maximum number of consecutive PDCCH-subframe(s) for as soon as a DL retransmission is expected by the UE.

DRX Short Cycle Timer: This parameter specifies the number of consecutive subframe(s)the UE shall follow the short DRX cycle after the DRX Inactivity Timer has expired.

HARQ information: HARQ information consists of New Data Indicator (NDI), Redundancy Version (RV), Transport Block (TB) size. For DL-SCH transmissions the HARQ info also includes HARQ process ID.

HARQ RTT Timer: This parameter specifies the minimum amount of subframe(s) before a DL HARQ retransmission is expected by the UE.

On Duration Timer: Specifies the number of consecutive PDCCH-subframe(s) at the beginning of a DRX Cycle.

RA-RNTI: The Random Access RNTI is used on the PDCCH when Random Access Response messages are transmitted. It unambiguously identifies which time-frequency resource was utilized by the UE to transmit the Random Access preamble.

PDCCH-subframe: For FDD UE operation, this represents any subframe; for TDD, only downlink subframes.

NOTE: A timer is running once it is started, until it is stopped or until it expires.

NOTE: When defining On Duration Timer, DRX Inactivity Timer, DRX Retransmission Timer and Contention Resolution Timer, PDCCH-subframes and subframes including DwPTS are considered as subframes where the timer, if running, shall be updated.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

BSR	Buffer Status Report
C-RNTI	Cell RNTI
CQI	Channel Quality Indicator
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
MAC	Medium Access Control
LCG	Logical Channel Group
PHR	Power Headroom Report
PMI	Precoding Matrix Index
P-RNTI	Paging RNTI
RA-RNTI	Random Access RNTI
RI	Rank Indicator
RNTI	Radio Network Temporary Identifier
SI-RNTI	System Information RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbols

TB Transport Block
TPC-PUCCH-RNTI Transmit Power Control-Physical Uplink Control Channel-RNTI
TPC-PUSCH-RNTI Transmit Power Control-Physical Uplink Shared Channel-RNTI

4 General

4.1 Introduction

The objective is to describe the MAC architecture and the MAC entity from a functional point of view.

4.2 MAC architecture

The description in this sub clause is a model and does not specify or restrict implementations.

RRC is in control of configuration of MAC.

4.2.1 MAC Entities

E-UTRA defines two MAC entities; one in the UE and one in the E-UTRAN. These MAC entities handle the following transport channels:

- Broadcast Channel (BCH);
- Downlink Shared Channel (DL-SCH);
- Paging Channel (PCH);
- Uplink Shared Channel (UL-SCH);
- Random Access Channel(s) (RACH).

The exact functions performed by the MAC entities are different in the UE from those performed in the E-UTRAN.

4.3 Services

4.3.1 Services provided to upper layers

This clause describes the different services provided by MAC sublayer to upper layers.

- data transfer
- radio resource allocation

4.3.2 Services expected from physical layer

The physical layer provides the following services to MAC:

- data transfer services;
- signalling of HARQ feedback;
- signalling of Scheduling Request;
- measurements (e.g. Channel Quality Indication (CQI)).

The access to the data transfer services is through the use of transport channels. The characteristics of a transport channel are defined by its transport format (or format set), specifying the physical layer processing to be applied to the

transport channel in question, such as channel coding and interleaving, and any service-specific rate matching as needed.

4.4 Functions

The following functions are supported by MAC sublayer:

- mapping between logical channels and transport channels;
- multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels;
- demultiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels;
- scheduling information reporting;
- error correction through HARQ;
- priority handling between UEs by means of dynamic scheduling;
- priority handling between logical channels of one UE;
- Logical Channel prioritisation;
- transport format selection.

NOTE: How the multiplexing relates to the QoS of the multiplexed logical channels is FFS.

The location of the different functions and their relevance for uplink and downlink respectively is illustrated in Table 4.4-1.

Table 4.4-1: MAC function location and link direction association.

MAC function	UE	eNB	Downlink	Uplink
Mapping between logical channels and transport channels	**X**		**X**	**X**
		X	**X**	**X**
Multiplexing	**X**			**X**
		X	**X**	
Demultiplexing	**X**		**X**	
		X		**X**
Error correction through HARQ	**X**		**X**	**X**
		X	**X**	**X**
Transport Format Selection		**X**	**X**	**X**
Priority handling between UEs		**X**	**X**	**X**
Priority handling between logical channels of one UE		**X**	**X**	**X**
Logical Channel prioritisation	**X**			**X**
Scheduling information reporting	**X**			**X**

4.5 Channel structure

The MAC sublayer operates on the channels defined below; transport channels are SAPs between MAC and Layer 1, logical channels are SAPs between MAC and RLC.

4.5.1 Transport Channels

The transport channels used by MAC are described in Table 4.5.1-1 below.

Table 4.5.1-1: Transport channels used by MAC

Transport channel name	Acronym	Downlink	Uplink
Broadcast Channel	**BCH**	**X**	
Downlink Shared Channel	**DL-SCH**	**X**	
Paging Channel	**PCH**	**X**	
Uplink Shared Channel	**UL-SCH**		**X**
Random Access Channel	**RACH**		**X**

4.5.2 Logical Channels

The MAC layer provides data transfer services on logical channels. A set of logical channel types is defined for different kinds of data transfer services as offered by MAC.

Each logical channel type is defined by what type of information is transferred.

MAC provides the control and traffic channels listed in Table 4.5.2-1 below. When MAC uses the PDCCH to indicate radio resource allocation, the RNTI that is mapped on the PDCCH depends on the logical channel type:

- C-RNTI, Temporary C-RNTI and Semi-Persistent Scheduling C-RNTI for DCCH and DTCH;
- P-RNTI for PCCH;
- RA-RNTI for Random Access Response on DL-SCH;
- Temporary C-RNTI for CCCH during the random access procedure;
- SI-RNTI for BCCH.

Table 4.5.2-1: Logical channels provided by MAC.

Logical channel name	Acronym	Control channel	Traffic channel
Broadcast Control Channel	**BCCH**	**X**	
Paging Control Channel	**PCCH**	**X**	
Common Control Channel	**CCCH**	**X**	
Dedicated Control Channel	**DCCH**	**X**	
Dedicated Traffic Channel	**DTCH**		**X**

4.5.3 Mapping of Transport Channels to Logical Channels

The mapping of logical channels on transport channels depends on the multiplexing that is configured by RRC.

4.5.3.1 Uplink mapping

The MAC entity is responsible for mapping logical channels for the uplink onto uplink transport channels. The uplink logical channels can be mapped as described in Figure 4.5.3.1-1 and Table 4.5.3.1-1.

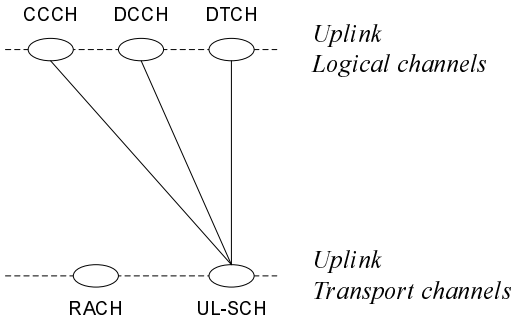

Figure 4.5.3.1-1

Table 4.5.3.1-1: Uplink channel mapping.

Logical channel \ Transport channel	UL-SCH	RACH
CCCH	**X**	
DCCH	**X**	
DTCH	**X**	

4.5.3.2 Downlink mapping

The MAC entity is responsible for mapping the downlink logical channels to downlink transport channels. The downlink logical channels can be mapped as described in Figure 4.5.3.2-1 and Table 4.5.3.2-1.

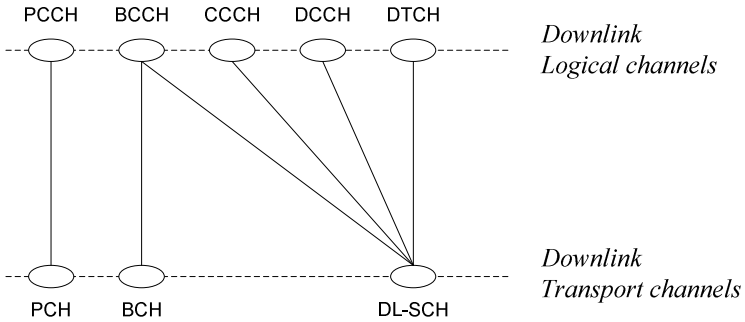

Figure 4.5.3.2-1

Table 4.5.3.2-1: Downlink channel mapping.

Logical channel \ Transport channel	BCH	PCH	DL-SCH
BCCH	**X**		**X**
PCCH		**X**	
CCCH			**X**
DCCH			**X**
DTCH			**X**

5 MAC procedures

5.1 Random Access procedure

5.1.1 Random Access Procedure initialization

The Random Access procedure described in this subclause is initiated by a PDCCH order or by the MAC sublayer itself. The PDCCH order or RRC optionally indicate a Random Access Preamble and PRACH resource.

