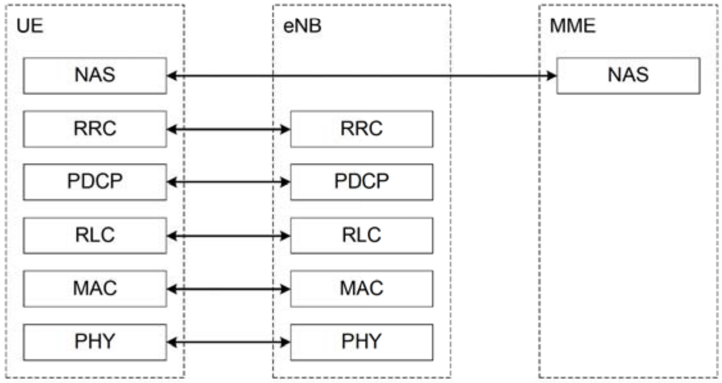

Figure 4.3.2-1: Control-plane protocol stack

4.4 Synchronization

Diverse methods and techniques are preferred depending on synchronization requirements. As no single method can cover all E-UTRAN applications a logical port at eNB may be used for reception of timing and/or frequency and/or phase inputs pending to the synchronization method chosen.

4.5 IP fragmentation

Fragmentation function in IP layer on S1 and X2 shall be supported.

Configuration of S1-U (X2-U) link MTU in the eNB/ S-GW according to the MTU of the network domain the node belongs to shall be considered as a choice at network deployment. The network may employ various methods to handle IP fragmentation, but the specific methods to use are implementation dependant.

At the establishment/modification of an EPS bearer, the network may signal a value that is to be used as MTU by the UE IP stack (it is FFS how the requirement on the UE should be formulated). It is also FFS if the MTU is signalled by the MME or the eNB.

5 Physical Layer for E-UTRA

The generic frame structure is illustrated in Figure 5-1. Each 10 ms radio frame is divided into ten equally sized sub-frames. Each sub-frame consists of two equally sized slots. Each sub-frame can be assigned for either downlink or uplink transmission [*there are certain restrictions in the assignment as the first and sixth sub-frame of each frame include the downlink synchronization signals*]

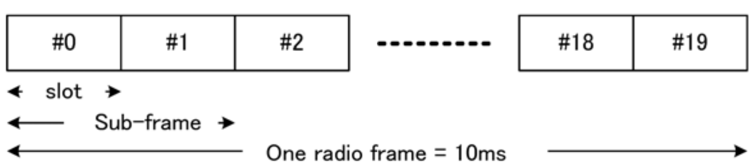

Figure 5-1: Generic frame structure

In addition, for coexistence with LCR-TDD, an alternative frame structure illustrated in Figure 5-2 is also supported when operating E-UTRA in TDD mode.

SAMSUNG 1017-0071

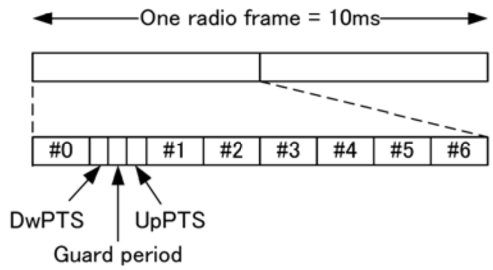

Figure 5-2: alternative frame structure

The physical channels of E-UTRA are:

Physical broadcast channel (PBCH)

- The coded BCH transport block is mapped to four subframes within a 40 ms interval;
- 40 ms timing is blindly detected, i.e. there is no explicit signalling indicating 40 ms timing;
- Each subframe is assumed to be self-decodable, i.e. the BCH can be decoded from a single reception, assuming sufficiently good channel conditions.

Physical control format indicator channel (PCFICH)

- Informs the UE about the number of OFDM symbols used for the PDCCHs;
- Transmitted in every subframe.

Physical downlink control channel (PDCCH)

- Informs the UE about the resource allocation of PCH and DL-SCH, and Hybrid ARQ information related to DL-SCH;
- Carries the uplink scheduling grant.

Physical Hybrid ARQ Indicator Channel (PHICH)

- Carries Hybrid ARQ ACK/NAKs in response to uplink transmissions.

Physical downlink shared channel (PDSCH)

- Carries the DL-SCH and PCH.

Physical multicast channel (PMCH)

- Carries the MCH.

Physical uplink control channel (PUCCH)

- Carries Hybrid ARQ ACK/NAKs in response to downlink transmission;
- Carries Scheduling Request (SR);
- Carries CQI reports.

Physical uplink shared channel (PUSCH)

- Carries the UL-SCH.

Physical random access channel (PRACH)

- Carries the random access preamble.

5.1 Downlink Transmission Scheme

5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is Δf = 15 kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min}$ = 6 to $N_{RB\text{-}max}$ = [110].

In addition there is also a reduced sub-carrier spacingΔf_{low} = 7.5 kHz, only for MBMS-dedicated cell.

In the case of 15 kHz sub-carrier spacing there are two cyclic-prefix lengths, corresponding to seven and six OFDM symbols per slot respectively.

- Normal cyclic prefix: $T_{CP} = 160 \times Ts$ (OFDM symbol #0) , $T_{CP} = 144 \times Ts$ (OFDM symbol #1 to #6)
- Extended cyclic prefix: $T_{CP\text{-}e} = 512 \times Ts$ (OFDM symbol #0 to OFDM symbol #5)

  where $T_s = 1/(2048 \times \Delta f)$

In case of 7.5 kHz sub-carrier spacing, there is only a single cyclic prefix length $T_{CP\text{-}low} = 1024 \times Ts$, corresponding to 3 OFDM symbols per slot.

In case of FDD, operation with half duplex from UE point of view is supported.

For operation in unpaired spectrum with generic frame structure, DL/UL switching points are generated by not transmitting in certain symbols while idle periods, required by the Node B at UL/DL switching points are created using time advance mechanism. For the alternative frame structure, the cyclic prefix length, in case of 15 kHz sub-carrier spacing, is

- Normal cyclic prefix: $T_{CP} = 224 \times Ts$ (OFDM symbol #0 to #8)
- Extended cyclic prefix: $T_{CP\text{-}e} = 512 \times Ts$ (OFDM symbol #0 to #7)

5.1.2 Physical-layer processing

The downlink physical-layer processing of transport channels consists of the following steps:

- CRC insertion: 24 bit CRC is the baseline for PDSCH;
- Channel coding: Turbo coding based on QPP inner interleaving with trellis termination;
- Physical-layer hybrid-ARQ processing;
- Channel interleaving;
- Scrambling: transport-channel specific scrambling on DL-SCH, BCH, and PCH. Common MCH scrambling for all cells involved in a specific MBSFN transmission;
- Modulation: QPSK, 16QAM, and 64QAM;
- Layer mapping and pre-coding;
- Mapping to assigned resources and antenna ports.

5.1.3 Physical downlink control channel

The downlink control signalling (PDCCH) is located in the first n OFDM symbols where $n \leq 3$ and consists of:

- Transport format, resource allocation, and hybrid-ARQ information related to DL-SCH, and PCH;
- Transport format, resource allocation, and hybrid-ARQ information related to UL-SCH;

Transmission of control signalling from these groups is mutually independent.

Multiple physical downlink control channels are supported and a UE monitors a set of control channels.

Control channels are formed by aggregation of control channel elements, each control channel element consisting of a set of resource elements. Different code rates for the control channels are realized by aggregating different numbers of control channel elements.

QPSK modulation is used for all control channels.

Each separate control channel has its own set of x-RNTI.

There is an implicit relation between the uplink resources used for dynamically scheduled data transmission, or the DL control channel used for assignment, and the downlink ACK/NAK resource used for feedback

5.1.4 Downlink Reference signal

The downlink reference signals consist of known reference symbols inserted in the first and third last OFDM symbol of each slot. There is one reference signal transmitted per downlink antenna port. The number of downlink antenna ports equals 1, 2, or 4. The two-dimensional reference signal sequence is generated as the symbol-by-symbol product of a two-dimensional orthogonal sequence and a two-dimensional pseudo-random sequence. There are 3 different two-dimensional orthogonal sequences and 170 different two-dimensional pseudo-random sequences. Each cell identity corresponds to a unique combination of one orthogonal sequence and one pseudo-random sequence, thus allowing for 510 unique cell identities 170 cell identity groups with 3 cell identities in each group).

Frequency hopping can be applied to the downlink reference signals. The frequency hopping pattern has a period of one frame (10 ms). Each frequency hopping pattern corresponds to one cell identity group.

The downlink MBSFN reference signals consist of known reference symbols inserted every other sub-carrier in the 3rd, 7th and 11th OFDM symbol of sub-frame in case of 15kHz sub-carrier spacing and extended cyclic prefix

5.1.5 Downlink multi-antenna transmission

Multi-antenna transmission with 2 and 4 transmit antennas is supported. The maximum number of codeword is two irrespective to the number of antennas with fixed mapping between code words to layers.

Spatial division multiplexing (SDM) of multiple modulation symbol streams to a single UE using the same time-frequency (-code) resource, also referred to as Single-User MIMO (SU-MIMO) is supported. When a MIMO channel is solely assigned to a single UE, it is known as SU-MIMO. Spatial division multiplexing of modulation symbol streams to different UEs using the same time-frequency resource, also referred to as MU-MIMO, is also supported. There is semi-static switching between SU-MIMO and MU-MIMO per UE.

In addition, the following techniques are supported:

- Code-book-based pre-coding with a single pre-coding feedback per full system bandwidth when the system bandwidth (or subset of resource blocks) is smaller or equal to12RB and per 5 adjacent resource blocks or the full system bandwidth (or subset of resource blocks) when the system bandwidth is larger than 12RB.

- Rank adaptation with single rank feedback referring to full system bandwidth. Node B can override rank report.

5.1.6 MBSFN transmission

MBSFN is supported for the MCH transport channel. Multiplexing of transport channels using MBSFN and non-MBSFN transmission is done on a per-sub-frame basis. Additional reference symbols, transmitted using MBSFN are transmitted within MBSFN subframes.

5.1.7 Physical layer procedure

5.1.7.1 Link adaptation

Link adaptation (AMC: adaptive modulation and coding) with various modulation schemes and channel coding rates is applied to the shared data channel. The same coding and modulation is applied to all groups of resource blocks belonging to the same L2 PDU scheduled to one user within one TTI and within a single stream.

5.1.7.2 Power Control

Downlink power control can be used.

5.1.7.3 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 72 sub-carriers and upwards.

E-UTRA cell search is based on following signals transmitted in the downlink: the primary and secondary synchronization signals, the downlink reference signals.

The primary and secondary synchronization signals are transmitted over the centre 72 sub-carriers in the first and sixth subframe of each frame.

Neighbour-cell search is based on the same downlink signals as initial cell search.

5.1.8 Physical layer measurements definition

The physical layer measurements to support mobility are classified as:

- within E-UTRAN (intra-frequency, inter-frequency);
- between E-UTRAN and GERAN/UTRAN (inter-RAT);
- between E-UTRAN and non-3GPP RAT (Inter 3GPP access system mobility).

For measurements within E-UTRAN at least two basic UE measurement quantities shall be supported:

- Reference symbol received power (RSRP);
- E-UTRA carrier received signal strength indicator (RSSI).

5.2 Uplink Transmission Scheme

5.2.1 Basic transmission scheme

For both FDD and TDD, the uplink transmission scheme is based on single-carrier FDMA, more specifically DFTS-OFDM.

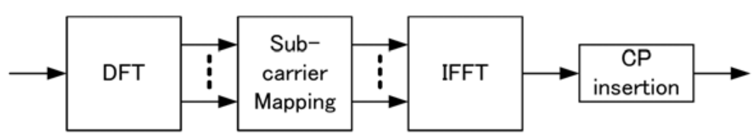

Figure 5.2.1-1: Transmitter scheme of SC-FDMA

The uplink sub-carrier spacing Δf = 15 kHz. The sub-carriers are grouped into sets of 12 consecutive sub-carriers, corresponding to the uplink resource blocks. 12 consecutive sub-carriers during one slot correspond to one uplink *resource block*. In the frequency domain, the number of resource blocks, N_{RB}, can range from $N_{RB\text{-}min}$ = 6 to $N_{RB\text{-}max}$ = [110].

There are two cyclic-prefix lengths defined: Normal cyclic prefix and extended cyclic prefix corresponding to seven and six SC-FDMA symbol per slot respectively.

- Normal cyclic prefix: T_{CP} = 160×Ts (SC-FDMA symbol #0) , T_{CP} = 144×Ts (SC-FDMA symbol #1 to #6)
- Extended cyclic prefix: $T_{CP\text{-}e}$ = 512×Ts (SC-FDMA symbol #0 to SC-FDMA symbol #5)

Correspondingly, for the alternative frame structure, the cyclic prefix length is listed in table 5.2.1-1.