Before the procedure can be initiated, the following information is assumed to be available:

- the available set of PRACH resources for the transmission of the Random Access Preamble and their corresponding RA-RNTIs.
- the groups of Random Access Preambles and the set of available Random Access Preambles in each group:

  The preambles that are contained in Random Access Preambles group A and Random Access Preambles group B are calculated from the parameters *numberOfRA-Preambles* and *sizeOfRA-PreamblesGroupA* [8]:

  If *sizeOfRA-PreamblesGroupA* is equal to *numberOfRA-Preambles* then there is no Random Access Preambles group B. The preambles in Random Access Preamble group A are the preambles 1 to *sizeOfRA-PreamblesGroupA* and, if it exists, the preambles in Random Access Preamble group B are the preambles *sizeOfRA-PreamblesGroupA* +1 to *numberOfRA-Preambles* from the set of 64 preambles as defined in [7].
- the thresholds, PARTITION_PATHLOSS_THRESHOLD and MESSAGE_SIZE_GROUP_A, that are required for selecting one of the two groups of Random Access Preambles.
- the RA response window size *ra-ResponseWindowSize* [8].
- the power-ramping factor POWER_RAMP_STEP.
- the parameter PREAMBLE_TRANS_MAX [integer > 0].
- the initial preamble power PREAMBLE_ INITIAL_RECEIVED_TARGET_POWER.
- the parameter Maximum number of Message3 HARQ transmissions.

[Note that the above parameters may be updated from higher layers before each Random Access procedure is initiated.]

The Random Access procedure shall be performed as follows:

- Flush the [Message3] buffer;
- set the PREAMBLE_TRANSMISSION_COUNTER to 1;
- set the backoff parameter value in the UE to 0 ms;
- proceed to the selection of the Random Access Resource (see subclause 5.1.2).

NOTE: There is only one Random Access procedure ongoing at any point in time. If the UE receives a request for a new Random Access procedure while another is already ongoing, it is up to UE implementation whether to continue with the ongoing procedure or start with the new procedure.

5.1.2 Random Access Resource selection

The Random Access Resource procedure shall be performed as follows:

- If the Random Access Preamble and PRACH resource have been explicitly signalled:
  - the UE can directly proceed to the transmission of the Random Access Preamble (see subclause 5.1.3).
- else the Random Access Preamble shall be selected by the UE as follows:

- If the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU has not yet been transmitted, the UE shall:
  - if Random Access Preambles group B exists and if the potential message size (data available for transmission plus MAC header and, where required, MAC control elements) is greater than MESSAGE_SIZE_GROUP_A and if the pathloss is less than PARTITION_PATHLOSS_THRESHOLD then:
    - select the Random Access Preambles group B;
  - else:
    - select the Random Access Preambles group A.
- else, if the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU is being retransmitted, the UE shall:
  - select the same group of Random Access Preambles as was used for the preamble transmission attempt corresponding to the first transmission of the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU.
- randomly select a Random Access Preamble within the selected group. The random function shall be such that each of the allowed selections can be chosen with equal probability;
- if more than one PRACH resources are available in the same subframe (TDD), randomly select one. The random function shall be such that each of the allowed selections can be chosen with equal probability;
- proceed to the transmission of the Random Access Preamble (see subclause 5.1.3).

5.1.3 Random Access Preamble transmission

The random-access procedure shall be performed as follows:

- If PREAMBLE_TRANSMISSION_COUNTER = PREAMBLE_TRANS_MAX + 1:
  - indicate a Random Access problem to upper layers.

[- set the parameter PREAMBLE_RECEIVED_TARGET_POWER to PREAMBLE_INITIAL_RECEIVED_TARGET_POWER + (PREAMBLE_TRANSMISSION_COUNTER-1) * POWER_RAMP_STEP;]

- determine the next available Random Access occasion (a UE may take into account the possible occurrence of measurement gaps when determining the next available Random Access occasion);
- instruct the physical layer to transmit a preamble using the selected PRACH resource, corresponding RA-RNTI, preamble index and PREAMBLE_RECEIVED_TARGET_POWER.

5.1.4 Random Access Response reception

Once the Random Access Preamble is transmitted and regardless of the possible occurrence of a measurement gap, the UE shall monitor the PDCCH for Random Access Response(s) identified by the RA-RNTI defined below, in the TTI window RA_WINDOW_BEGIN—RA_WINDOW_END which starts at the subframe that contains the end of the preamble transmission [7] plus three subframes and has length *ra-ResponseWindowSize* subframes. The RA-RNTI associated with the PRACH resource in which the Random Access Preamble is transmitted, is computed as:

$$\text{RA-RNTI} = t\_id + 10 * f\_id$$

Where t_id is the index of the first subframe of the specified PRACH resource ($0 \leq t\_id < 10$), and f_id is the index of the specified PRACH resource within that subframe, in ascending order of frequency domain ($0 \leq f\_id < 6$). The UE may stop monitoring for Random Access Response(s) after successful reception of a Random Access Response corresponding to the Random Access Preamble transmission.

- If a downlink assignment for this TTI has been received on the PDCCH for the RA-RNTI and the received TB is successfully decoded, the UE shall regardless of the possible occurrence of a measurement gap:

- if the Random Access Response contains a Backoff Indicator subheader:
  - set the backoff parameter value in the UE as indicated by the BI field of the Backoff Indicator subheader and Table 7.2-1.
- else, set the backoff parameter value in the UE to 0 ms.
- if the Random Access Response contains a Random Access Preamble identifier corresponding to the transmitted Random Access Preamble (see subclause 5.1.3), the UE shall:
  - consider this Random Access Response reception successful;
  - process the received Timing Alignment value (see subclause 5.2);
  - process the received UL grant value and indicate it to the lower layers;
  - if the Random Access Preamble was explicitly signalled (i.e., not selected by MAC):
    - consider the Random Access procedure successfully completed.
  - else, if the Random Access Preamble was selected by UE MAC:
    - set the Temporary C-RNTI to the value received in the Random Access Response message no later than at the time of the first transmission corresponding to the UL grant provided in the Random Access Response message;
    - if this is the first successfully received Random Access Response within this Random Access procedure:
      - if the transmission is not being made for the CCCH logical channel, indicate to the Multiplexing and assembly entity to include a C-RNTI MAC control element in the subsequent uplink transmission;
      - obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity and store it in the [Message3] buffer.

NOTE: When an uplink transmission is required, e.g., for contention resolution, the eNB should not provide a grant smaller than 80 bits in the Random Access Response.

NOTE: If within a Random Access procedure, an uplink grant provided in the Random Access Response for the same group of Random Access Preambles has a different size than the first uplink grant allocated during that Random Access procedure, the UE behavior is not defined.

If no Random Access Response is received within the TTI window [RA_WINDOW_BEGIN—RA_WINDOW_END], or if all received Random Access Responses contain Random Access Preamble identifiers that do not match the transmitted Random Access Preamble, the Random Access Response reception is considered not successful and the UE shall:

- if the Random Access procedure was initiated by the MAC sublayer itself; or
- if the Random Access procedure was initiated by a PDCCH order and the PREAMBLE_TRANSMISSION_COUNTER is less than PREAMBLE_TRANS_MAX:
  - increment PREAMBLE_TRANSMISSION_COUNTER by 1;
  - if in this Random Access procedure:
    - the Random Access Preamble was selected by MAC:
      - based on the backoff parameter in the UE, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value;
      - delay the subsequent Random Access transmission by the backoff time;
  - proceed to the selection of a Random Access Resource (see subclause 5.1.2).

Editor"s note: Whether error conditions are specified is FFS.

5.1.5 Contention Resolution

Contention Resolution is based on C-RNTI on PDCCH and UE Contention Resolution Identity on DL-SCH.

Once the uplink message containing the C-RNTI MAC control element or the uplink message including the CCCH SDU is transmitted, the UE shall:

- start the Contention Resolution Timer;
- regardless of the possible occurrence of a measurement gap, monitor the PDCCH until the Contention Resolution Timer expires;
- if notification of a reception of a PDCCH transmission is received from lower layers, the UE shall:
  - if the C-RNTI MAC control element was included in uplink message:
    - if the Random Access procedure was initiated by the MAC sublayer itself and the PDCCH transmission is addressed to the C-RNTI and contains an UL grant; or
    - if the Random Access procedure was initiated by a PDCCH order and the PDCCH transmission is addressed to the C-RNTI:
      - consider this Contention Resolution successful;
      - stop the Contention Resolution Timer;
      - discard the Temporary C-RNTI;
      - consider this Random Access procedure successfully completed.
  - else if the uplink message included the CCCH SDU and the PDCCH transmission is addressed to its Temporary C-RNTI:
    - if the MAC PDU is successfully decoded:
      - stop the Contention Resolution Timer;
      - if the MAC PDU contains a UE Contention Resolution Identity MAC control element; and
      - if the UE Contention Resolution Identity included in the MAC control element matches the CCCH SDU transmitted in the uplink message:
        - consider this Contention Resolution successful and finish the disassembly and demultiplexing of the MAC PDU;
        - set the C-RNTI to the value of the Temporary C-RNTI;
        - consider this Random Access procedure successfully completed.
      - else
        - consider this Contention Resolution not successful and discard the successfully decoded MAC PDU.
      - discard the Temporary C-RNTI.
- if the Contention Resolution Timer expires:
  - consider the Contention Resolution not successful.
- if the Contention Resolution is considered not successful the UE shall:
  - if the Random Access procedure was initiated by the MAC sublayer itself; or
  - if the Random Access procedure was initiated by a PDCCH order and the PREAMBLE_TRANSMISSION_COUNTER is less than PREAMBLE_TRANS_MAX:
    - increment PREAMBLE_TRANSMISSION_COUNTER by 1;

- based on the backoff parameter in the UE, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value;
- delay the subsequent Random Access transmission by the backoff time;
- proceed to the selection of a Random Access Resource (see subclause 5.1.2).

- discard the Temporary C-RNTI.

5.1.6 Completion of the Random Access procedure

At successful completion of the Random Access procedure, the UE shall:

- flush the HARQ buffer used for transmission of the MAC PDU in the [Message3] buffer and consider the next transmission for this process as the very first transmission;
- if the PREAMBLE_TRANSMISSION_COUNTER is greater than PREAMBLE_TRANS_MAX:
  - indicate recovery from a Random Access problem to upper layers.

5.2 Maintenance of Uplink Time Alignment

The UE has a configurable Time Alignment Timer. The Time Alignment Timer is valid only in the cell for which it was configured and started.

If the Time Alignment Timer has been configured, the UE shall:

- when a Timing Advance MAC control element is received:
  - apply the Timing Advance Command;
  - start the Time Alignment Timer (if not running) or restart the Time Alignment Timer (if already running).
- when a Time Alignment Command is received in a Random Access Response message:
  - if the Random Access Preamble and PRACH resource were explicitly signalled:
    - apply the Time Alignment Command;
    - start the Time Alignment Timer (if not running) or restart the Time Alignment Timer (if already running).
  - else, if the Time Alignment Timer is not running or has expired:
    - apply the Time Alignment Command;
    - start the Time Alignment Timer;
    - when the contention resolution is considered not successful as described in subclause 5.1.5, stop the Time Alignment Timer.
  - else:
    - ignore the received Time Alignment Command.
- when the Time Alignment Timer has expired or is not running:
  - prior to any uplink transmission, use the Random Access procedure (see subclause 5.1) in order to obtain uplink Time Alignment.
- when the Time Alignment Timer expires:
  - flush all HARQ buffers and consider the next transmission for each process as the very first transmission;
  - release all PUCCH resources;
  - release any assigned SRS resources.

5.3 DL-SCH data transfer

Editor"s note: Current text applies to, at least, FDD.

5.3.1 DL Assignment reception

Downlink assignments transmitted on the PDCCH indicate if there is a transmission on the DL-SCH for a particular UE and provide the relevant HARQ information.

When the UE has a C-RNTI, Semi-Persistent Scheduling C-RNTI, or Temporary C-RNTI, the UE shall for each TTI during Active Time, for each TTI when a Random Access Response or Contention Resolution is expected and for each TTI for which a DL assignment has been configured:

- if a downlink assignment for this TTI has been received on the PDCCH for the UE"s C-RNTI, or Temporary C-RNTI:
  - indicate the presence of a downlink assignment and deliver the associated HARQ information to the HARQ entity for this TTI.
- else, if a downlink assignment for this TTI has been received on the PDCCH for the UE"s Semi-Persistent Scheduling C-RNTI:
  - if the NDI in the received HARQ information is 1:
    - consider the NDI not to have been toggled;
    - indicate a downlink assignment and the associated HARQ information to the HARQ entity for this TTI.
  - else, if the NDI in the received HARQ information is 0:
    - store the downlink assignment and the associated HARQ information as configured downlink assignment;
    - initialise (if not active) or re-initialise (if already active) the configured downlink assignment to start in this TTI and to recur with the periodicity configured via RRC;
    - set the HARQ Process ID to [the HARQ Process ID associated with this TTI];
    - consider the NDI bit to have been toggled;
    - indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.
- else, if [PDCCH condition for deactivation of SPS]:
  - clear the configured downlink assignment (if any).
- else, if a downlink assignment for this TTI has been configured:
  - instruct the physical layer to receive, in this TTI, transport(s) block on the DL-SCH according to the configured downlink assignment and to deliver it to the HARQ entity;
  - set the HARQ Process ID to [the HARQ Process ID associated with this TTI];
  - consider the NDI bit to have been toggled;
  - indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.

When the UE needs to read BCCH, the UE shall:

- if a downlink assignment for this TTI has been received on the PDCCH for the SI-RNTI;
  - indicate a downlink assignment for the dedicated broadcast HARQ process to the HARQ entity for this TTI.

NOTE: Downlink assignments for both C-RNTI and SI-RNTI can be received in the same TTI.

Editor"s note: L1 is configured, as needed, by upper layers or MAC [FFS] to monitor PDCCH for C-RNTI, and by MAC to monitor PDCCH for Temporary C-RNTI and RA-RNTI.

5.3.2 HARQ operation

5.3.2.1 HARQ Entity

There is one HARQ entity at the UE which maintains a number of parallel HARQ processes. Each HARQ process is associated with a HARQ process identifier. The HARQ entity directs HARQ information and associated TBs received on the DL-SCH to the corresponding HARQ processes (see subclause 5.3.2.2).

The number of DL HARQ processes and softbuffers are specified in [5], subclause 5.1.4.1.2.

When the physical layer is configured for spatial multiplexing [2], one or two TBs are expected per subframe. Otherwise, one TB is expected per subframe.

The UE shall:

- If a downlink assignment has been indicated for this TTI:
  - allocate the TBs received from the physical layer and the associated HARQ information to the HARQ processes indicated by the associated HARQ information.
- If a downlink assignment has been indicated for the broadcast HARQ process:
  - allocate the received TB to the broadcast HARQ process.

NOTE: In case of BCCH a dedicated broadcast HARQ process is used.

5.3.2.2 HARQ process

For each received TB and associated HARQ information, the HARQ process shall:

- if the NDI, when provided, has been toggled compared to the value of the previous received transmission for this HARQ process; or
- if the HARQ process is equal to the broadcast process and the physical layer indicates a new transmission; or
- if this is the very first received transmission for this HARQ process:
  - replace the data currently in the soft buffer for this HARQ process with the received data.
- else:
  - if the data has not yet been successfully decoded:
    - combine the received data with the data currently in the soft buffer for this HARQ process.
  - if the TB size is different from the last valid TB size signalled for this HARQ process:
    - the UE may replace the data currently in the soft buffer for this HARQ process with the received data.
- attempt to decode the data in the soft buffer;
- if the data in the soft buffer was successfully decoded:
  - if the HARQ process is equal to the broadcast process:
    - deliver the decoded MAC PDU to RRC.
  - else:
    - deliver the decoded MAC PDU to the disassembly and demultiplexing entity.
  - generate a positive acknowledgement (ACK) of the data in this HARQ process.

- else:
  - generate a negative acknowledgement (NACK) of the data in this HARQ process.
- if the HARQ process is associated with a transmission indicated with a Temporary C-RNTI and the Contention Resolution is not successful (see subclause 5.1.5); or
- if the HARQ process is equal to the broadcast process; or
- if there is a measurement gap at the time of the transmission of the HARQ feedback:
  - do not indicate the generated positive or negative acknowledgement to the physical layer.
- else:
  - indicate the generated positive or negative acknowledgement to the physical layer.

5.3.3 Disassembly and demultiplexing

Editor"s note: This section describes the disassembly and demultiplexing of MAC PDUs into MAC SDUs.

5.4 UL-SCH data transfer

Editor"s note: Current text applies to, at least, FDD.

5.4.1 UL Grant reception

In order to transmit on the UL-SCH the UE must have a valid uplink grant (except for non-adaptive HARQ retransmissions) which it may receive dynamically on the PDCCH or in a Random Access Response or which may be configured semi-persistently. To perform requested transmissions, the MAC layer receives HARQ information from lower layers.