Table 5.2.1-1: Cyclic prefix length for alternative frame structure

<table>
<tr><th rowspan="3">l</th><th colspan="4">Normal cyclic prefix</th><th colspan="4">Extended cyclic prefix</th></tr>
<tr><th colspan="2">$N_{\mathrm{BW}}^{\mathrm{UL}} \le 300$</th><th colspan="2">$300 < N_{\mathrm{BW}}^{\mathrm{UL}}$</th><th colspan="2">$N_{\mathrm{BW}}^{\mathrm{UL}} \le 300$</th><th colspan="2">$300 < N_{\mathrm{BW}}^{\mathrm{UL}}$</th></tr>
<tr><th>$N_{\mathrm{CP},l}$</th><th>N_{d}</th><th>$N_{\mathrm{CP},l}$</th><th>N_{d}</th><th>$N_{\mathrm{CP},l}$</th><th>N_{d}</th><th>$N_{\mathrm{CP},l}$</th><th>N_{d}</th></tr>
<tr><td>0</td><td>320</td><td>2048</td><td>224</td><td>2048</td><td>560</td><td>2048</td><td>472</td><td>2048</td></tr>
<tr><td>1</td><td rowspan="9">192</td><td>1024</td><td rowspan="9">204</td><td>1024</td><td rowspan="8">423</td><td>1024</td><td rowspan="8">456</td><td>1024</td></tr>
<tr><td>2</td><td rowspan="6">2048</td><td rowspan="6">2048</td><td rowspan="5">2048</td><td rowspan="5">2048</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td><td>1024</td><td>1024</td></tr>
<tr><td>8</td><td>1024</td><td>1024</td><td>2048</td><td>2048</td></tr>
<tr><td>9</td><td>2048</td><td>2048</td></tr>
</table>

5.2.2 Physical-layer processing

The uplink physical layer processing of transport channels consists of the following steps:

- CRC insertion: 24 bit CRC is the baseline for PUSCH;
- Channel coding: turbo coding based on QPP inner interleaving with trellis termination;
- Physical-layer hybrid-ARQ processing;
- Scrambling: UE-specific scrambling;
- Modulation: QPSK, 16QAM, and 64QAM (64 QAM optional in UE);
- Mapping to assigned resources [*and antennas*].

5.2.3 Physical uplink control channel

The PUCCH shall be mapped to a control channel resource in the uplink. A control channel resource is defined by a code and two resource blocks, consecutive in time, with hopping at the slot boundary.

Depending on presence or absence of uplink timing synchronization, the uplink physical control signalling can differ.

In the case of time synchronization being present, the outband control signalling consists of:

- CQI;
- ACK/NAK;
- Scheduling Request (SR).

The CQI informs the scheduler about the current channel conditions as seen by the UE. If MIMO transmission is used, the CQI includes necessary MIMO-related feedback.

The HARQ feedback in response to downlink data transmission consists of a single ACK/NAK bit per HARQ process.

PUCCH resources for SR and CQI reporting are assigned and can be revoked through RRC signalling. An SR is not necessarily assigned to UEs acquiring synchronization through the RACH (i.e. synchronised UEs may or may not have a dedicated SR channel). PUCCH resources for SR and CQI are lost when the UE is no longer synchronized.

5.2.4 Uplink Reference signal

Uplink reference signals [for channel estimation for coherent demodulation] are transmitted in the 4-th block of the slot [*assumed normal CP*]. The uplink reference signals sequence length equals the size (number of sub-carriers) of the assigned resource.

The uplink reference signals are based on [*prime-length*] Zadoff-chu sequences that are either truncated or cyclically extended to the desired length

Multiple reference signals can be created:

- Based on different Zadoff-Chu sequence from the same set of Zadoff-Chu sequences;
- Different shifts of the same sequence.

5.2.5 Random access preamble

The physical layer random access burst consists of a cyclic prefix, a preamble, and a guard time during which nothing is transmitted.

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, ZC-ZCZ, generated from one or several root Zadoff-Chu sequences.

5.2.6 Uplink multi-antenna transmission

The baseline antenna configuration for uplink MIMO is MU-MIMO. To allow for MU-MIMO reception at the Node B, allocation of the same time and frequency resource to several UEs, each of which transmitting on a single antenna, is supported.

Closed loop type adaptive antenna selection transmit diversity shall be supported for FDD (optional in UE).

5.2.7 Physical channel procedure

5.2.7.1 Link adaptation

Uplink link adaptation is used in order to guarantee the required minimum transmission performance of each UE such as the user data rate, packet error rate, and latency, while maximizing the system throughput.

Three types of link adaptation are performed according to the channel conditions, the UE capability such as the maximum transmission power and maximum transmission bandwidth etc., and the required QoS such as the data rate, latency, and packet error rate etc. Three link adaptation methods are as follows.

- Adaptive transmission bandwidth;
- Transmission power control;
- Adaptive modulation and channel coding rate.

5.2.7.2 Uplink Power control

Intra-cell power control: the power spectral density of the uplink transmissions can be influenced by the eNB.

5.2.7.3 Uplink timing control

The timing advance is derived from the UL received timing and sent by the eNB to the UE which the UE uses to advance/delay its timings of transmissions to the eNB so as to compensate for propagation delay and thus time align the transmissions from different UEs with the receiver window of the eNB.

The timing advance command is on a per need basis with a granularity in the step size of 0.52 μs ($16 \times T_s$).

5.3 Transport Channels

The physical layer offers information transfer services to MAC and higher layers. The physical layer transport services are described by *how* and with what characteristics data are transferred over the radio interface. An adequate term for this is “Transport Channel”.

NOTE: This should be clearly separated from the classification of *what* is transported, which relates to the concept of logical channels at MAC sublayer.

Downlink transport channel types are:

1. **Broadcast Channel (BCH)** characterised by:
   - fixed, pre-defined transport format;
   - requirement to be broadcast in the entire coverage area of the cell.
2. **Downlink Shared Channel (DL-SCH)** characterised by:
   - support for HARQ;
   - support for dynamic link adaptation by varying the modulation, coding and transmit power;
   - possibility to be broadcast in the entire cell;
   - possibility to use beamforming;
   - support for both dynamic and semi-static resource allocation;
   - support for UE discontinuous reception (DRX) to enable UE power saving;
   - support for MBMS transmission.

NOTE: the possibility to use slow power control depends on the physical layer.

3. **Paging Channel (PCH)** characterised by:
   - support for UE discontinuous reception (DRX) to enable UE power saving (DRX cycle is indicated by the network to the UE);
   - requirement to be broadcast in the entire coverage area of the cell;
   - mapped to physical resources which can be used dynamically also for traffic/other control channels.
4. **Multicast Channel (MCH)** characterised by:
   - requirement to be broadcast in the entire coverage area of the cell;
   - support for MBSFN combining of MBMS transmission on multiple cells;
   - support for semi-static resource allocation e.g. with a time frame of a long cyclic prefix.

Uplink transport channel types are:

1. **Uplink Shared Channel (UL-SCH)** characterised by:
   - possibility to use beamforming; (likely no impact on specifications)
   - support for dynamic link adaptation by varying the transmit power and potentially modulation and coding;
   - support for HARQ;
   - support for both dynamic and semi-static resource allocation.

NOTE: the possibility to use uplink synchronisation and timing advance depend on the physical layer.

2. **Random Access Channel(s) (RACH)** characterised by:
   - limited control information;
   - collision risk;

NOTE: the possibility to use open loop power control depends on the physical layer solution.

5.3.1 Mapping between transport channels and physical channels

The figures below depict the mapping between transport and physical channels:

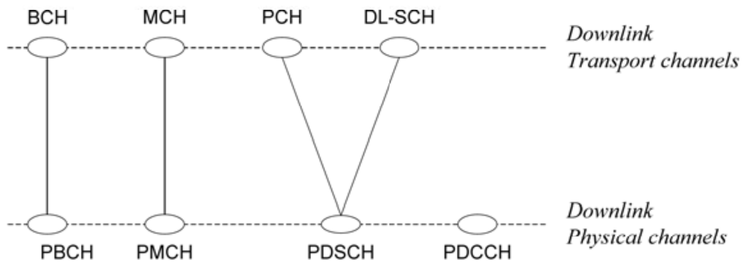

Figure 5.3.1-1: Mapping between downlink transport channels and downlink physical channels

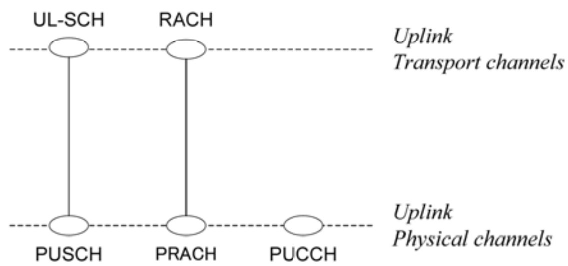

Figure 5.3.1-2: Mapping between uplink transport channels and uplink physical channels

5.4 E-UTRA physical layer model

The E-UTRAN physical layer model is captured in TS 36.302 [9].

5.4.1 Void

5.4.2 Void

6 Layer 2

Layer 2 is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC) and Packet Data Convergence Protocol (PDCP).

This subclause gives a high level description of the Layer 2 sub-layers in terms of services and functions. The two figures below depict the PDCP/RLC/MAC architecture for downlink and uplink, where:

- Service Access Points (SAP) for peer-to-peer communication are marked with circles at the interface between sublayers. The SAP between the physical layer and the MAC sublayer provides the transport channels. The SAPs between the MAC sublayer and the RLC sublayer provide the logical channels.

- The multiplexing of several logical channels (i.e. radio bearers) on the same transport channel (i.e. transport block) is performed by the MAC sublayer;

- In both uplink and downlink, only one transport block is generated per TTI in the non-MIMO case.

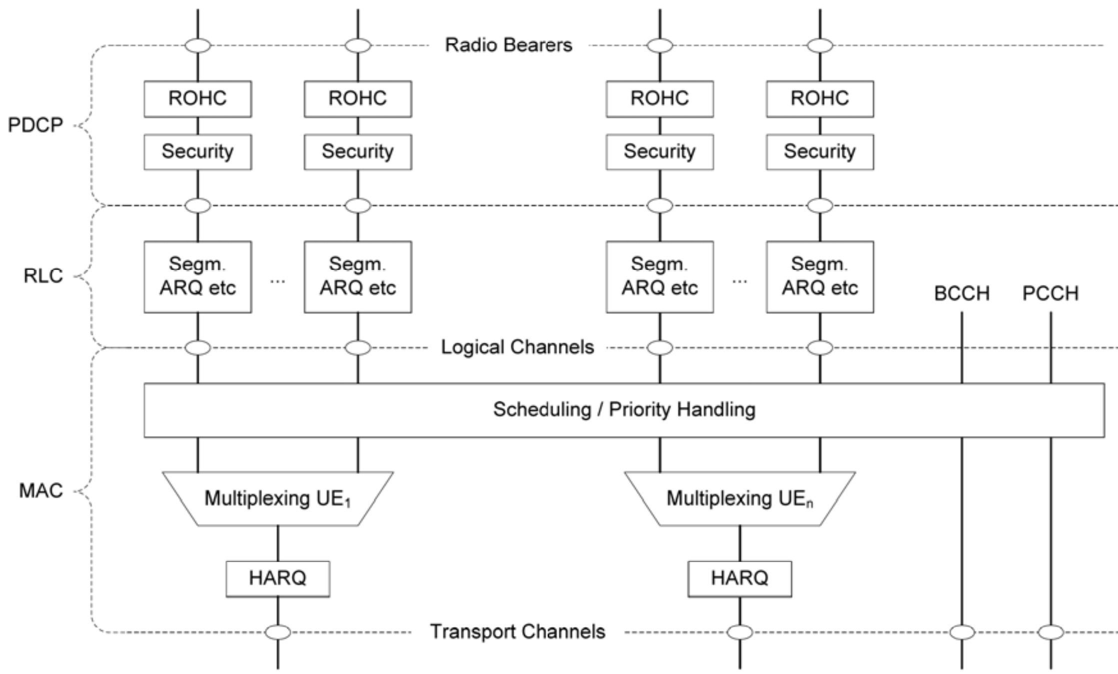

Figure 6-1: Layer 2 Structure for DL

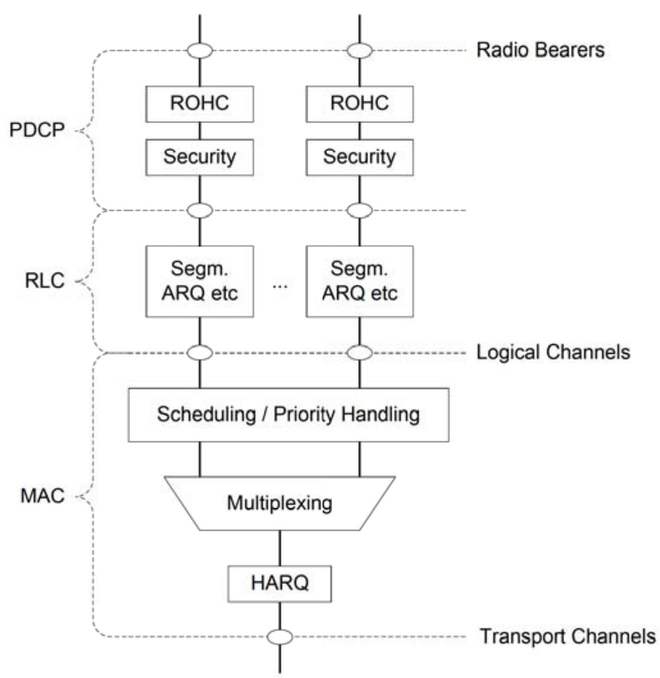

Figure 6-2: Layer 2 Structure for UL

6.1 MAC Sublayer

This subclause provides an overview on services and functions provided by the MAC sublayer.

6.1.1 Services and Functions

The main services and functions of the MAC sublayer include:

- Mapping between logical channels and transport channels;
- Multiplexing/demultiplexing of RLC PDUs belonging to one or different radio bearers into/from transport blocks (TB) delivered to/from the physical layer on transport channels;
- Traffic volume measurement reporting;
- Error correction through HARQ;
- Priority handling between logical channels of one UE;
- Priority handling between UEs by means of dynamic scheduling;
- Transport format selection;
- Padding.

6.1.2 Logical Channels

Different kinds of data transfer services as offered by MAC. Each logical channel type is defined by what type of information is transferred.

A general classification of logical channels is into two groups:

- Control Channels (for the transfer of control plane information);
- Traffic Channels (for the transfer of user plane information).