When the UE has a C-RNTI, Semi-Persistent Scheduling C-RNTI, or Temporary C-RNTI, the UE shall for each TTI:

- if an uplink grant for this TTI has been received on the PDCCH for the UE"s C-RNTI or Temporary C-RNTI; or
- if an uplink grant for this TTI has been received in a Random Access Response:
  - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if an uplink grant for this TTI has been received on the PDCCH for the UE"s Semi-Persistent C-RNTI:
  - if the NDI in the received HARQ information is 1:
    - consider the NDI not to have been toggled;
    - indicate a valid uplink grant and the associated HARQ information to the HARQ entity for this TTI.
  - else if the NDI in the received HARQ information is 0:
    - store the uplink grant and the associated HARQ information as configured uplink grant;
    - initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI and to recur with the periodicity configured via RRC;
    - consider the NDI bit to have been toggled;
    - indicate a configured uplink grant, valid for new transmission, and the associated HARQ information to the HARQ entity for this TTI.
- else, if [PDCCH condition for deactivation of SPS]:
  - clear the configured uplink grant (if any).
- else, if an uplink grant for this TTI has been configured:

- consider the NDI bit to have been toggled;
- deliver the configured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

NOTE: The period of configured uplink grants is expressed in TTIs.

NOTE: If the UE receives both a grant for its RA-RNTI and a grant for its C-RNTI, the UE may choose to continue with either the grant for its RA-RNTI or the grant for its C-RNTI.

5.4.2 HARQ operation

5.4.2.1 HARQ entity

There is one HARQ entity at the UE, which maintains a number of parallel HARQ processes allowing transmissions to take place continuously while waiting for the feedback on the successful or unsuccessful reception of previous transmissions.

The number of parallel HARQ processes is specified in [2], clause 8.

At a given TTI, if an uplink grant is indicated for the TTI, the HARQ entity identifies the HARQ process for which a transmission should take place. It also routes the received feedback (ACK/NACK information), MCS and resource, relayed by the physical layer, to the appropriate HARQ process.

If TTI bundling is configured, the parameter TTI_BUNDLE_SIZE provides the number of TTIs of a TTI bundle. Within a bundle HARQ retransmissions are non-adaptive and shall be performed without waiting for feedback from previous transmissions according to TTI_BUNDLE_SIZE. The feedback for a bundle is only received for the TTI corresponding to TTI_BUNDLE_SIZE. A retransmission of a TTI bundle is also a TTI bundle.

For transmission of an uplink message containing the C-RNTI MAC control element or an uplink message including a CCCH SDU during Random Access (see section 5.1.5) TTI bundling does not apply.

For each TTI, the HARQ entity shall:

- identify the HARQ process associated with this TTI;
- if an uplink grant has been indicated for this TTI:
  - if the received grant was not addressed to a Temporary C-RNTI on PDCCH and if the NDI provided in the associated HARQ information has been toggled compared to the value in the previous transmission of this HARQ process; or
  - if this is the very first transmission for this HARQ process (i.e. , no previous NDI is available); or
  - if the uplink grant was received in a Random Access Response:
    - if there is an ongoing Random Access procedure and there is a MAC PDU in the [Message3] buffer:
      - obtain the MAC PDU to transmit from the [Message3] buffer.
    - else:
      - obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity;
    - deliver the MAC PDU and the uplink grant and the HARQ information to the identified HARQ process;
    - instruct the identified HARQ process to trigger a new transmission.
  - else:
    - deliver the uplink grant and the HARQ information (redundancy version) to the identified HARQ process;
    - instruct the identified HARQ process to generate an adaptive retransmission.
- else, if the HARQ buffer of the HARQ process corresponding to this TTI is not empty:

- instruct the identified HARQ process to generate a non-adaptive retransmission.

When determining if NDI has been incremented compared to the value in the previous transmission UE shall ignore NDI received in all uplink grants on PDCCH for its Temporary C-RNTI.

NOTE: A retransmission triggered by the HARQ entity should be cancelled by the corresponding HARQ process if it collides with a measurement gap or if a non-adaptive retransmission is not allowed.

5.4.2.2 HARQ process

Each HARQ process is associated with a HARQ buffer.

Each HARQ process shall maintain a state variable CURRENT_TX_NB, which indicates the number of transmissions that have taken place for the MAC PDU currently in the buffer. When the HARQ process is established, CURRENT_TX_NB shall be initialized to 0.

The sequence of redundancy versions is 0, 2, 3, 1. The variable CURRENT_IRV is an index into the sequence of redundancy versions. This variable is up-dated modulo 4.

New transmissions and adaptive retransmissions are performed on the resource and with the MCS indicated on PDCCH, while a non-adaptive retransmission is performed on the same resource and with the same MCS as was used for the last made transmission attempt,

The UE is configured with a Maximum number of HARQ transmissions and a Maximum number of Message3 HARQ transmissions by RRC. For transmissions on all HARQ processes and all logical channels except for transmission of a MAC PDU stored in the [Message3] buffer, maximum number of transmissions shall be set to Maximum number of HARQ transmissions. For transmission of a MAC PDU stored in the [Message3] buffer, maximum number of transmissions shall be set to Maximum number of Message3 HARQ transmissions.

If the HARQ entity requests a new transmission, the HARQ process shall:

- set CURRENT_TX_NB to 0;
- set CURRENT_IRV to 0;
- store the MAC PDU in the associated HARQ buffer;
- store the uplink grant received from the HARQ entity;
- if there is no measurement gap at the time of the transmission or if the MAC PDU was obtained from the [Message3] buffer:
  - generate a transmission as described below.

If the HARQ entity requests a retransmission, the HARQ process shall:

- increment CURRENT_TX_NB by 1;
- if there is no measurement gap at the time of the retransmission:
  - if the HARQ entity requests an adaptive retransmission:
    - store the uplink grant received from the HARQ entity;
    - set CURRENT_IRV to the value provided in the HARQ information;
    - generate a transmission as described below.
  - else if the HARQ entity requests a non-adaptive retransmission:
    - if TTI bundling is not configured and the last received feedback for this HARQ process is a HARQ NACK; or

- if TTI bundling is configured and CURRENT_TX_NB modulo TTI_BUNDLE_SIZE = 0 and the last received feedback for this HARQ process is a HARQ NACK; or
- if TTI bundling is configured and CURRENT_TX_NB modulo TTI_BUNDLE_SIZE != 0:
  - generate a transmission as described below.

NOTE: When receiving a HARQ ACK alone, the UE keeps the data in the HARQ buffer.

NOTE: When a non-adaptive retransmission does not take place due to the occurrence of a measurement gap, the last received HARQ feedback for this HARQ process is the the feedback corresponding to the preceding transmission.

To generate a transmission, the HARQ process shall:

- instruct the physical layer to generate a transmission according to the stored uplink grant with the redundancy version corresponding to the CURRENT_IRV value;
- increment CURRENT_IRV by 1;
- if there is a measurement gap at the time of the feedback reception for this transmission, consider the feedback coinciding with the measurement gap to be a HARQ ACK i.e the "last received feedback" for a retransmission of this HARQ process will be considered as a HARQ ACK.

The HARQ process shall:

- if CURRENT_TX_NB = maximum number of transmissions - 1:
  - flush the HARQ buffer;

The HARQ process may:

- if CURRENT_TX_NB = maximum number of transmissions - 1; and
  - if the last feedback received (i.e., the feedback received for the last transmission of this process) is a HARQ NACK except for the transmission of a MAC PDU stored in the [Message3] buffer:
    - notify the relevant ARQ entities in the upper layer that the transmission of the corresponding RLC PDUs failed.

5.4.3 Multiplexing and assembly

Editor"s note: This subclause describes the procedure for creation of MAC SDUs including multiplexing of MAC SDUs and creating the MAC header.

5.4.3.1 Logical channel prioritization

The Logical Channel Prioritization procedure is applied when a new transmission is performed.

RRC can control the scheduling of uplink data by giving each logical channel a priority where increasing priority values indicate lower priority levels. In addition, each logical channel is given a Prioritized Bit Rate (PBR).

The UE shall maintain a variable Bj for each logical channel j. Bj shall be initialized to zero, and incremented by PBR of the logical channel j for each TTI. However, the value of Bj can never exceed the bucket size and if the value of Bj is larger than the bucket size of logical channel j, it shall be set to the bucket size.

The UE shall perform the following Logical Channel Prioritization procedure when a new transmission is performed:

- The UE shall allocate resources to the logical channels in the following steps:

- Step 1: All the logical channels with Bj > 0 are allocated resources in a decreasing priority order. If the PBR of a radio bearer is set to 'infinity', the UE shall allocate resources for all the data that is available for transmission on the radio bearer before meeting the PBR of the lower priority radio bearer(s);

- Step 2: the UE shall decrement Bj by the amount of data served to logical channel j in Step 1

NOTE: The value of Bj can be negative.

- Step 3: if any resources remain, all the logical channels are served in a strict decreasing priority order (regardless of the value of Bj) until either the data for that logical channel or the UL grant is exhausted, whichever comes first.

- The UE shall also follow the rules below during the scheduling procedures above:

  - the UE should not segment an RLC SDU (or partially transmitted SDU or retransmitted RLC PDU) if the whole SDU (or partially transmitted SDU or retransmitted RLC PDU) fits into the remaining resources;

  - if the UE segments an RLC SDU from the logical channel, it shall maximize the size of the segment to fill the grant as much as possible;

  - UE should maximise the transmission of data.

Logical channels configured with the same priority shall be served equally by the UE.

MAC control elements for BSR, with exception of Padding BSR, have higher priority than U-plane Logical Channels.

At serving cell change, the first UL-DCCH MAC SDU to be transmitted in the new cell has higher priority than MAC control elements for BSR.

5.4.3.2 Multiplexing of MAC SDUs

Editor"s note: This subclause describes the construction of MAC PDUs from MAC SDUs as prioritised and selected by the Logical channel prioritisation entity.

5.4.4 Scheduling Request

The Scheduling Request (SR) is for requesting UL-SCH resources.

If an SR has been triggered, the UE shall for each TTI, until UL-SCH resources are granted for a new transmission:

- if no UL-SCH resources are available in this TTI:

  - if a PUCCH is configured for the UE to send an SR in this TTI and if there is no measurement gap in this TTI, instruct the physical layer to signal the SR on PUCCH;

  - if no PUCCH for SR is configured for the UE in any TTI, initiate a Random Access procedure (see subclause 5.1).

NOTE: A triggered SR is considered pending and is repeated until UL-SCH resources are granted for a new transmission.

5.4.5 Buffer Status Reporting

The Buffer Status reporting procedure is used to provide the serving eNB with information about the amount of data in the UL buffers of the UE.

A Buffer Status Report (BSR) shall be triggered if any of the following events occur:

- UL data becomes available for transmission in the RLC entity or in the PDCP entity (the definition of what data shall be considered as available for transmission is specified in [3] and [4] respectively) and the data belongs to a logical channel with higher priority than those for which data already existed in the UE transmission buffer, in which case the BSR is referred below to as 'Regular BSR';

- UL resources are allocated and number of padding bits is equal to or larger than the size of the Buffer Status Report MAC control element, in which case the BSR is referred below to as 'Padding BSR';

- a serving cell change occurs, in which case the BSR is referred below to as 'Regular BSR';

- the PERIODIC BSR TIMER expires, in which case the BSR is referred below to as 'Periodic BSR'.

For Regular and Periodic BSR:

- if only one LCG has data available for transmission in the TTI where the BSR is transmitted: report Short BSR;

- else if more than one LCG has data available for transmission in the TTI where the BSR is transmitted: report Long BSR.

For Padding BSR:

- if the number of padding bits is equal to or larger than the size of the Short BSR plus its subheader but smaller than the size of the Long BSR plus its subheader:

  - if more than one LCG has buffered data in the TTI where the BSR is transmitted: report Truncated BSR of the LCG with the highest priority logical channel with data available for transmission;

  - else report Short BSR.

- else if the number of padding bits is equal to or larger than the size of the Long BSR plus its subheader, report Long BSR.

If the Buffer Status reporting procedure determines that a BSR has been triggered since the last transmission of a BSR or this is the first time that a BSR is triggered:

- if the UE has UL resources allocated for new transmission for this TTI:

  - instruct the Multiplexing and Assembly procedure to generate a BSR MAC control element;

  - start/restart the PERIODIC BSR TIMER.

- else if a Regular BSR has been triggered:

  - a Scheduling Request shall be triggered.

NOTE: Even if multiple events occur by the time a BSR can be transmitted, only one BSR will be included in the MAC PDU.

A pending BSR shall be cancelled in case the UL grant can accommodate all pending data available for transmission but is not sufficient to additionally accommodate the BSR MAC control element.

5.4.6 Power Headroom Reporting

The Power Headroom reporting procedure is used to provide the serving eNB with information about the difference between the UE TX power and the maximum UE TX power (for the positive values of the power headroom) and about the difference between the maximum UE TX power and the calculated UE TX power, according to the UL power control formula, when it exceeds the maximum UE TX power (for the negative values of the power headroom).

A Power Headroom Report (PHR) shall be triggered if any of the following events occur:

- the PROHIBIT_PHR_TIMER expires or has expired and the path loss has changed more than *DL_PathlossChange* dB since the last power headroom report;

- the PERIODIC PHR TIMER expires, in which case the PHR is referred below to as 'Periodic PHR';

- upon configuration and reconfiguration of a Periodic PHR.

If the Power Headroom reporting procedure determines that a PHR has been triggered since the last transmission of a PHR:

- if the UE has UL resources allocated for new transmission for this TTI:

- obtain the value of the power headroom from the physical layer;
- instruct the Multiplexing and Assembly procedure to generate a PHR MAC control element based on the value reported by the physical layer;
- if the PHR is a 'Periodic PHR', restart the PERIODIC PHR TIMER;
- restart the PROHIBIT_PHR_TIMER.

NOTE: Even if multiple events occur by the time a PHR can be transmitted, only one PHR is included in the MAC PDU.

5.5 PCH reception

When in RRC_IDLE, the UE shall at its paging occasions:

- if a PCH assignment has been received on the PDCCH for the P-RNTI:
  - attempt to decode the TB on the PCH as indicated by the PDCCH information.
- if a TB on the PCH has been successfully decoded:
  - deliver the decoded MAC PDU to higher layers.

5.6 BCH reception

When the UE needs to receive BCH, the UE shall:

- receive and attempt to decode the BCH;
- if a TB on the BCH has been successfully decoded:
  - deliver the decoded MAC PDU to higher layers.

5.7 Discontinuous Reception (DRX)

The UE may be configured by RRC with a DRX functionality that allows it to monitor the PDCCH discontinuously. DRX operation is based on a Long DRX cycle, a DRX Inactivity Timer, a HARQ RTT Timer, a DRX Retransmission Timer and optionally a Short DRX Cycle and a DRX Short Cycle Timer, all defined in subclause 3.1.

When a DRX cycle is configured, the Active Time includes the time while:

- the On Duration Timer or the DRX Inactivity Timer or a DRX Retransmission Timer or the Contention Resolution Timer (as described in subclause 5.1.5) is running; or
- a Scheduling Request is pending (as described in subclause 5.4.4); or
- an uplink grant for a pending HARQ retransmission can occur; or
- a PDCCH indicating a new transmission addressed to the C-RNTI or Temporary C-RNTI of the UE has not been received after successful reception of a Random Access Response (as described in subclause 5.1.4).

When DRX is configured, the UE shall for each subframe:

- If the Short DRX Cycle is used and [(SFN * 10) + subframe number] modulo (Short DRX Cycle) = DRX Start Offset; or
- if the Long DRX Cycle is used and [(SFN * 10) + subframe number] modulo (Long DRX Cycle) = DRX Start Offset:
  - start the On Duration Timer.

- if a HARQ RTT Timer expires in this subframe and the data in the soft buffer of the corresponding HARQ process was not successfully decoded:
  - start the DRX Retransmission Timer for the corresponding HARQ process.
- if a DRX Command MAC control element is received:
  - stop the On Duration Timer;
  - stop the DRX Inactivity Timer.
- if the DRX Inactivity Timer expires or a DRX Command MAC control element is received in this subframe:
  - if the short DRX cycle is configured:
    - start or restart the DRX Short Cycle Timer;
    - use the Short DRX Cycle.
  - else:
    - use the Long DRX cycle.
- if the DRX Short Cycle Timer expires in this subframe:
  - use the long DRX cycle.
- during the Active Time, for a PDCCH-subframe except if the subframe is required for uplink transmission for half-duplex FDD UE operation and except if the subframe is part of a configured measurement gap:
  - monitor the PDCCH;
  - if the PDCCH indicates a DL transmission or if a DL assignment has been configured for this subframe:
    - start the HARQ RTT Timer for the corresponding HARQ process;
    - stop the DRX Retransmission Timer for the corresponding HARQ process.
  - if the PDCCH indicates a new transmission (DL or UL):
    - start or restart the DRX Inactivity Timer.
- when not in active time, CQI/SRS/PMI/RI shall not be reported.

Regardless of whether the UE is monitoring PDCCH or not the UE receives and transmits HARQ feedback when such is expected.

5.8 MAC reconfiguration

Editor"s note: This subclause describes the procedure for handling reconfiguration of MAC parameters during normal operation.

5.9 MAC Reset

Editor"s note: This subclause describes the procedure for resetting MAC [FFS]; e.g. at handover.

5.X Handling of unknown, unforeseen and erroneous protocol data

Editor"s note: This subclause describes how MAC treats and acts on unexpected data.