There is one MAC entity per cell. MAC generally consists of several function blocks (transmission scheduling functions, per UE functions, MBMS functions, MAC control functions, transport block generation…). Transparent Mode is only applied to BCCH, CCCH and PCCH.

6.1.2.1 Control Channels

Control channels are used for transfer of control plane information only. The control channels offered by MAC are:

- **Broadcast Control Channel (BCCH)**

  A downlink channel for broadcasting system control information.

- **Paging Control Channel (PCCH)**

  A downlink channel that transfers paging information. This channel is used when the network does not know the location cell of the UE.

- **Common Control Channel (CCCH)**

  Channel for transmitting control information between UEs and network. This channel is used for UEs having no RRC connection with the network.

- **Multicast Control Channel (MCCH)**

  A point-to-multipoint downlink channel used for transmitting MBMS control information from the network to the UE, for one or several MTCHs. This channel is only used by UEs that receive MBMS.

NOTE: It is FFS how MBMS scheduling is transmitted by either L2/3 signalling on MCCH or L1 signalling.

- **Dedicated Control Channel (DCCH)**

  A point-to-point bi-directional channel that transmits dedicated control information between a UE and the network. Used by UEs having an RRC connection.

6.1.2.2 Traffic Channels

Traffic channels are used for the transfer of user plane information only. The traffic channels offered by MAC are:

- **Dedicated Traffic Channel (DTCH)**

  A Dedicated Traffic Channel (DTCH) is a point-to-point channel, dedicated to one UE, for the transfer of user information. A DTCH can exist in both uplink and downlink.

- **Multicast Traffic Channel (MTCH)**

  A point-to-multipoint downlink channel for transmitting traffic data from the network to the UE. This channel is only used by UEs that receive MBMS.

6.1.3 Mapping between logical channels and transport channels

6.1.3.1 Mapping in Uplink

The figure below depicts the mapping between uplink logical channels and uplink transport channels:

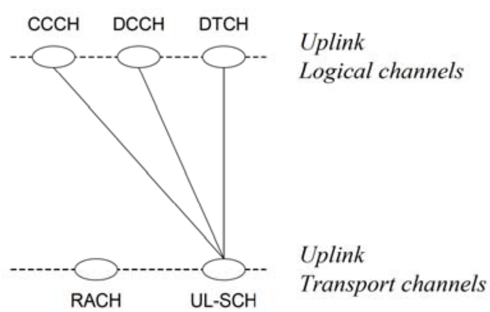

Figure 6.1.3.1-1: Mapping between uplink logical channels and uplink transport channels

In Uplink, the following connections between logical channels and transport channels exist:

- CCCH can be mapped to UL-SCH;
- DCCH can be mapped to UL- SCH;
- DTCH can be mapped to UL-SCH.

6.1.3.2 Mapping in Downlink

The figure below depicts the mapping between downlink logical channels and downlink transport channels:

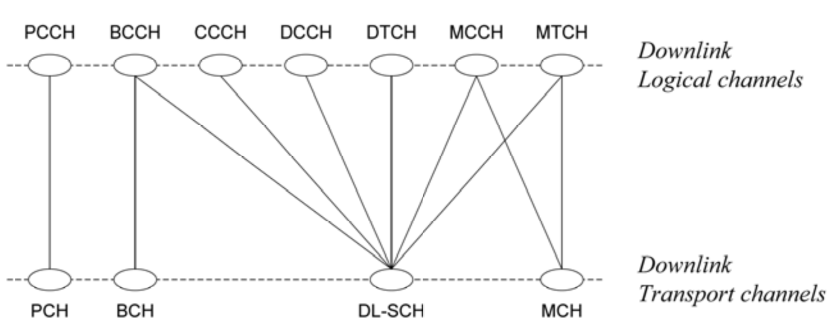

Figure 6.1.3.2-1: Mapping between downlink logical channels and downlink transport channels

In Downlink, the following connections between logical channels and transport channels exist:

- BCCH can be mapped to BCH;
- BCCH can be mapped to DL-SCH;
- PCCH can be mapped to PCH;
- CCCH can be mapped to DL-SCH;
- DCCH can be mapped to DL-SCH;
- DTCH can be mapped to DL-SCH;
- MTCH can be mapped to DL-SCH;
- MTCH can be mapped to MCH;
- MCCH can be mapped to DL-SCH;
- MCCH can be mapped to MCH.

6.2 RLC Sublayer

This subclause provides an overview on services, functions and PDU structure provided by the RLC sublayer. Note that:

- The reliability of RLC is configurable: some radio bearers may tolerate rare losses (e.g. TCP traffic);
- Radio Bearers are not characterized by a fixed sized data unit (e.g. a fixed sized RLC PDU).

6.2.1 Services and Functions

The main services and functions of the RLC sublayer include:

- Transfer of upper layer PDUs supporting AM or UM;
- TM data transfer;
- Error Correction through ARQ (CRC check provided by the physical layer, in other words no CRC needed at RLC level);
- Segmentation according to the size of the TB: only if an RLC SDU does not fit entirely into the TB then the RLC SDU is segmented into variable sized RLC PDUs, which do not include any padding;
- Re-segmentation of PDUs that need to be retransmitted: if a retransmitted PDU does not fit entirely into the new TB used for retransmission then the RLC PDU is re-segmented;
- The number of re-segmentations is not limited;
- Concatenation of SDUs for the same radio bearer;
- In-sequence delivery of upper layer PDUs except at HO;
- Duplicate Detection;
- Protocol error detection and recovery;
- SDU discard;
- Reset.

6.2.2 PDU Structure

Figure 6.2.2-1 below depicts the RLC PDU structure where:

- The PDU sequence number carried by the RLC header is independent of the SDU sequence number (i.e. PDCP sequence number);
- A red dotted line indicates the occurrence of segmentation;
- Because segmentation only occurs when needed and concatenation is done in sequence, the content of an RLC PDU can generally be described by the following relations:
  - {0; 1} last segment of SDU_i + [0; n] complete SDUs + {0; 1} first segment of SDU_{i+n+1} ; or
  - 1 segment of SDU_i .

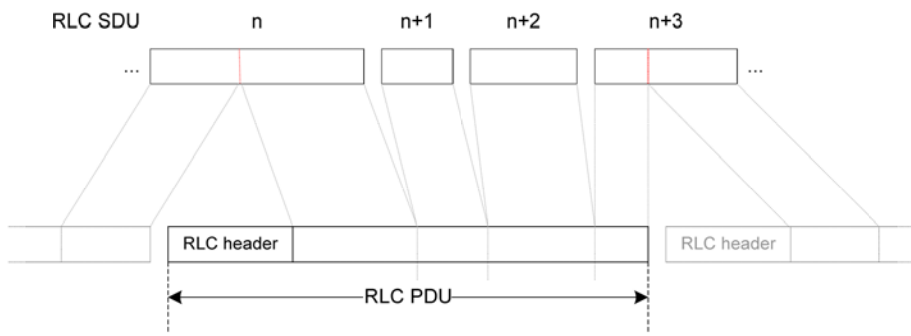

Figure 6.2.2-1: RLC PDU Structure

6.3 PDCP Sublayer

This subclause provides an overview on services, functions and PDU structure provided by the PDCP sublayer.

6.3.1 Services and Functions

The main services and functions of the PDCP sublayer for the user plane include:

- Header compression and decompression: ROHC only;
- Transfer of user data: transmission of user data means that PDCP receives PDCP SDU from the NAS and forwards it to the RLC layer and vice versa;
- In-sequence delivery of upper layer PDUs at handover for RLC AM;
- Duplicate detection of lower layer SDUs at handover for RLC AM;
- Retransmission of PDCP SDUs at handover for RLC AM;
- Ciphering;
- Timer-based SDU discard in uplink.

NOTE: When compared to UTRAN, the *lossless DL RLC PDU size change* is not required.

The main services and functions of the PDCP for the control plane include:

- Ciphering and Integrity Protection;
- Transfer of control plane data: transmission of control plane data means that PDCP receives PDCP SDUs from RRC and forwards it to the RLC layer and vice versa.

6.3.2 PDU Structure

Figure 6.3.2-1 below depicts the PDCP PDU structure where:

- PDCP PDU and PDCP header are octet-aligned;
- PDCP header can be either 1 or 2 bytes long.

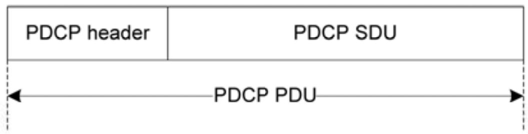

Figure 6.3.2-1: PDCP PDU Structure

6.4 Data flows through Layer 2

7 RRC

This subclause provides an overview on services and functions provided by the RRC sublayer.

7.1 Services and Functions

The main services and functions of the RRC sublayer include:

- Broadcast of System Information related to the non-access stratum (NAS);
- Broadcast of System Information related to the access stratum (AS);
- Paging;
- Establishment, maintenance and release of an RRC connection between the UE and E-UTRAN including:
  - Allocation of temporary identifiers between UE and E-UTRAN;
  - Configuration of signalling radio bearer(s) for RRC connection:
    - Low priority SRB and high priority SRB.
- Security functions including key management;
- Establishment, configuration, maintenance and release of point to point Radio Bearers;
- Mobility functions including:
  - UE measurement reporting and control of the reporting for inter-cell and inter-RAT mobility;
  - Inter-cell handover;
  - UE cell selection and reselection and control of cell selection and reselection;
  - Context transfer between eNBs.
- Notification for MBMS services;
- Establishment, configuration, maintenance and release of Radio Bearers for MBMS services;
- QoS management functions;

- UE measurement reporting and control of the reporting;
- NAS direct message transfer to/from NAS from/to UE.

7.2 RRC protocol states & state transitions

RRC uses the following states:

- **RRC_IDLE**:
  - PLMN selection;
  - DRX configured by NAS (Option to have UE specific DRX is FFS);
  - Broadcast of system information;
  - Paging;
  - Cell re-selection mobility;
  - The UE shall have been allocated an id which uniquely identifies the UE in a tracking area;
  - No RRC context stored in the eNB.
- **RRC_CONNECTED**:
  - UE has an E-UTRAN-RRC connection;
  - UE has context in E-UTRAN;
  - E-UTRAN knows the cell which the UE belongs to;
  - Network can transmit and/or receive data to/from UE;
  - Network controlled mobility (handover and inter-RAT cell change order to GERAN with NACC);
  - Neighbour cell measurements;
  - At PDCP/RLC/MAC level:
    - UE can transmit and/or receive data to/from network;
    - UE monitors control signalling channel for shared data channel to see if any transmission over the shared data channel has been allocated to the UE;
    - UE also reports channel quality information and feedback information to eNB;
    - DRX period can be configured according to UE activity level for UE power saving and efficient resource utilization. This is under control of the eNB.

7.3 Transport of NAS messages

In E-UTRAN, NAS messages are either concatenated with RRC messages or carried in RRC without concatenation. Initial Direct Transfer is not used in E-UTRAN and no NAS message is concatenated with RRC connection request.

NOTE: NAS messages are integrity protected and ciphered by PDCP, in addition to the integrity protection and ciphering performed by NAS.

7.4 System Information

Scheduling information (indicating starting times) is provided for a group of system information blocks (SIBs) that have the same scheduling requirements (i.e. periodicity). RRC concatenates such a group of SIBs into a Scheduling Unit (SU) message. It is expected that typically 3 or 4 SUs will be used. The mapping of SIBs on to SUs may be configurable or fixed in the specification (FFS). When multiple SUs are sent in the same TTI, they are mapped on the same downlink transport block.

The following system information is carried on the BCH:

- Physical layer parameters:
  - Downlink system bandwidth [4 bits];
  - Number of transmit antennas [1..2 bits];
  - Reference-Signal transmit power [0..6 bits];
- System Frame Number (SFN [10 bits], unless provided otherwise);
- Scheduling information of the most frequently repeated Scheduling Unit (SU-1) (FFS) [1 bit];

The system information carried on BCH is contained in a System Information Block called the Master Information Block (MIB).

All system information other than contained in the MIB is carried on DL-SCH. The following system information is carried within the most frequently repeated Scheduling Unit (SU-1):

- One or more PLMN identities;
- Tracking Area Code;
- Cell identity;
- One bit for "cell barring" common for all sharing PLMNs;
- One bit for "cell reserved for operator use" per sharing PLMN (up to 6);
- One bit for "cell reservation extension" common for all sharing PLMNs;
- Value_tag (Common for all SUs);
- Scheduling information i.e. the periodicity of the other Scheduling Units (other than SU-1);
- SIB mapping information i.e. indication in which SU the SIB is included (FFS).

The scheduling information, as contained within SU-1, is carried in a System Information Block called the Scheduling Block (SB). Besides this SB, SU-1 includes one or more other SIBs. SU-1 should include all access restriction related parameters. SU-1 is carried on the DL-SCH and uses a fixed schedule with a periodicity of 80 ms.

In the case of TDD, BCCH indicates the frame configuration.

SU-1 is scheduled in the subframe #5 for frame structure Type 1 (FDD and TDD). For frame structure Type 2, SU-1 is scheduled in subframe #0 of the second half frame. Different frame structure types are described in TS 36.211 [4]. It is FFS if further SUs are scheduled in subsequent consecutive subframes. The eNB may schedule DL-SCH transmissions concerning logical channels other than BCCH in the same subframe as used for BCCH. The minimum UE capability restricts the BCCH mapped to DL-SCH e.g. regarding the maximum rate. It is FFS if the eNB may schedule more than one SU in a subframe.

During RRC_IDLE state, the UE can identify changes in system information through paging message, so that the UE is not required to do any additional reception activities except from time instants when the UE receives paging channel.

During RRC_CONNECTED state, the UEs checks periodically to identify changes in system information. Whenever a change is detected, all SUs that are relevant to the UE are refreshed.

For very dynamic SI change handling (e.g. similar to SIB7 of UTRAN) UE timer based approach is used.