Editor"s note: The subclause on 'Handling of unknown, unforeseen and erroneous protocol data' should be the last subsection of Section 'MAC procedures'.

6 Protocol Data Units, formats and parameters

6.1 Protocol Data Units

6.1.1 General

A MAC PDU is a bit string that is byte aligned (i.e. multiple of 8 bits) in length. In the figures in subclause 6.1, bit strings are represented by tables in which the most significant bit is the leftmost bit of the first line of the table, the least significant bit is the rightmost bit on the last line of the table, and more generally the bit string is to be read from left to right and then in the reading order of the lines. The bit order of each parameter field within a MAC PDU is represented with the first and most significant bit in the leftmost bit and the last and least significant bit in the rightmost bit.

MAC SDUs are bit strings that are byte aligned (i.e. multiple of 8 bits) in length. An SDU is included into a MAC PDU from the first bit onward.

6.1.2 MAC PDU (DL-SCH and UL-SCH)

A MAC PDU consists of a MAC header, zero or more MAC Service Data Units (MAC SDU), zero, or more MAC control elements, and optionally padding; as described in Figure 6.1.2-3.

Both the MAC header and the MAC SDUs are of variable sizes.

A MAC PDU header consists of one or more MAC PDU sub-headers; each subheader corresponding to either a MAC SDU, a MAC control element or padding.

A MAC PDU subheader consists of the six header fields R/R/E/LCID/F/L but for the last subheader in the MAC PDU and for fixed sized MAC control elements. The last subheader in the MAC PDU and sub-headers for fixed sized MAC control elements consist solely of the four header fields R/R/E/LCID. It follows that a MAC PDU subheader corresponding to padding consists of the four header fields R/R/E/LCID.

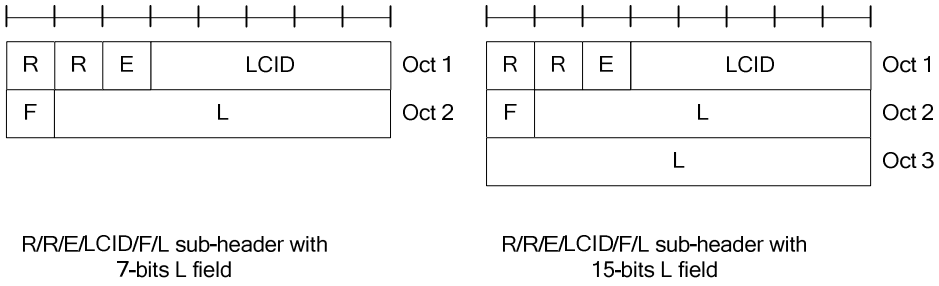

Figure 6.1.2-1: R/R/E/LCID/F/L MAC subheader

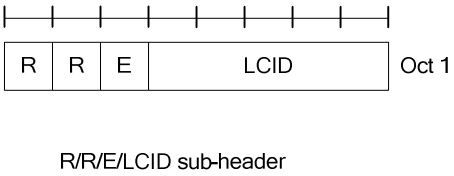

Figure 6.1.2-2: R/R/E/LCID MAC subheader

MAC PDU sub-headers have the same order as the corresponding MAC SDUs, MAC control elements and padding.

MAC control elements, are always placed before any MAC SDU.

Padding occurs at the end of the MAC PDU, except when single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU.

When single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU, one or two MAC PDU sub-headers corresponding to padding are inserted before the first MAC PDU subheader corresponding to a MAC SDU; or if such subheader is not present, before the last MAC PDU subheader corresponding to a MAC control element.

A maximum of one MAC PDU can be transmitted per TB per UE.

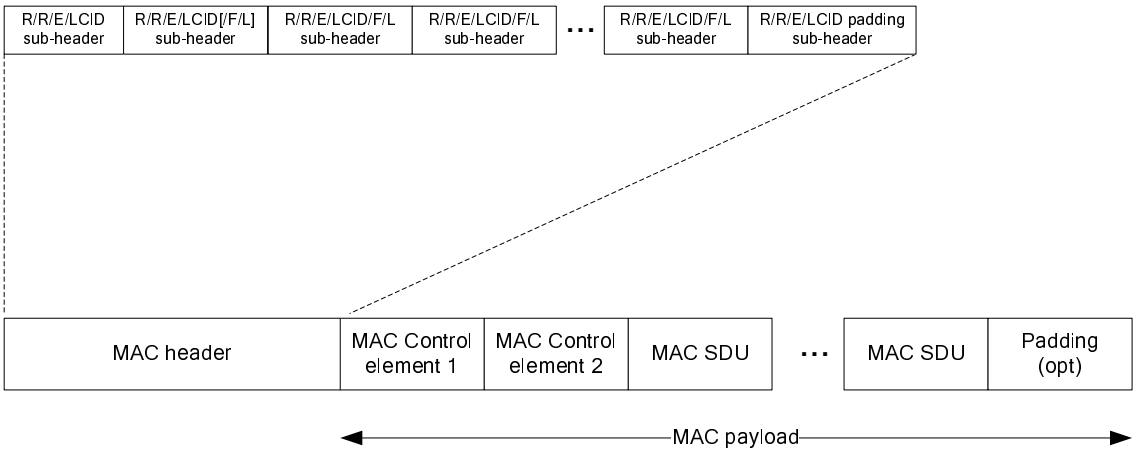

Figure 6.1.2-3: MAC PDU consisting of MAC header, MAC control elements, MAC SDUs and padding

Editor"s note: It is FFS whether this MAC PDU applies only to DL/UL SCH or also to other transport channels

6.1.3 MAC Control Elements

6.1.3.1 Buffer Status Report MAC Control Elements

Buffer Status Report (BSR) MAC control elements consist of either:

- Short BSR and Truncated BSR format: one LCG ID field and one corresponding BS field (figure 6.1.3.1-1); or
- Long BSR format: four Buffer Size fields, corresponding to LCG IDs #1 through #4 (figure 6.1.3.1-2).

The BSR formats are identified by MAC PDU subheaders with LCIDs as specified in table 6.2.1.-1.

The fields LCG ID and BS are defined as follow:

- LCG ID: The Logical Channel Group ID field identifies the group of logical channel(s) which buffer status is being reported. The length of the field is 2 bits;
- Buffer Size: The Buffer Size field identifies the total amount of data available across all logical channels of a logical channel group after the MAC PDU has been built. The amount of data is indicated in number of bytes. It shall include all data that is available for transmission in the RLC layer and in the PDCP layer; the definition of what data shall be considered as available for transmission is specified in [3] and [4] respectively. The size of the RLC and MAC headers are not considered in the buffer size computation. The length of this field is 6 bits. The values taken by the Buffer Size field are shown in Table 6.1.3.1-1.

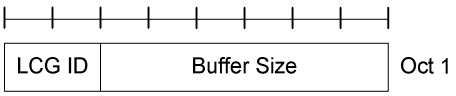

Figure 6.1.3.1-1: Short BSR and Truncated BSR MAC control element

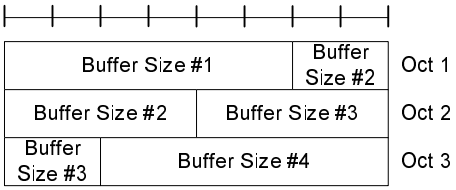

Figure 6.1.3.1-2: Long BSR MAC control element

Table 6.1.3.1-1: Buffer size levels for BSR

Index	Buffer Size (BS) value [bytes]	Index	Buffer Size (BS) value [bytes]
0	BS = 0	32	1132 < BS <= 1326
1	0 < BS <= 10	33	1326 < BS <= 1552
2	10 < BS <= 12	34	1552 < BS <= 1817
3	12 < BS <= 14	35	1817 < BS <= 2127
4	14 < BS <= 17	36	2127 < BS <= 2490
5	17 < BS <= 19	37	2490 < BS <= 2915
6	19 < BS <= 22	38	2915 < BS <= 3413
7	22 < BS <= 26	39	3413 < BS <= 3995
8	26 < BS <= 31	40	3995 < BS <= 4677
9	31 < BS <= 36	41	4677 < BS <= 5476
10	36 < BS <= 42	42	5476 < BS <= 6411
11	42 < BS <= 49	43	6411 < BS <= 7505
12	49 < BS <= 57	44	7505 < BS <= 8787
13	57 < BS <= 67	45	8787 < BS <= 10287
14	67 < BS <= 78	46	10287 < BS <= 12043
15	78 < BS <= 91	47	12043 < BS <= 14099
16	91 < BS <= 107	48	14099 < BS <= 16507
17	107 < BS <= 125	49	16507 < BS <= 19325
18	125 < BS <= 146	50	19325 < BS <= 22624
19	146 < BS <= 171	51	22624 < BS <= 26487
20	171 < BS <= 200	52	26487 < BS <= 31009
21	200 < BS <= 234	53	31009 < BS <= 36304
22	234 < BS <= 274	54	36304 < BS <= 42502
23	274 < BS <= 321	55	42502 < BS <= 49759
24	321 < BS <= 376	56	49759 < BS <= 58255
25	376 < BS <= 440	57	58255 < BS <= 68201
26	440 < BS <= 515	58	68201 < BS <= 79846
27	515 < BS <= 603	59	79846 < BS <= 93479
28	603 < BS <= 706	60	93479 < BS <= 109439
29	706 < BS <= 826	61	109439 < BS <= 128125
30	826 < BS <= 967	62	128125 < BS <= 150000
31	967 < BS <= 1132	63	BS > 150000

6.1.3.2 C-RNTI MAC Control Element

The C-RNTI MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-2.