System information may also be provided to the UE by means of dedicated signalling e.g. upon handover.

7.5 RRC Procedures

8 E-UTRAN identities

8.1 E-UTRAN related UE identities

The following E-UTRAN related UE identities are used:

a) C-RNTI:

- The C-RNTI provides a unique UE identification at the cell level identifying RRC Connection;
- It is assumed that this identity is used for scheduling unless the cost would turn out to be too high and the introduction of a separate MAC identity would be required.

b) Random value for contention resolution:

- During some transient states, the UE is temporarily identified with a random value for contention resolution purposes.

8.2 Network entity related Identities

The following identities are used in E-UTRAN for identifying a specific network entity:

a) MME identity:

- a UE in ECM-IDLE establishing an RRC connection has to provide a unique identification of its current MME to the eNB in order for the eNB to fetch the UE context from the MME;
- Within the S-TMSI, one field contains the identifier of the MME that allocated the S-TMSI. The identifier of MME is needed to ensure that the S-TMSI remains unique in a tracking area shared by multiple MMEs.

b) eNB identity or cell identity (FFS):

- The signalling sequence to be followed in case a UE in ECM-CONNECTED accesses a cell in which no UE context has been established yet (kind of "cell update") is currently not agreed. Identified options are:
    1) In order to obtain the UE context/data from the old eNB, the new eNB directly contacts the old eNB without consulting the MME;
    2) In order to obtain the UE context/data from the old eNB, the new eNB consults the MME to obtain the identity of the old eNB;
    3) In order to obtain a UE context, the new eNB contacts the MME.
- If it is required for the new eNB to be able to contact the old eNB without involving the MME (case 1 above), the UE has to provide a network entity related identification that enables the new eNB to contact the old eNB, and that enables the old eNB to uniquely identify the UE for retrieving the correct UE context. For this purpose either an eNB identity or cell identity could be used.

c) Tracking Area identity (TAI):

- This is the identity used to identify tracking areas. The Tracking Area Identity is constructed from the MCC (Mobile Country Code), MNC (Mobile Network Code) and TAC (Tracking Area Code).

The following identities are broadcast in every E-UTRAN cell:

a) Cell identity:

- Uniquely identifying the cell in the area (size of area is FFS).

b) Tracking Area identity:

- Tracking Area this cell belongs to.

c) One or more PLMNs:

- PLMN (s) for which this cell is providing radio access.

9 ARQ and HARQ

E-UTRAN provides ARQ and HARQ functionalities. The ARQ functionality provides error correction by retransmissions in acknowledged mode at Layer 2. The HARQ functionality ensures delivery between peer entities at Layer 1.

9.1 HARQ principles

The HARQ within the MAC sublayer has the following characteristics:

- N-process Stop-And-Wait;
- HARQ transmits and retransmits transport blocks;
- In the downlink:
  - Asynchronous adaptive HARQ;
  - Uplink ACK/NAKs in response to downlink (re)transmissions are sent on PUCCH or PUSCH;
  - PDCCH signals the HARQ process number and if it is a transmission or retransmission;
  - Retransmissions are always scheduled through PDCCH.
- In the uplink:
  - Synchronous HARQ;
  - Maximum number of retransmissions configured per UE (as opposed to per radio bearer);
  - Downlink ACK/NAKs in response to uplink (re)transmissions are sent on PHICH;
  - Non-adaptive retransmissions (compared to the previous (re)transmission) are triggered by a NACK on PHICH only, while adaptive retransmissions are scheduled through PDCCH;
- Measurement gaps are of higher priority than HARQ retransmissions: whenever an HARQ retransmission collides with a measurement gap, the HARQ retransmission does not take place.

9.2 ARQ principles

The ARQ within the RLC sublayer has the following characteristics:

- ARQ retransmits RLC PDUs or RLC PDU segments;
  - ARQ retransmissions are based on RLC status reports, and optionally can also be based on HARQ/ARQ interactions (see subclause 9.3).
- Polling for RLC status report is used when needed by RLC;
- Status reports can be triggered by upper layers.

9.3 HARQ/ARQ interactions

In HARQ assisted ARQ operation, ARQ uses knowledge obtained from the HARQ about the transmission status of a TB: if the HARQ transmitter detects a failed delivery of a TB due to e.g. maximum retransmission limit is reached, the relevant transmitting ARQ entities are notified and potential retransmissions and re-segmentation can be initiated.

10 Mobility

Load balancing is achieved in E-UTRAN with redirection mechanisms (upon RRC establishment, in RRC_CONNECTED and upon RRC release) and through the usage of inter-frequency and inter-RAT Qoffset.

Measurements to be performed by a UE for mobility are classified in at least three measurement types:

- Intra-frequency E-UTRAN measurements;
- Inter-frequency E-UTRAN measurements;
- Inter-RAT measurements for UTRAN and GERAN.

For each measurement type a measurement identity is used by E-UTRAN when configuring measurements as well as by the UE when reporting results of the measurements. Measurement quantities and reporting events are considered separately for each measurement type. Measurement commands are used by E-UTRAN to order the UE to start measurements, modify measurements or stop measurements. Three reporting criteria are used: event triggered reporting, periodic reporting and event triggered periodic reporting.

10.1 Intra E-UTRAN

In E-UTRAN RRC_CONNECTED state, network-controlled UE-assisted handovers are performed and various DRX cycles are supported.

In E-UTRAN RRC_IDLE state, cell reselections are performed and DRX is supported.

10.1.1 Mobility Management in ECM-IDLE

10.1.1.1 Cell selection

The principles of PLMN selection in E-UTRA are based on the 3GPP PLMN selection principles. Cell selection is required on transition from EMM_DETACHED to EMM-REGISTERED and from ECM-IDLE or ECM-CONNECTED.

Cell selection:

- The UE NAS identifies a selected PLMN and equivalent PLMNs;
- The UE searches the E-UTRA frequency bands and for each carrier frequency identifies the strongest cell. It reads cell system information broadcast to identify its PLMN(s):
    - The UE may search each carrier in turn ("initial cell selection") or make use of stored information to shorten the search ("stored information cell selection").
- The UE seeks to identify a suitable cell; if it is not able to identify a suitable cell it seeks to identify an acceptable cell. When a suitable cell is found or if only an acceptable cell is found it camps on that cell and commence the cell reselection procedure:
    - A suitable cell is one for which the measured cell attributes satisfy the cell selection criteria; the cell PLMN is the selected PLMN, registered or an equivalent PLMN; the cell is not barred or reserved and the cell is not part of a tracking area which is in the list of "forbidden tracking areas for roaming";
    - An acceptable cell is one for which the measured cell attributes satisfy the cell selection criteria and the cell is not barred;

Transition to RRC_IDLE:

On transition from RRC_CONNECTED to RRC_IDLE, a UE should camp on the last cell for which it was in RRC_CONNECTED or a cell/any cell of set of cells or frequency be assigned by RRC in the state transition message.

Recovery from out of coverage:

The UE should attempt to find a suitable cell in the manner described for stored information or initial cell selection above. If no suitable cell is found on any frequency or RAT the UE should attempt to find an acceptable cell.

10.1.1.2 Cell reselection

UE in RRC_IDLE performs cell reselection. The principles of the procedure are the following:

- The UE makes measurements of attributes of the serving and neighbour cells to enable the reselection process:
  - There is no need to indicate neighbouring cell in the serving cell system information to enable the UE to search and measure a cell i.e. E-UTRAN relies on the UE to detect the neighbouring cells;
  - For the search and measurement of inter-frequency neighbouring cells, only the carrier frequencies need to be indicated;
  - Measurements may be omitted if the serving cell attribute fulfils particular search or measurement criteria.
- Cell reselection identifies the cell that the UE should camp on. It is based on cell reselection criteria which involves measurements of the serving and neighbour cells:
  - Intra-frequency reselection is based on ranking of cells;
  - Inter-frequency reselection is based on absolute priorities where UE tries to camp on highest priority frequency available. Absolute priorities for reselection are provided only by the RPLMN and valid only within the RPLMN; priorities are given by the system information and valid for all UEs in a cell, specific priorities per UE can be signalled in the RRC Connection Release message. A validity time can be associated with UE specific priorities.
  - For inter-frequency neighbouring cells, it is possible to indicate layer-specific cell reselection parameters (e.g., layer specific offset). These parameters are common to all neighbouring cells on a frequency;
  - An NCL can optionally be provided by the serving cell to handle specific cases for intra- and inter-frequency neighbouring cells. This NCL can contain cell specific cell reselection parameters (e.g., cell specific offset) for specific neighbouring cells;
  - It should be possible to prevent the UE from reselecting to specific detected neighbouring cells;
  - Cell reselection can be speed dependent (speed detection based on UTRAN solution);
  - Cell reselection parameters are applicable for all UEs in a cell, but it is possible to configure specific reselection parameters per UE group or per UE.

Cell access restrictions apply as for UTRAN, which consist of access class (AC) barring and cell reservation (e.g. for cells "reserved for operator use") applicable for mobiles in RRC_IDLE mode.

10.1.1.3 Handling in eNB

10.1.1.4 Handling above eNB

10.1.1.5 Mobility Management Entity (MME)

10.1.2 Mobility Management in ECM-CONNECTED

The Intra-E-UTRAN-Access Mobility Support for UEs in ECM-CONNECTED handles all necessary steps for relocation/handover procedures, like processes that precede the final HO decision on the source network side (control and evaluation of UE and eNB measurements taking into account certain UE specific area restrictions), preparation of resources on the target network side, commanding the UE to the new radio resources and finally releasing resources on the (old) source network side. It contains mechanisms to transfer context data between evolved nodes, and to update node relations on C-plane and U-plane.

In E-UTRAN RRC_CONNECTED state, network-controlled UE-assisted handovers are performed and various DRX cycles are supported:

The UE makes measurements of attributes of the serving and neighbour cells to enable the process:

- There is no need to indicate neighbouring cell to enable the UE to search and measure a cell i.e. E-UTRAN relies on the UE to detect the neighbouring cells;
- For the search and measurement of inter-frequency neighbouring cells, only the carrier frequencies need to be indicated (other information FFS);
- Network signals reporting criteria for event-triggered and periodical reporting;
- An NCL can optionally be provided by the serving cell to handle specific cases. This NCL can contain cell specific cell reselection parameters (e.g. cell specific offset) for specific neighbouring cells.

Depending on whether the UE needs transmission/reception gaps to perform the relevant measurements, measurements are classified as gap assisted or non-gap assisted. A non-gap assisted measurement is a measurement on a cell that does not require transmission/reception gaps to allow the measurement to be performed. A gap assisted measurement is a measurement on a cell that does require transmission/reception gaps to allow the measurement to be performed. Gap patterns (as opposed to individual gaps) are configured and activated by RRC.

10.1.2.1 Handover

The intra E-UTRAN HO in RRC_CONNECTED state is UE assisted NW controlled HO, with HO preparation signalling in E-UTRAN:

- Part of the HO command comes from the target eNB and is transparently forwarded to the UE by the source eNB;
- The QoS profiles in use by the UE (EPS bearer attributes) are sent to the target eNB by the source eNB, and it is FFS if also the currently used AS configuration is sent (intra-MME case);
- Both the source eNB and UE keep some context (e.g. C-RNTI) to enable the return of the UE in case of HO failure;
- UE accesses the target cell via RACH following a contention-free procedure using a dedicated RACH preamble or following a contention-based procedure if dedicated RACH preambles are not available:
  - If an end-time is associated to the dedicated preamble, the UE follows a contention-based procedure after reaching the end time;
  - If an end-time is not associated to the dedicated preamble, the UE uses the dedicated preamble until the handover procedure is finished (successfully or unsuccessfully);
- If the RACH procedure towards the target cell is not successful within a certain time, the UE initiates radio link failure recovery using the best cell;

- No ROHC context is transferred during inter eNB mobility.

10.1.2.1.1 C-plane handling

The HO procedure is performed without EPC involvement, i.e. preparation messages are directly exchanged between the eNBs. The release of the resources at the source side during the HO completion phase is triggered by the eNB. The figure below depicts the basic handover scenario where neither MME nor Serving Gateway changes:

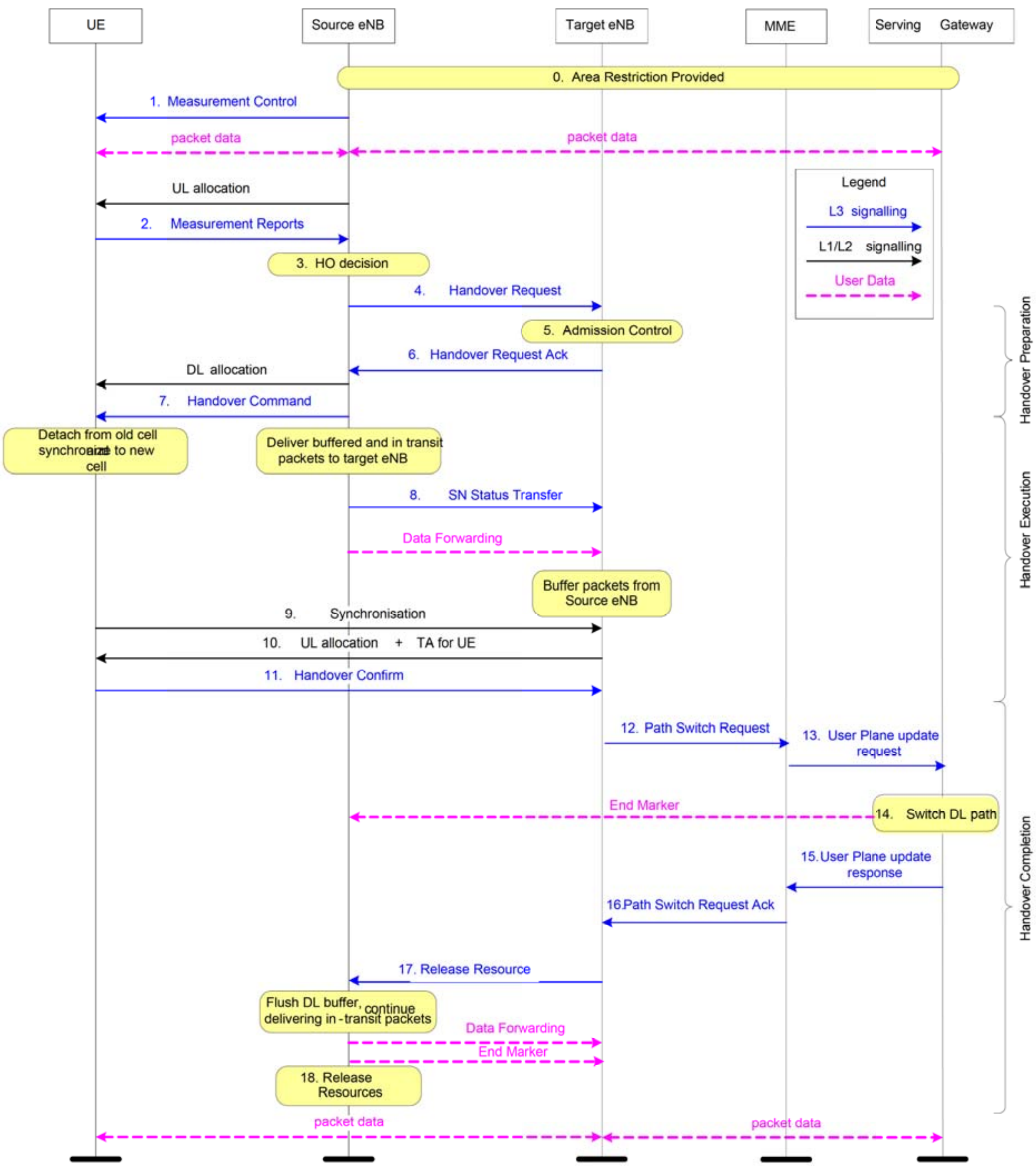

Figure 10.1.2.1.1-1: Intra-MME/Serving Gateway HO

Below is a more detailed description of the intra-MME/Serving Gateway HO procedure:

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0 The UE context within the source eNB contains information regarding roaming restrictions which where provided either at connection establishment or at the last TA update.

1 The source eNB configures the UE measurement procedures according to the area restriction information. Measurements provided by the source eNB may assist the function controlling the UE's connection mobility.

2 UE is triggered to send MEASUREMENT REPORT by the rules set by i.e. system information, specification etc.

3 Source eNB makes decision based on MEASUREMENT REPORT and RRM information to hand off UE.

4 The source eNB issues a HANDOVER REQUEST message to the target eNB passing necessary information to prepare the HO at the target side (UE X2 signalling context reference at source eNB, UE S1 EPC signalling context reference, target cell ID, K_{eNB*}, RRC context including the C-RNTI of the UE in the source eNB, AS-configuration (excluding physical layer configuration), EPS bearer context and physical layer ID of the source cell + MAC for possible RLF recovery). UE X2 / UE S1 signalling references enable the target eNB to address the source eNB and the EPC. The EPS bearer context includes necessary RNL and TNL addressing information, and QoS profiles of the EPS bearers.

5 Admission Control may be performed by the target eNB dependent on the received EPS bearer QoS information to increase the likelihood of a successful HO, if the resources can be granted by target eNB. The target eNB configures the required resources according to the received EPS bearer QoS information and reserves a C-RNTI and optionally a RACH preamble. The AS-configuration to be used in the target cell can either be specified independently (i.e. an "establishment") or as a delta compared to the AS-configuration used in the source cell (i.e. a "reconfiguration").

6 Target eNB prepares HO with L1/L2 and sends the HANDOVER REQUEST ACKNOWLEDGE to the source eNB. The HANDOVER REQUEST ACKNOWLEDGE message includes a transparent container to be sent to the UE as part of the Handover Command. The container includes a new C-RNTI, target eNB security algorithm identifiers for the selected security algorithms, may include a dedicated RACH preamble, indication of the expiry time of the dedicated RACH preamble, and possibly some other parameters i.e. access parameters, SIBs, etc. The HANDOVER REQUEST ACKNOWLEDGE message may also include RNL/TNL information for the forwarding tunnels, if necessary.

NOTE: As soon as the source eNB receives the HANDOVER REQUEST ACKNOWLEDGE, or as soon as the transmission of the handover command is initiated in the downlink, data forwarding may be initiated.

Steps 7 to 16 provide means to avoid data loss during HO and are further detailed in 10.1.2.1.2 and 10.1.2.3.

7 The source eNB generates the HANDOVER COMMAND (RRC message) towards the UE. The HANDOVER COMMAND includes the transparent container, which has been received from the target eNB. The source eNodeB performs the necessary integrity protection and ciphering of the message. The UE receives the HANDOVER COMMAND with necessary parameters (i.e. new C-RNTI, target eNB security algorithm identifiers, and optionally dedicated RACH preamble, possible expiry time of the dedicated RACH preamble, target eNB SIBs etc) and is commanded by the source eNB to perform the HO. The UE does not need to delay the handover execution for delivering the HARQ/ARQ responses to source eNB.

8 The source eNB sends the SN STATUS TRANSFER message to the target eNB to convey the uplink PDCP SN receiver status and the downlink PDCP SN transmitter status of SAE bearers for which PDCP status preservation applies. The uplink PDCP SN receiver status includes at least the PDCP SN of the last in-sequence received UL SDU and may include a bit map of the receive status of the out of sequence missing (FFS) UL SDUs that the UE may need to retransmit in the target cell, if there are any such SDUs. The downlink PDCP SN transmitter status indicates the next PDCP SN that the target eNB shall assign to new SDUs, not having a PDCP SN yet. The source eNB may omit sending this message if none of the SAE bearers of the UE shall be treated with PDCP status preservation.

9 After receiving the HANDOVER COMMAND, UE performs synchronisation to target eNB and accesses the target cell via RACH following a contention-free procedure if a dedicated RACH preamble was allocated in HANDOVER COMMAND or following a contention-based procedure if no dedicated preamble was allocated. UE derives target eNB specific keys and configures the selected security algorithms to be used in the target cell.

10 Network responds with UL allocation and timing advance.

11 When the UE has successfully accessed the target cell, the UE sends the HANDOVER CONFIRM message (C-RNTI) along with an uplink Buffer Status Report when required to the target eNB to indicate that the handover

procedure is completed for the UE. The target eNB verifies the C-RNTI sent in the HANDOVER CONFIRM message. The target eNB can now begin sending data to the UE. Based on further optimizations, the downlink data transmission can begin as early as after step 8.

12 The target eNB sends a PATH SWITCH message to MME to inform that the UE has changed cell.

13 The MME sends a USER PLANE UPDATE REQUEST message to the Serving Gateway.

14 The Serving Gateway switches the downlink data path to the target side. The Serving gateway sends one or more "end marker" packets on the old path to the source eNB and then can release any U-plane/TNL resources towards the source eNB.

15 Serving Gateway sends a USER PLANE UPDATE RESPONSE message to MME.

16 The MME confirms the PATH SWITCH message with the PATH SWITCH ACK message.

17 By sending RELEASE RESOURCE the target eNB informs success of HO to source eNB and triggers the release of resources. The target eNB sends this message after the PATH SWITCH ACK message is received from the MME.

18 Upon reception of the RELEASE RESOURCE message, the source eNB can release radio and C-plane related resources associated to the UE context.

NOTE: Details on updating of roaming/area restriction information within E-UTRAN in the course of the HO procedure are FFS

With respect to SRBs, the following principles apply:

- No forwarding or retransmissions of RRC messages in the target;
- The PDCP SN and HFN are reset in the target eNB.

10.1.2.1.2 U-plane handling

The U-plane handling during the Intra-E-UTRAN-Access mobility activity for UEs in ECM-CONNECTED takes the following principles into account to avoid data loss during HO:

- During HO preparation U-plane tunnels can be established between the source eNB and the target eNB. There is one tunnel established for uplink data forwarding and another one for downlink data forwarding for each SAE bearer for which data forwarding is applied.
- During HO execution, user data can be forwarded from the source eNB to the target eNB. The forwarding may take place in a service and deployment dependent and implementation specific way.
  - Forwarding of downlink user data from the source to the target eNB should take place in order as long as packets are received at the source eNB from the EPC or the source eNB buffer has not been emptied.
- During HO completion:
  - The target eNB sends a PATH SWITCH message to MME to inform that the UE has gained access and MME sends a USER PLANE UPDATE REQUEST message to the Serving Gateway, the U-plane path is switched by the Serving Gateway from the source eNB to the target eNB.
  - The source eNB should continue forwarding of U-plane data as long as packets are received at the source eNB from the Serving Gateway or the source eNB buffer has not been emptied.

For **RLC-AM bearers**:

- For in-sequence delivery and duplication avoidance, PDCP SN is maintained on a bearer basis and the source eNB informs the target eNB about the next DL PDCP SN to allocate to a packet which does not have a PDCP sequence number yet (either from source eNB or from the Serving Gateway).
- For security synchronisation, HFN is also maintained and the source eNB provides to the target one reference HFN for the UL and one for the DL i.e. HFN and corresponding SN.
- In both the UE and the target eNB, a window-based mechanism is needed for duplication detection.

- The occurrence of duplicates over the air interface in the target eNB is minimised by means of PDCP SN based reporting at the target eNB by the UE. In uplink, the reporting is optionally configured on a bearer basis by the eNB and the UE should first start by transmitting those reports when granted resources in the target eNB. In downlink, the eNB is free to decide when and for which bearers a report is sent and the UE does not wait for the report to resume uplink transmission.
- The target eNB re-transmits and prioritizes all downlink PDCP SDUs forwarded by the source eNB (i.e. the target eNB should send data with PDCP SNs from X2 before sending data from S1), with the exception of PDCP SDUs of which the reception was acknowledged through PDCP SN based reporting by the UE.
- The UE re-transmits in the target eNB all uplink PDCP SDUs starting from the first PDCP SDU following the last consecutively confirmed PDCP SDU i.e. the oldest PDCP SDU that has not been acknowledged at RLC in the source, excluding the PDCP SDUs of which the reception was acknowledged through PDCP SN based reporting by the target.

For **RLC-UM bearers**:

- The PDCP SN and HFN are reset in the target eNB.
- No PDCP SDUs are retransmitted in the target eNB.
- The target eNB prioritize all downlink PDCP SDUs forwarded by the source eNB if any (i.e. the target eNB should send data with PDCP SNs from X2 before sending data from S1),.
- The UE PDCP entity does not attempt to retransmit any PDCP SDU in the target cell for which transmission had been completed in the source cell. Instead UE PDCP entity starts the transmission with other PDCP SDUs.

10.1.2.2 Path Switch

After the downlink path is switched at the Serving GW downlink packets on the forwarding path and on the new direct path may arrive interchanged at the target eNB. The target eNodeB should first deliver all forwarded packets to the UE before delivering any of the packets received on the new direct path. The method employed in the target eNB to enforce the correct delivery order of packets is outside the scope of the standard.

In order to assist the reordering function in the target eNB, the Serving GW shall send one or more "end marker" packets on the old path immediately after switching the path for each SAE bearer of the UE. The "end marker" packet shall not contain user data. The "end marker" is indicated in the GTP header. After completing the sending of the tagged packets the GW shall not send any further user data packets via the old path.

Upon receiving the "end marker" packets, the source eNB shall, if forwarding is activated for that bearer, forward the packet toward the target eNB.

On detection of an "end marker" the target eNB shall discard the end marker packet and initiate any necessary processing to maintain in sequence delivery of user data forwarded over X2 interface and user data received from the serving GW over S1 as a result of the path switch.

10.1.2.3 Data forwarding

10.1.2.3.1 For RLC-AM bearers

Upon handover, the source eNB forwards in order to the target eNB all downlink PDCP SDUs with their SN that have not been acknowledged by the UE. In addition, the source eNB may forward without a PDCP SN fresh data arriving over S1 to the target eNB. In addition, the source eNB may forward fresh data arriving over S1 to the target eNB.

NOTE: Target eNB does not have to wait for the completion of forwarding from the source eNB before it begins transmitting packets to the UE.

The source eNB discards any remaining downlink RLC PDUs. Correspondingly, the source eNB does not forward the downlink RLC context to the target eNB.

NOTE: Source eNB does not need to abort on going RLC transmissions with the UE as it starts data forwarding to the target eNB.

Upon handover, the source eNB forwards uplink PDCP SDUs successfully received in-sequence to the Serving Gateway, may forward uplink PDCP SDUs with their SN received out-of-sequence to the target eNB and shall discard any remaining uplink RLC PDUs. Correspondingly, the source eNB does not forward the uplink RLC context to the target eNB.

The PDCP SN of forwarded SDUs is carried in the "PDCP PDU number" field of the GTP-U extension header. The target eNB shall use the PDCP SN if it is available in the forwarded GTP-U packet.

In-sequence delivery of upper layer PDUs during handover is based on a continuous PDCP SN and is provided by the re-ordering function at the PDCP layer, which can be activated at least during inter-eNB mobility:

- in the downlink, the re-ordering function at the UE PDCP layer guarantees in-sequence delivery of downlink PDCP SDUs;

- in the uplink, the re-ordering function at the target eNB PDCP layer guarantees in-sequence delivery of uplink PDCP SDUs.

After handover, when the UE receives a PDCP SDU from the target eNB, it can deliver it to higher layer together with all PDCP SDUs with lower SNs regardless of possible gaps.