It has a fixed size and consists of a single field defined as follows (figure 6.1.3.2-1):

- C-RNTI: This field contains the C-RNTI of the UE. The length of the field is 16 bits.

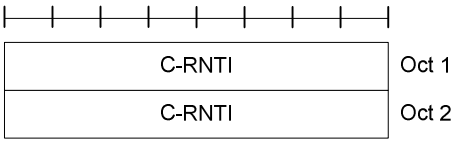

Figure 6.1.3.2-1: C-RNTI MAC control element

6.1.3.3 DRX Command MAC Control Element

The DRX Command MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1.

It has a fixed size of zero bits.

6.1.3.4 UE Contention Resolution Identity MAC Control Element

The UE Contention Resolution Identity MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1. This control element has a fixed 48-bit size and consists of a single field defined as follows (figure 6.1.3.4-1)

- UE Contention Resolution Identity: This field contains the uplink CCCH SDU transmitted by MAC.

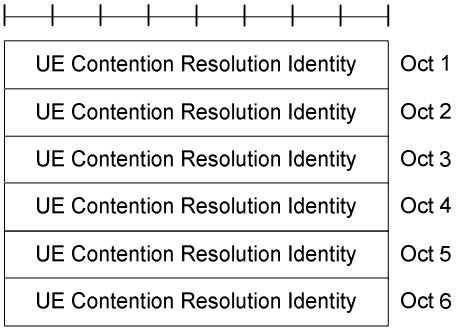

Figure 6.1.3.4-1: UE Contention Resolution Identity MAC control element

6.1.3.5 Timing Advance MAC Control Element

The Timing Advance MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1.

It has a fixed size and consists of a single field defined as follows (figure 6.1.3.4-1):

- Timing Advance: This field indicates the amount of timing adjustment in 0.5 μs that UE has to apply. The length of the field is [8] bits.

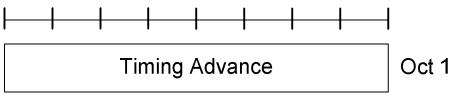

Figure 6.1.3.5-1: Timing Advance MAC control element

Editor"s note: Whether all 8 bits are needed and what the value range is are FFS.

6.1.3.6 Power Headroom MAC Control Element

The Power Headroom MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.6-1):

- R: reserved bits;
- Power Headroom: this field indicates the power headroom. The length of the field is 6 bits.

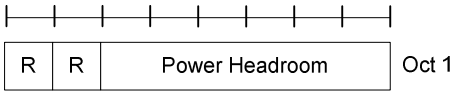

Figure 6.1.3.5-1: Power Headroom MAC control element

6.1.4 MAC PDU (transparent MAC)

A MAC PDU consists solely of a MAC Service Data Unit (MAC SDU) whose size is aligned to a TB; as described in figure 6.1.4-1.

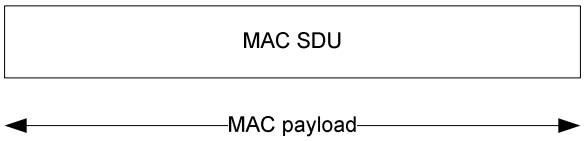

Figure 6.1.4-1: MAC PDU (transparent MAC)

6.1.5 MAC PDU (Random Access Response)

A MAC PDU consists of a MAC header and one or more MAC Random Access Responses (MAC RAR) as described in figure 6.1.5-4.

The MAC header is of variable size.

A MAC PDU header consists of one or more MAC PDU sub-headers; each subheader corresponding to a MAC RAR except for the Backoff Indicator sub-header.

A MAC PDU subheader consists of the three header fields E/T/RAPID (as described in figure 6.1.5-1) but for the Backoff Indicator subheader which consists of the five header field E/T/R/R/BI (as described in figure 6.1.5-2).

A MAC RAR consists of the four fields R/TA/UL Grant/Temporary C-RNTI (as described in figure 6.1.5-3). The R bit is reserved.

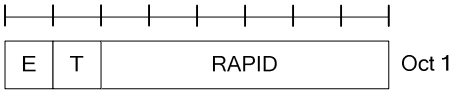

Figure 6.1.5-1: E/T/RAPID MAC sub-header

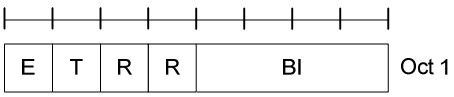

Figure 6.1.5-2: E/T/R/R/BI MAC sub-header

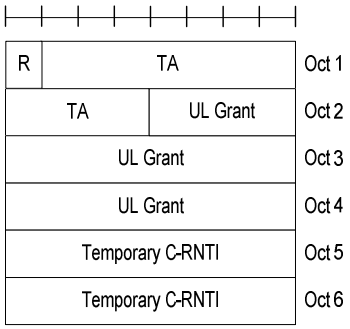

Figure 6.1.5-3: MAC RAR

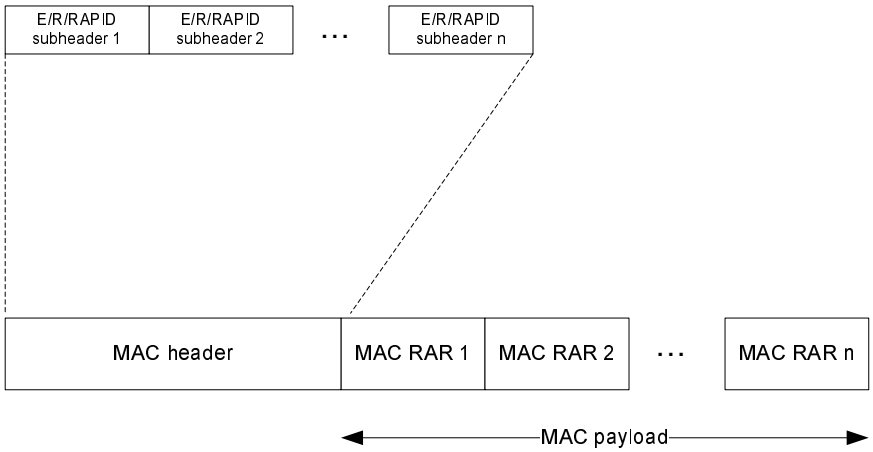

Figure 6.1.5-4: MAC PDU consisting of a MAC header and MAC RARs

6.2 Formats and parameters

6.2.1 MAC header for DL-SCH and UL-SCH

The MAC header is of variable size and consists of the following fields:

- LCID: The Logical Channel ID field identifies the logical channel instance of the corresponding MAC SDU or the type of the corresponding MAC control element or padding as described in tables 6.2.1-1 and 6.2.1-2 for the DL and UL-SCH respectively. There is one LCID field for each MAC SDU, MAC control element or padding included in the MAC PDU. The LCID field size is 5 bits;

- L: The Length field indicates the length of the corresponding MAC SDU or MAC control element in bytes. There is one L field per MAC PDU subheader except for the last subheader and sub-headers corresponding to fixed-sized MAC control elements. The size of the L field is indicated by the F field;

- F: The Format field indicates the size of the Length field as indicated in table 6.2.1-3. There is one F field per MAC PDU subheader except for the last subheader and sub-headers corresponding to fixed-sized MAC control elements. The size of the F field is 1 bit. If the size of the MAC SDU or MAC control element is less than 128 bytes, the UE shall set the value of the F field to 0, otherwise the UE shall set it to 1;

- E: The Extension field is a flag indicating if more fields are present in the MAC header or not. The E field is set to "1" to indicate another set of at least R/R/E/LCID fields. The E field is set to "0" to indicate that either a MAC SDU, a MAC control element or padding starts at the next byte;

- R: Reserved bits.

The MAC header and sub-headers are octet aligned.

Table 6.2.1-1 Values of LCID for DL-SCH

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011-11011	Reserved
11100	UE Contention Resolution Identity
11101	Timing Advance
11110	DRX Command
11111	Padding

Table 6.2.1-2 Values of LCID for UL-SCH

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011-11001	Reserved
11010	Power Headroom Report
11011	C-RNTI
11100	Truncated BSR
11101	Short BSR
11110	Long BSR
11111	Padding

Table 6.2.1-3 Values of F field:

Index	Size of Length field (in bits)
0	7
1	15

Editor"s note: It is FFS whether this MAC header applies only to DL/UL SCH or also to other transport channels.