10.1.2.3.2 For RLC-UM bearers

Upon handover, the source eNB does not forward to the target eNB downlink PDCP SDUs for which transmission had been completed in the source cell. PDCP SDUs that have not been transmitted may be forwarded. In addition, the source eNB may forward fresh data arriving over S1 to the target eNB. The source eNB discards any remaining downlink RLC PDUs. Correspondingly, the source eNB does not forward the downlink RLC context to the target eNB.

Upon handover, the source eNB forwards all uplink PDCP SDUs successfully received to the Serving Gateway and discards any remaining uplink RLC PDUs. Correspondingly, the source eNB does not forward the uplink RLC context to the target eNB.

10.1.2.4 Handling in eNB

10.1.2.5 Handling above eNB

10.1.2.6 Mobility Management Entity (MME)

10.1.2.7 Timing Advance

In RRC_CONNECTED, the eNB is responsible for maintaining the timing advance. In some cases (e.g. during DRX), the timing advance is not necessarily always maintained and the MAC sublayer knows if the L1 is synchronised and which procedure to use to start transmitting in the uplink:

- as long as the L1 is non-synchronised, uplink transmission can only take place on PRACH.

For one UE, cases where the UL synchronisation status moves from "synchronised" to "non-synchronised" include:

- Expiration of a timer;

- Non-synchronised handover;

- Explicit request by MAC or RRC in the eNB (FFS);

The value of the timer is either UE specific and managed through dedicated signalling between the UE and the eNB, or cell specific and indicated via broadcast information. In both cases, the timer is always restarted whenever a new timing advance is given by the eNB:

- restarted to a UE specific value if any; or

- restarted to a cell specific value otherwise.

Upon DL data arrival, dedicated signature on PRACH can be allocated by the eNB to UE. When a dedicated signature on PRACH is allocated, the UE shall perform the corresponding random access procedure regardless of its L1 synchronisation status.

TA updates are signalled by the eNB to the UE in MAC PDUs addressed via C-RNTI, and embedded with user data or alone.

10.1.3 Measurements

Measurements to be performed by a UE for intra/inter-frequency mobility can be controlled by E-UTRAN, using broadcast or dedicated control. In RRC_IDLE state, a UE shall follow the measurement parameters defined for cell reselection specified by the E-UTRAN broadcast (as in UTRAN SIB). The use of dedicated measurement control for RRC_IDLE state is FFS. In RRC_CONNECTED state, a UE shall follow the measurement configurations specified by RRC directed from the E-UTRAN (e.g. as in UTRAN MEASUREMENT_CONTROL).

Intra-frequency neighbour (cell) measurements and inter-frequency neighbour (cell) measurements are defined as follows:

- Intra-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are intra-frequency measurements when the current and target cell operates on the same carrier frequency. The UE shall be able to carry out such measurements without measurement gaps.

- Inter-frequency neighbour (cell) measurements: Neighbour cell measurements performed by the UE are inter-frequency measurements when the neighbour cell operates on a different carrier frequency, compared to the current cell. The UE should not be assumed to be able to carry out such measurements without measurement gaps.

Whether a measurement is non gap assisted or gap assisted depends on the UE's capability and current operating frequency. The UE determines whether a particular cell measurement needs to be performed in a transmission/reception gap and the scheduler needs to know whether gaps are needed:

- Same carrier frequency and cell bandwidths (Scenario A): an intra-frequency scenario; not measurement gap assisted.

- Same carrier frequency, bandwidth of the target cell smaller than the bandwidth of the current cell (Scenario B): an intra-frequency scenario; not measurement gap assisted.

- Same carrier frequency, bandwidth of the target cell larger than the bandwidth of the current cell (Scenario C): FFS.

- Different carrier frequencies, bandwidth of the target cell smaller than the bandwidth of the current cell and bandwidth of the target cell within bandwidth of the current cell (Scenario D): an inter-frequency scenario; measurement gap-assisted scenario.

- Different carrier frequencies, bandwidth of the target cell larger than the bandwidth of the current cell and bandwidth of the current cell within bandwidth of the target cell (Scenario E): an inter-frequency scenario; measurement gap-assisted scenario.

- Different carrier frequencies and non-overlapping bandwidth, (Scenario F): an inter-frequency scenario; measurement gap-assisted scenario.

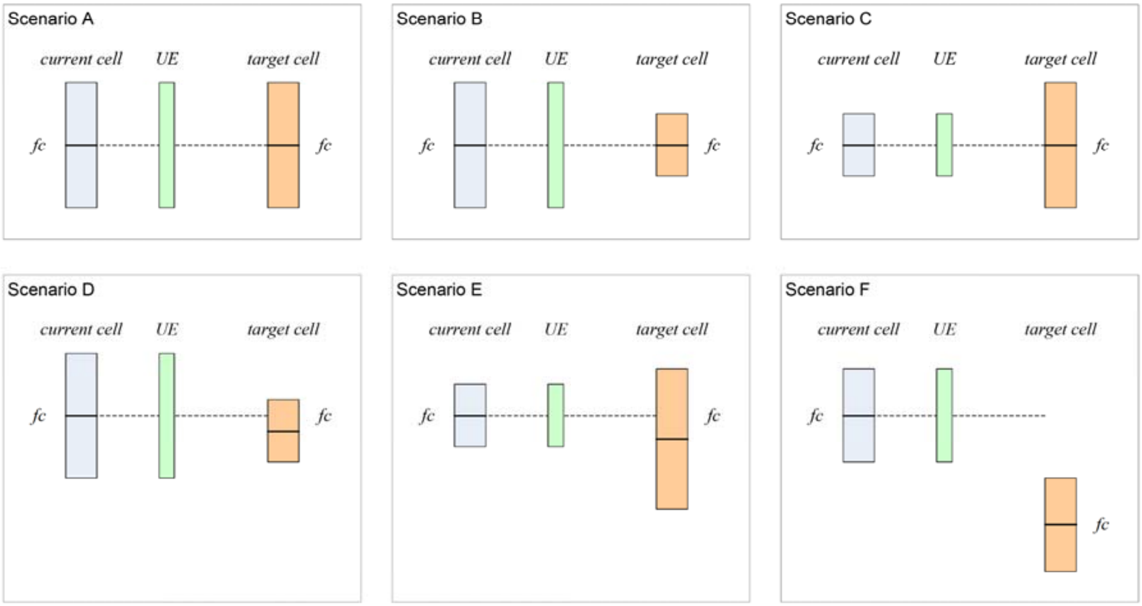

Figure 10.1.3-1: Inter and Intra-frequency measurements scenarios

Measurement gaps patterns are configured and activated by RRC. Measurement gaps are of higher priority than HARQ retransmissions i.e. if an HARQ retransmissions collides with a measurement gap, the HARQ retransmission does not take place.

10.1.3.1 Intra-frequency neighbour (cell) measurements

In a system with frequency reuse = 1, mobility within the same frequency layer (i.e. between cells with the same carrier frequency) is predominant. Good neighbour cell measurements are needed for cells that have the same carrier frequency as the serving cell in order to ensure good mobility support and easy network deployment. Search for neighbour cells with the same carrier frequency as the serving cell, and measurements of the relevant quantities for identified cells are needed.

NOTE: To avoid UE activity outside the DRX cycle, the reporting criteria for neighbour cell measurements should match the used DRX cycle.

10.1.3.2 Inter-frequency neighbour (cell) measurements

Regarding mobility between different frequency layers (i.e. between cells with a different carrier frequency), UE may need to perform neighbour cell measurements during DL/UL idle periods that are provided by DRX or packet scheduling (i.e. gap assisted measurements).

10.1.4 Paging and C-plane establishment

Paging groups (where multiple UEs can be addressed) are used on L1/L2 signalling channel:

- Precise UE identity is found on PCH;
- DRX configurable via BCCH (UE specific DRX is FFS);
- Only one subframe allocated per paging interval per UE;
- The network may divide UEs to different paging occasions in time;
- There is no grouping within paging occasion;
- One paging RNTI for PCH.

10.1.5 Random Access Procedure

The random access procedure is characterized by:

- Common procedure for FDD and TDD;
- One procedure irrespective of cell size;

The random access procedure is performed for the following five events:

- Initial access from RRC_IDLE;
- Initial access after radio link failure;
- Handover requiring random access procedure;
- DL data arrival during RRC_CONNECTED requiring random access procedure;
  - E.g. when UL synchronisation status is "non-synchronised";
- UL data arrival during RRC_CONNECTED requiring random access procedure;
  - E.g. when UL synchronisation status is "non-synchronised" or there are no PUCCH resources for SR available.

Furthermore, the random access procedure takes two distinct forms:

- Contention based (applicable to all five events);
- Non-contention based (applicable to only handover and DL data arrival).

Normal DL/UL transmission can take place after the random access procedure.

10.1.5.1 Contention based random access procedure

The contention based random access procedure is outlined on Figure 10.1.5.1-1 below:

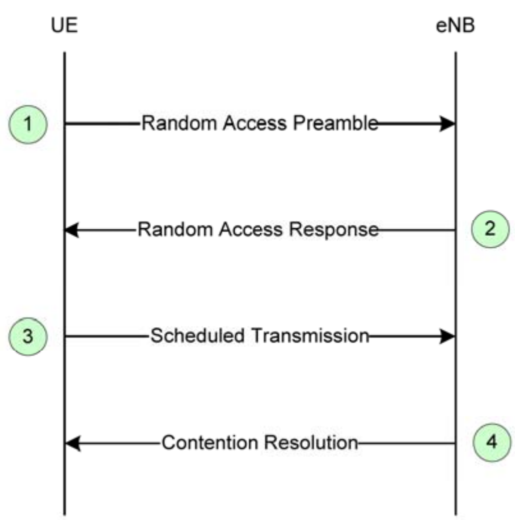

Figure 10.1.5.1-1: Contention based Random Access Procedure

The four steps of the contention based random access procedures are:

1) Random Access Preamble on RACH in uplink:
   - 6 bits to carry: a 5 bit random ID, and 1 bit to indicate information on size of message 3 or requested resource blocks (FFS) limited by radio conditions. The groups of signatures that are used for indicating the 1 bit information, as well as necessary thresholds are broadcast on system information.

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NOTE: the total number of bits is 5 for TDD Frame Structure Type II.

2) Random Access Response generated by MAC on DL-SCH:

- Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
- No HARQ;
- Addressed to RA-RNTI on L1/L2 control channel;
- Conveys at least RA-preamble identifier, Timing Alignment information, initial UL grant and assignment of Temporary C-RNTI (which may or may not be made permanent upon RRC Contention Resolution);
- Intended for a variable number of UEs in one DL-SCH message.

3) First scheduled UL transmission on UL-SCH:

- Uses HARQ;
- Size of the transport blocks depends on the UL grant conveyed in step 2 and is at least 80 bits.
- For initial access:
  - Conveys the RRC Connection Request generated by the RRC layer and transmitted via CCCH;
  - Conveys at least NAS UE identifier but no NAS message;
  - RLC TM: no segmentation;
- After radio link failure:
  - Conveys the RRC Connection Re-establishment Request generated by the RRC layer and transmitted via CCCH;
  - RLC TM: no segmentation;
  - Does not contain any NAS message.
- After handover, in the target cell:
  - Conveys the ciphered and integrity protected RRC Handover Confirm generated by the RRC layer and transmitted via DCCH;
  - Conveys the C-RNTI of the UE (which was allocated via the Handover Command);
  - Includes an uplink Buffer Status Report when possible.
- For other events:
  - Conveys at least the C-RNTI of the UE.

4) Contention Resolution on DL-SCH:

- Early contention resolution shall be used i.e. eNB does not wait for NAS reply before resolving contention
- Not synchronised with message 3;
- HARQ is supported;
- Addressed to:
  - The Temporary C-RNTI on L1/L2 control channel for initial access and after radio link failure;
  - The C-RNTI for UE in RRC_CONNECTED;
- HARQ feedback is transmitted only by the UE which detects its own UE identity, as provided in message 3, echoed in the RRC Contention Resolution message;
- For initial access and after radio link failure, no segmentation is used (RLC-TM).

The Temporary C-RNTI is promoted to C-RNTI for a UE which detects RA success and does not already have a C-RNTI; it is dropped by others. A UE which detects RA success and already has a C-RNTI, resumes using its C-RNTI.

10.1.5.2 Non-contention based random access procedure

The non-contention based random access procedure is outlined on Figure 10.1.5.2-1 below:

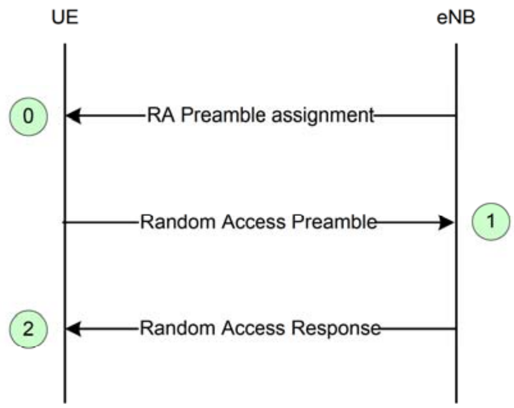

Figure 10.1.5.2-1: Non-contention based Random Access Procedure

The three steps of the non-contention based random access procedures are:

0) Random Access Preamble assignment via dedicated signalling in DL:
   - eNB assigns to UE a non-contention Random Access Preamble (a Random Access Preamble not within the set broadcasted on BCH).
   - Signalled via:
     - HO command generated by target eNB and sent via source eNB for handover;
     - MAC signalling (L1/L2 control channel or MAC control PDU is FFS) in case of DL data arrival.
1) Random Access Preamble on RACH in uplink:
   - UE transmits the assigned non-contention Random Access Preamble.
2) Random Access Response on DL-SCH:
   - Semi-synchronous (within a flexible window of which the size is one or more TTI) with message 1;
   - No HARQ;
   - Addressed to RA-RNTI on L1/L2 control channel;
   - Conveys at least:
     - Timing Alignment information and initial UL grant for handover;
     - Timing Alignment information for DL data arrival;
     - RA-preamble identifier.
     - Intended for one or multiple UEs in one DL-SCH message.

10.1.5.3 Interaction model between L1 and L2/3 for Random Access Procedure

Random access procedure described above is modelled in Figure 10.1.5.3-1 below from L1 and L2/3 interaction point of view. L2/L3 receives indication from L1 whether ACK is received or DTX is detected after indication of Random

Access Preamble transmission to L1. L2/3 indicates L1 to transmit first scheduled UL transmission (RRC Connection Request in case of initial access) if necessary or Random Access Preamble based on the indication from L1.

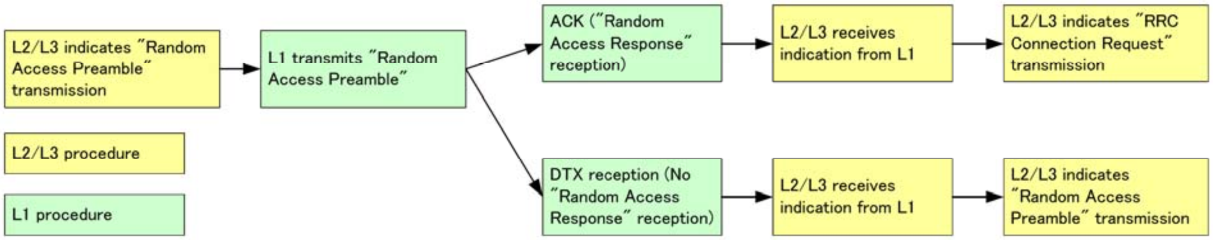

Figure 10.1.5.3-1: Interaction model between L1 and L2/3 for Random Access Procedure

10.1.6 Radio Link Failure

Two phases governs the behaviour associated to radio link failure as shown on Figure 10.1.6-1:

- First phase:
  - started upon radio problem detection;
  - leads to radio link failure detection;
  - no UE-based mobility;
  - based on timer or other (e.g. counting) criteria (T_1).
- Second Phase:
  - started upon radio link failure detection or handover failure;
  - leads to RRC_IDLE;
  - UE-based mobility;
  - Timer based (T_2).

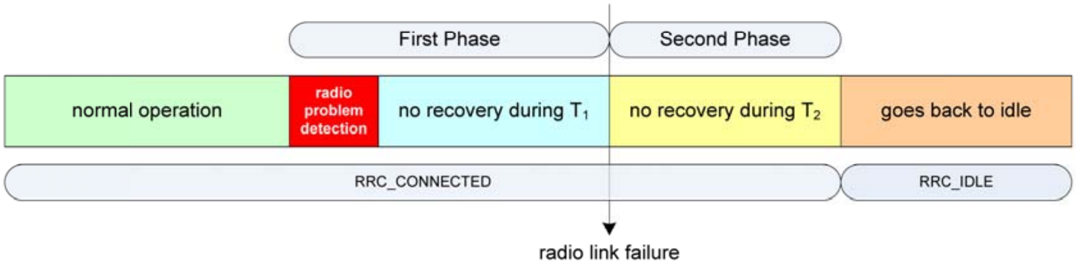

Figure 10.1.6-1: Radio Link Failure

Table 10.1.6-1 below describes how mobility is handled with respect to radio link failure:

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Table 10.1.6-1: Mobility and Radio Link Failure

Cases	First Phase	Second Phase	T2 expired
UE returns to the same cell	Continue as if no radio problems occurred	Activity is resumed by means of explicit signalling between UE and eNB	Go via RRC_IDLE
UE selects a different cell from the same eNB	N/A	Activity is resumed by means of explicit signalling between UE and eNB	Go via RRC_IDLE
UE selects a cell of a prepared eNB (NOTE)	N/A	Activity is resumed by means of explicit signalling between UE and eNB	Go via RRC_IDLE
UE selects a cell of a different eNB that is not prepared (NOTE)	N/A	Go via RRC_IDLE (FFS)	Go via RRC_IDLE
NOTE: a prepared eNB is an eNB which has admitted the UE during an earlier executed HO preparation phase.			

In the Second Phase, in order to resume activity and avoid going via RRC_IDLE when the UE returns to the same cell or when the UE selects a different cell from the same eNB, or when the UE selects a cell from a different eNB, the following procedure applies:

- The UE stays in RRC_CONNECTED;
- The UE accesses the cell through the random access procedure;
- The UE identifier used in the random access procedure for contention resolution (i.e. C-RNTI of the UE in the cell where the RLF occurred + physical layer identity of that cell + MAC based on the keys of that cell) is used by the selected eNB to authenticate the UE and check whether it has a context stored for that UE:
  - If the eNB finds a context that matches the identity of the UE, it indicates to the UE that its connection can be resumed;
  - If the context is not found, RRC connection is released and UE initiates procedure to establish new RRC connection. In this case UE may be required to go via RRC_IDLE (FFS).

10.1.7 Radio Access Network Sharing

E-UTRAN shall support radio access network sharing based on support for multi-to-multi relationship between E-UTRAN nodes and EPC nodes (S1-flex).

If the E-UTRAN is shared by multiple operators, the system information broadcasted in each shared cell contains the PLMN-id of each operator (up to 6) and a single tracking area code (TAC) valid within all the PLMNs sharing the radio access network resources.

The UE shall be able to read up to 6 PLMN-ids, to select one of the PLMN-ids at initial attachment and to indicate this PLMN-id to the E-UTRAN in subsequent instances of the Random Access procedures (e.g. as defined in subclause 10.1.5). The E-UTRAN shall select an appropriate MME for the PLMN indicated by the UE. Once attached to an MME, the UE shall be able to indicate the allocated MME in subsequent instances of the Random Access procedures. Whether the indication of the selected PLMN or the allocated MME is contained in the temporary UE identity or signalled separately is FFS.

Handling of area restrictions for UE in ECM-CONNECTED shall follow the principles specified in sub-clause 10.4.

10.1.8 Handling of Roaming and Area Restrictions for UEs in ECM-CONNECTED

Handling of roaming/area restrictions and handling of subscription specific preferences in ECM-CONNECTED is performed in the eNB based on information provided by the EPC over the S1 interface.

10.2 Inter RAT

Service-based redirection between GERAN / UTRAN and E-UTRAN is supported in both directions. This should not require inter-RAT reporting in RRC CONNECTION REQUEST.

10.2.1 Cell reselection

A UE in RRC_IDLE performs cell reselection. The principles of this procedure are as follows:

- The UE makes **measurements** of attributes of the serving and neighbour cells to enable the reselection process:
    - For a UE to search and measure neighbouring GERAN cells, the ARFCNs of the BCCH carriers need to be indicated in the serving cell system information (i.e., an NCL). The NCL does not contain BSICs or cell specific offsets and Qrxlevmin is given per frequency band.
    - For a UE to search and measure neighbouring UTRAN cells, the serving cell can indicate an NCL containing a list of carrier frequencies and scrambling codes.
    - Measurements may be omitted if the serving cell attribute fulfils particular search or measurement criteria.
- **Cell reselection** identifies the cell that the UE should camp on. It is based on cell reselection criteria which involves measurements of the serving and neighbour cells:
    - Inter-RAT reselection is based on absolute priorities where UE tries to camp on highest priority RAT available. Absolute priorities for inter-RAT reselection are provided only by the RPLMN and valid only within the RPLMN; priorities are given by the system information and valid for all UEs in a cell, specific priorities per UE can be signalled in the RRC Connection Release message. A validity time can be associated with UE specific priorities.
    - It should be possible to prevent the UE from reselecting to specific detected neighbouring cells;
    - The UE is allowed to "leave" the source E-UTRAN cell to read the target GERAN cell broadcast, in order to determine its "suitability", prior to completing the cell reselection;
    - Cell reselection can be speed dependent (speed detection based on UTRAN solution);

Cell access restrictions apply as for UTRAN, which consist of access class (AC) barring and cell reservation (e.g. for cells "reserved for operator use") applicable for mobiles in RRC_IDLE mode.

When performing cell reselection while the UE is camped on another RAT, the principles of this procedure are as follows:

- The UE measures attributes of the E-UTRA neighbouring cells:
    - Only the carrier frequencies need to be indicated to enable the UE to search and measure E-UTRA neighbouring cells;
- Cell reselection identifies the cell that the UE should camp on. It is based on cell reselection criteria which involves measurements of the serving and neighbour cells:
    - For E-UTRA neighbouring cells, there is no need to indicate cell-specific cell reselection parameters i.e. these parameters are common to all neighbouring cells on an E-UTRA frequency;
- Cell reselection parameters are applicable to all UEs in a cell, but it is possible to configure specific reselection parameters per UE group or per UE.
- It should be possible to prevent the UE from reselecting to specific detected neighbouring cells.

10.2.2 Handover

Inter RAT HO is designed so that changes to GERAN and UTRAN are minimised. This can be done by following the principles specified for GERAN to/from UTRAN intersystem HO. In particular the following principles are applied to E-UTRAN Inter RAT HO design:

1. Inter RAT HO is network controlled through source access system. The source access system decides about starting the preparation and provides the necessary information to the target system in the format required by the target system. That is, the source system adapts to the target system. The actual handover execution is decided in the source system.

2. Inter RAT HO is backwards handover, i.e. radio resources are prepared in the target 3GPP access system before the UE is commanded by the source 3GPP access system to change to the target 3GPP access system.

3. To enable backwards handover, and while RAN level interfaces are not available, a control interface exists in CN level. In Inter RAT HO involving E-UTRAN access, this interface is between 2G/3G SGSN and corresponding MME/Serving Gateway.

4. The target access system will be responsible for giving exact guidance for the UE on how to make the radio access there (this includes radio resource configuration, target cell system information etc.). This information is given during the handover preparation and should be transported completely transparently through the source access system to the UE.

5. Mechanisms for avoiding or mitigating the loss of user data (i.e. forwarding) can be used until the 3GPP Anchor determines that it can send DL U-plane data directly to the target system.

6. The handover procedure should not require any UE to CN signalling in order for data to start to flow in the target system. This requires that the security context, UE capability context and QoS context is transferred (or translated) within the network between source and target system.

7. Similar handover procedure should apply for handovers of both real time and non-real time services.

8. Similar handover procedure should apply for both Inter RAT Handover and intra-LTE Handover with EPC node change.

9. Network controlled mobility is supported even if no prior UE measurements have been performed on the target cell and/or frequency i.e. "blind HO" is supported.

10.2.2a Inter-RAT cell change order to GERAN with NACC

For interworking towards GERAN, inter-RAT cell change order with NACC is supported even if no prior UE measurements have been performed on the system i.e. "blind NACC" is supported.

10.2.3 Measurements

10.2.3.1 Inter-RAT handovers from E-UTRAN

Measurements to be performed by a UE for inter-RAT mobility can be controlled by E-UTRAN, using broadcast or dedicated control. In RRC_CONNECTED state, a UE shall follow the measurement parameters specified by RRC or MAC commands (FFS) directed from the E-UTRAN (e.g. as in UTRAN MEASUREMENT_CONTROL).

UE performs inter-RAT neighbour cell measurements during DL/UL idle periods that are provided by the network through suitable DRX/DTX period or packet scheduling if necessary.

10.2.3.2 Inter-RAT handovers to E-UTRAN

From UTRAN, UE performs E-UTRAN measurements by using idle periods created by compressed mode (CELL_DCH), FACH measurement occasions (CELL_FACH - FFS), or DRX (other states).

From GERAN, E-UTRAN measurements are performed in the same way as WCDMA measurements for handover to UTRAN: E-UTRAN measurements are performed in GSM idle frames in a time multiplexed manner. However, it should be discussed with GERAN how to ensure that inter-RAT measurements do not take too much measurement time, while the requested 3GPP inter-RAT measurements can be performed well enough.

Design constraints of 3GPP inter-RAT measurements should be considered when L1 details of E-UTRAN concept are defined.

10.2.3.3 Inter-RAT cell reselection from E-UTRAN

In RRC_IDLE state, a UE shall follow the measurement parameters specified by the E-UTRAN broadcast (as in UTRAN SIB). The use of dedicated measurement control is FFS.

10.2.3.4 Limiting measurement load at UE

Introduction of E-UTRA implies co-existence of various UE capabilities. Each UE may support different combinations of RATs, e.g., E-UTRA, UTRA, GSM, and non-3GPP RATs, and different combinations of frequency bands, e.g., 800 MHz, 1.7 GHz, 2 GHZ, etc. Moreover, some UEs may support the full E-UTRA spectrum bandwidth of 20 MHz, whereas some UEs may support only a part of 20 MHz. Despite such heterogeneous environment, the measurement load at UE should be minimised. To limit the measurement load and the associated control load:

- E-UTRAN can configure the RATs to be measured by UE;
- The number of measurement criteria (event and periodic reporting criteria) should be limited (as in TS 25.133 subclause 8.3.2 [7]);
- E-UTRAN should be aware of the UE capabilities for efficient measurement control, to prevent unnecessary waking up of the measurement entity;
- The UE capabilities should be categorised to prevent diversion of capabilities and conformance test scenarios, FFS;
- Support for blind HO (i.e., HO without measurement reports from UE) is FFS.

10.2.4 Network Aspects

Inter-frequency/inter-RAT UE based mobility relies on a "priority based scheme", where the network configures a list of RATs/frequencies to be taken as basis for UE's inter-frequency/inter-RAT cell reselection decisions in priority order. E-UTRAN cells can enable inter-frequency/inter-RAT cell reselection by broadcasting a common priority valid for all UEs in a given cell in addition to other inter-frequency/inter-RAT information.