6.2.2 MAC header for Random Access Response

The MAC header is of variable size and consists of the following fields:

- E: The Extension field is a flag indicating if more fields are present in the MAC header or not. The E field is set to "1" to indicate another set of at least E/T/RAPID or E/T/R/R/BI fields. The E field is set to "0" to indicate that a MAC RAR starts at the next byte;
- T: The Type field is a flag indicating whether the MAC subheader contains a Random Access ID or a Backoff Indicator. The T field is set to '0' to indicate the presence of a Backoff Indicator field in the subheader (BI). The T field is set to '1' to indicate the presence of a Random Access Preamble ID field in the subheader (RAPID);
- R: Reserved bit;
- BI: The Backoff Indicator field identifies the overload condition in the cell. The size of the BI field is 4 bits;
- RAPID: The Random Access Preamble IDentitfier field identifies the transmitted Random Access Preamble (see subclause 5.1.3). The size of the RAPID field is 6 bits.

The MAC header and sub-headers are octet aligned.

6.2.3 MAC payload for Random Access Response

The MAC RAR is of [fixed] size and consists of the following fields:

- TA: The Timing Advance field indicates the required adjustment to the uplink transmission timing to be used for timing synchronisation (see subclause 4.2.4 of [2]). The size of the TA field is [11] bits;

- UL Grant: The UpLink Grant field indicates the resources to be used on the uplink. The size of the UL Grant field is [21] bits;

- Temporary C-RNTI: The Temporary C-RNTI field indicates the temporary identity that is used by the UE during Random Access. The size of the Temporary C-RNTI field is 16 bits.

The MAC RAR is octet aligned.

Editor"s note: The size of the TA and UL Grant field is FFS

7 Variables and constants

Editor"s note: This subclause defines the variables and constants used by MAC.

7.1 RNTI values

RNTI values are presented in Table 7.1-1.

Table 7.1-1: RNTI values.

Value (hexa-decimal)		RNTI
FDD	TDD	
0000-0009	0000-003B	RA-RNTI
000A-FFF2	003C-FFF2	C-RNTI, Semi-Persistent Scheduling C-RNTI, Temporary C-RNTI, TPC-PUCCH-RNTI and TPC-PUSCH-RNTI
FFF3-FFFC		Reserved for future use
FFFE		P-RNTI
FFFF		SI-RNTI

7.2 Backoff Parameter values

Backoff Parameter values are presented in Table 7.2-1.

Table 7.2-1: Backoff Parameter values.

Index	Backoff Parameter value (ms)
0	0
1	10
2	20
3	30
4	40
5	60
6	80
7	120
8	160
9	240
10	320
11	480
12	960

Annex A (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2007-06	RAN2#58 bis	R2-072710			MAC Protocol Specification Baseline	-	
2007-06	RAN2#58 bis	R2-072912			Text Proposal for UL HARQ (Tdoc R2-072708) Text Proposal for DL HARQ (Tdoc R2-072707) Text Proposal for RACH procedure (Tdoc R2-072640) Text Proposal for Logical Channel prioritization (Tdoc R2-072643)		0.1.0
2007-06	RAN2#58 bis	R2-072994			Basic MAC PDU structure (Tdoc R2-072983) with updates Agreements on time-frequency resource configuration (Tdoc R2-072993) Agreement on RA-RNTI association (Tdoc R2-072993) Clarification on RA Response reception (Tdoc R2-072993)	0.1.0	0.1.1
2007-08	RAN2#59	R2-073715			Removed reference to non-existing table (Tdoc R2-073473) Incorrect mapping of logical to transport channel (Tdoc R2-073473) Un-necessary error checking in HARQ process procedure (Tdoc R2-073473) Removal of reference to timing relation for HARQ feedback (Tdoc R2-073473) Correction of Internal variable name (Tdoc R2-073473) Correction of procedure in case of successful HARQ reception (Tdoc R2-073473)	0.1.1	0.2.0
2007-09	RAN2#59	R2-073885			Text proposal for Random Access procedure Text proposal on HARQ clarification for TDD Text proposal on HARQ for grants	0.2.0	0.2.1
2007-09	RAN#37	RP-070688			Clean version for information	0.2.1	1.0.0
2007-10	RAN2#59 bis	R2-074530			Editorial update with Editor"s notes (Tdoc R2-074211).	1.0.0	1.1.0
2007-11	RAN2#60	R2-075093			Agreements on MAC PDU format (R2-074536) Corrections on Random Access Procedure (R2-074536)	1.1.0	1.1.1
2007-11	RAN2#60	R2-075243			Endorsement of v1.1.1 Removal of FFS on DL CCCH existence	1.1.1	1.2.0
2007-11	RAN2#60	R2-075488			Agreement on identity used Random Access Response (R2-075038) Agreement on Local Nack1 (R2-074949) PUCCH Resource handling (R2-075432) UL HARQ agreements (R2-075432) Agreements on semi-persistent scheduling (R2-075432, 36.300) Agreements on BSR/SR triggers (R2-075432) Agreements on BSR contents (R2-075432) Agreements on Timing Advance principles (36.300) Agreements on DRX control (36.300) Handling of P-BCH, D-BCH, PCH (R2-075246)	1.2.0	1.3.0
2007-11	RAN #38	RP-070917			Clean version, presented at TSG RAN-38 for approval	1.3.0	2.0.0
2007-12	RAN #38	-			Approved at TSG RAN-38 and placed under change control	2.0.0	8.0.0
2008-03	RAN #39	RP-080162	0001	2	CR to 36.321 with E-UTRA MAC protocol specification update	8.0.0	8.1.0
2008-05	RAN #40	RP-080410	0002	1	36.321 CR covering agreements of RAN2 #61bis and RAN2#62	8.1.0	8.2.0
2008-09	RAN #41	RP-080690	0003	-	Clarification on data available for transmission for BSR triggering	8.2.0	8.3.0
	RAN #41	RP-080690	0004	-	CR to 36.321 on failure indication after maximum number of HARQ transmissions	8.2.0	8.3.0
	RAN #41	RP-080690	0005	4	Clarifications and Corrections of DL and UL Data Transfer (SCH, RACH and SR)	8.2.0	8.3.0
	RAN #41	RP-080690	0006	-	CR to 36.321 on Buffer size levels for BSR	8.2.0	8.3.0
	RAN #41	RP-080690	0007	-	Clarifications on DRX	8.2.0	8.3.0
	RAN #41	RP-080690	0008	-	Clarification on UE behavior for DRX and configured measurement gaps	8.2.0	8.3.0
	RAN #41	RP-080690	0009	3	Correction to MAC Padding BSR	8.2.0	8.3.0
	RAN #41	RP-080690	0010	-	Correction to UE transmission power headroom report for LTE	8.2.0	8.3.0
	RAN #41	RP-080690	0011	-	Corrections on BSR	8.2.0	8.3.0
	RAN #41	RP-080690	0012	-	CR to 36.321 REL-8 on Format of UL grant in Message 2	8.2.0	8.3.0
	RAN #41	RP-080690	0015	-	CR to 36.321 REL-8 on PUSCH PUCCH Power Control RNTIs	8.2.0	8.3.0
	RAN #41	RP-080690	0016	-	CR to 36.321 REL-8 on RACH uniform random backoff	8.2.0	8.3.0
	RAN #41	RP-080690	0017	1	E-UTRA MAC protocol specification update	8.2.0	8.3.0
	RAN #41	RP-080690	0020	-	TP for number of HARQ processes and MIMO	8.2.0	8.3.0
	RAN #41	RP-080690	0022	-	Update of MAC dedicated preamble expiry	8.2.0	8.3.0

	RAN #41	RP-080690	0027	-	Handling of Semi-Persistent grants and assignments	8.2.0	8.3.0
	RAN #41	RP-080690	0051	1	Corrections relating to RACH	8.2.0	8.3.0
	RAN #41	RP-080690	0058	1	UL Channel Prioritisation	8.2.0	8.3.0
	RAN #41	RP-080690	0071	2	Corrections relating to RACH partitioning	8.2.0	8.3.0
	RAN #41	RP-080690	0091	-	Correction on Random Access Response reception behaviour	8.2.0	8.3.0
	RAN #41	RP-080690	0103	-	Upper limit of logical channel id	8.2.0	8.3.0
	RAN #41	RP-080690	0104	-	Clarifications and Corrections for HARQ operation at TAT expiry and RACH contention resolution	8.2.0	8.3.0

History

Document history		
V8.2.0	November 2008	Publication
V8.3.0	November 2008	Publication