NOTE: The same principles apply in UTRAN.

These common priorities can be overwritten by E-UTRAN through dedicated signalling to individual UEs at RRC_CONNECTED to RRC_IDLE transition.

NOTE: In order to have consistent inter-RAT operation, the same principles apply to inter-RAT reselection to E-UTRAN. For UTRAN this includes also the transitions within RRC_CONNECTED state from CELL_DCH to CELL_PCH and URA_PCH.

Setting dedicated priorities by E-UTRAN can be based on subscription related information provided by the MME.

NOTE: The same principle have been taken as a working assumption in UTRAN (awaiting for SA2 decision on feasibility of providing subscription related information by the CN).

10.3 Mobility between E-UTRAN and Non-3GPP radio technologies

10.3.1 UE Capability Configuration

A UE shall be able to communicate with the E-UTRAN about its radio access capability, such as the system (including the release and frequency band) it supports and it's receive and transmit capabilities (single/dual radio, dual receiver). UE shall transfer its capability about other radio technologies over E-UTRAN using the same procedure used to carry its E-UTRAN radio capability.

10.3.2 Mobility between E-UTRAN and cdma2000 network

This section describes the E-UTRAN mechanisms to support idle and active mode mobility between E-UTRAN and cdma2000 HRPD or 1xRTT. The overall system is described in [17].

10.3.2.1 Tunnelling of cdma2000 Messages over E-UTRAN between UE and cdma2000 Access Nodes

In order to efficiently support handover procedures when on E-UTRAN with a cdma2000 target system, cdma2000 messages are sent transparently to the target system over the E-UTRAN, with the eNB and MME acting as relay points.

To support the MME in its selection of the correct target system node to which it should route an Uplink tunnelled message and to provide the target system with information that is needed to resolve technology-specific measurement information (RouteUpdate and pilot strength measurements) that are delivered to the cdma2000 system each eNB cell is associated with a cdma2000 HRPD SectorID and/or with a cdma2000 1xRTT SectorID (generically referred to as cdma2000 reference cellid). This cdma2000 reference cellid is provided by the eNB to the MME using the cdma2000 message transfer capability over S1-AP and forwarded to the target system via the S101 interface and corresponding interface to the cdma2000 1xRTT system.

Tunnelling is achieved over the E-UTRAN radio interface by encapsulating tunnelled cdma2000 messages in the UL Information Transfer and DL Information Transfer RRC messages (e.g., similar to UMTS Uplink/Downlink Direct Transfer). A specific IE in these RRC messages is used to identify the type of information contained in the message (e.g., NAS, TunneledMsg). Additionally if the message is carrying a tunnelled message, an additional IE is included to carry RRC Tunnelling Procedure Information.

RRC Tunnelling Procedure Information in the UL direction will include:

- RAT type (1xRTT encapsulated, HRPD encapsulated);
- cdma2000 message type (e.g. pre-registration or handover initiation).

RRC Tunnelling Procedure Information in the DL direction will include:

- RAT type (1xRTT encapsulated, HRPD encapsulated).

AS level security will be applied for these UL Information Transfer and DL Information Transfer RRC messages as normal but there is no NAS level security for these tunnelled cdma2000 messages.

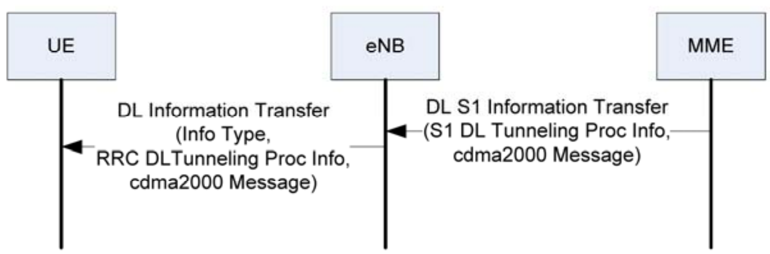

Figure 10.3.2.1-1: Downlink Direct Transfer

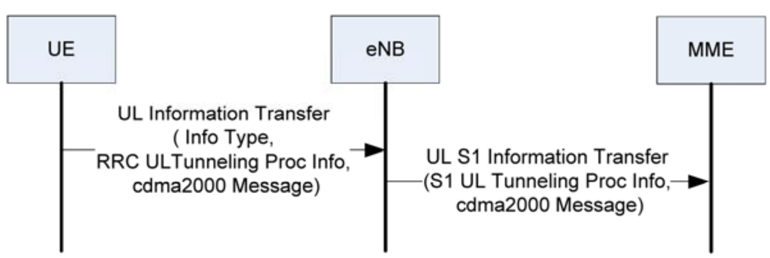

Figure 10.3.2.1-2: Uplink Direct Transfer

Tunnelling to the MME is achieved over the S1-MME interface by encapsulating the tunnelled cdma2000 message in a new S1-MME S1 Information Transfer message. These S1-MME messages carry S1 Tunnelling Procedure Information as well as the tunnelled message.

S1 Tunnelling Procedure Information in the UL direction will include:

- cdma2000 Reference Cell Id;

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- RAT type (1xRTT encapsulated, HRPD encapsulated);
- cdma2000 message type (e.g. pre-registration or handover initiation).

S1 Tunnelling Procedure Information in the DL direction will include:

- RAT type (1xRTT encapsulated, HRPD encapsulated);
- cdma2000 message type (e.g. pre-registration or handover completion);
- Data forwarding information if required.

10.3.2.2 Mobility between E-UTRAN and HRPD

10.3.2.2.1 Mobility from E-UTRAN to HRPD

10.3.2.2.1.1 HRPD System Information Transmission in E-UTRAN

The HRPD system information block (SIB) shall be sent on the E-UTRAN BCCH. The UE shall monitor the E-UTRAN BCCH during the RRC_IDLE and RRC_CONNECTED modes to retrieve the HRPD system information for the preparation of cell reselection or handover from the E-UTRAN to HRPD system. HRPD system information may also be provided to the UE by means of dedicated signalling. The following HRPD system information is transmitted on E-UTRAN BCCH:

- HRPD pre-registration allowed;
- HRPD Pre-registration Zone;
- HRPD Neighbour Bandclass;
- HRPD Neighbour Frequency;
- HRPD Neighbour PN Sequence Offset;
- HRPD Pilot PN sequence offset index increment;
- HRPD Timing Reference;
- HRPD Searching Window Size;
- Number of HRPD Neighbour Bandclass;
- Number of HRPD Neighbour Frequency;
- Number of HRPD Neighbour PN Sequence Offset;
- HRPD Start Measuring E-UTRAN Signal Quality Threshold;
- HRPD Start Measuring E-UTRAN Rx Power Strength Threshold.

10.3.2.2.1.2 Measuring HRPD from E-UTRAN

Measurement events and parameters for HRPD measurements are to be aligned with those defined in section 10.2.3.

10.3.2.2.1.2.1 Idle Mode Measurement Control

UE shall be able to make measurements on the HRPD cells in RRC_IDLE mode to perform cell re-selection.

The intra-3GPP inter-RAT idle mode measurement control is re-used to control the idle mode measurements on HRPD. The UE performs measurement on HRPD when the signal quality from E-UTRAN serving cell falls below a given threshold.

10.3.2.2.1.2.2 Active Mode Measurement Control

In RRC_CONNECTED mode, the UE shall perform radio measurements on the HRPD network when directed by the E-UTRAN network. The network provides the required HRPD neighbour cell list information and measurement controls to the UE through dedicated RRC signalling. When needed the eNB is responsible for configuring and activating the HRPD measurements on the UE via the dedicated RRC signalling message. Periodic and event-triggered measurements are supported.

For single-radio terminals, measurement gaps are needed to allow the UE to switch into the HRPD network and do radio measurements. These measurement gaps are network-controlled. The eNB is responsible for configuring the gap pattern and providing it to the UE through RRC dedicated signalling. Terminals with a dual receiver perform measurements on HRPD neighbour cells without tuning away from the E-UTRAN network. No DL gap patterns will be required for UEs which are capable of simultaneous reception on the involved frequency bands. No UL gap patterns will be required for UEs which are capable simultaneous transmission in one access and measuring on another access.

10.3.2.2.1.2.3 Active Mode Measurement

In RRC_CONNECTED mode, the UE measures the strengths of each of the HRPD neighbour cells and reports them in an RRC message.

10.3.2.2.1.3 Pre-registration to HRPD Procedure

Pre-registration allows a UE to establish a presence with an HRPD system in advance of a cell re-selection or handover. E-UTRAN network instructs the UE whether the pre-registration is needed over broadcast channel and in a dedicated RRC message.

E-UTRAN does not need to know whether a specific UE is pre-registered or not. The procedure is transparent to E-UTRAN network. In the pre-registration to HRPD, messages shall be tunnelled inside RRC and S1-AP messages between the UE and MME and in a generic "transfer" message between source MME and target RNC.

The UE is responsible for maintaining the HRPD context e.g. by performing periodic re-registrations if needed. The UE will use "HRPD Pre-registration Zone" to decide whether a re-registration shall be performed. A dual-receiver UE can ignore the parameter. E-UTRAN will provide the "HRPD Pre-registration Zone" parameter on the E-UTRAN system information broadcast channel or dedicated RRC signalling (unless it is determined that the UE will read the E-UTRAN system information broadcast channel in RRC_CONNECTED). Re-registrations are only allowed in areas where pre-registration is requested.

10.3.2.2.1.4 E-UTRAN to HRPD Cell Re-selection

The pre-condition for cell re-selection from E-UTRAN to HRPD is that the UE has previously established a presence in the target HRPD network, either through the pre-registration procedure or previous HRPD attachment. The UE performs Cell re-selection to HRPD while in RRC_IDLE.

Cell reselection from E-UTRAN to HRPD should be aligned with 3GPP inter RAT cell reselection mechanism. . .

10.3.2.2.1.5 E-UTRAN to HRPD Handover

The pre-condition for the E-UTRAN to HRPD Handover procedure is that the UE is attached in the E-UTRAN network in E-UTRAN_ACTIVE state and has pre-registered with the HRPD network. Based on measurement reports received from the UE the eNB initiates a handover by sending an RRC message to the UE to indicate to the UE that it should begin the handover procedure. This message shall include the specified target type and any cdma2000 specific HRPD parameters needed by the UE to create the appropriate HRPD messages needed to request a connection. These HRPD parameters are transparent to E-UTRAN. The set of the required HRPD parameters are out of scope of this specification.

The UE can continue to send and receive data on the E-UTRAN radio until it receives the “handover command”. After the "handover command" is received by the UE, the UE shall leave the E-UTRAN radio and start acquiring the HRPD traffic channel. The HRPD handover signalling is tunnelled between the UE and HRPD network. The HRPD network sends the high level progress of the ongoing HRPD signalling (e.g. Handover Success, Handover Failure) to E-UTRAN.

10.3.2.2.2 Mobility from HRPD to E-UTRAN

Mobility from HRPD to E-UTRAN has no impact on the E-UTRAN.

10.3.2.3 Mobility between E-UTRAN and cdma2000 1xRTT

10.3.2.3.1 Mobility from E-UTRAN to cdma2000 1xRTT

10.3.2.3.1.1 cdma2000 1xRTT System Information Transmission in E-UTRAN

The cdma2000 1xRTT system information block (SIB) shall be sent on E-UTRAN BCCH. The UE shall monitor the E-UTRAN BCCH during the LTE_IDLE and RRC_CONNECTED modes to retrieve the 1xRTT system information for the preparation of handover from the E-UTRAN to cdma 2000 1xRTT system. 1xRTT system information may also be provided to the UE by means of dedicated signalling. The following cdma2000 1xRTT system information shall be carried on E-UTRAN BCCH:

- cdma2000 1X Neighbour Bandclass;
- cdma2000 1X Neighbour Frequency;
- cdma2000 1X Neighbour PN Sequence Offset;
- cdma2000 1X Pilot PN sequence offset index increment;
- cdma2000 1X Timing Reference;
- cdma2000 1x Searching Window Size;
- Number of cdma2000 1X Neighbour Bandclass;
- Number of cdma2000 1X Neighbour Frequency;
- Number of cdma2000 1X Neighbour PN Sequence Offset;
- cdma2000 1X Start Measuring E-UTRAN Signal Quality Threshold;
- cdma2000 1X Start Measuring E-UTRAN Rx Power Strength Threshold.

10.3.2.3.1.2 Measuring cdma2000 1xRTT from E-UTRAN

Measurement events and parameters for 1xRTT measurements are to be aligned with those defined in section 10.2.3.

10.3.2.3.1.2.1 Idle Mode Measurement Control

UE shall be able to make measurements on the 1xRTT system cells in LTE_IDLE mode to perform cell re-selection. UE shall perform cdma2000 1xRTT neighbour cell measurements during DRX periods, between paging occasions.

The intra-3GPP inter-RAT idle mode measurement control is re-used to control the idle mode measurements on cdma2000 1xRTT. The UE performs measurement on cdma2000 1xRTT when the signal quality from E-UTRAN serving cell falls below a given threshold.

10.3.2.3.1.2.2 Active Mode Measurement Control

In the E-UTRAN network, in RRC_CONNECTED mode, the UE shall perform radio measurements on the cdma2000 1xRTT network when directed by the E-UTRAN network. The network provides the required cdma2000 1xRTT neighbour cell list information and measurement controls to the UE through dedicated RRC signalling. When needed the eNB is responsible for configuring and activating the cdma2000 1xRTT measurements on the UE via the dedicated RRC signalling message. As for intra-3GPP inter-RAT measurement reporting, periodic and event-triggered measurements are supported.

For single-radio terminals, measurement gaps are needed to allow the UE to switch into the cdma2000 1xRTT network and do radio measurements. These Measurement gaps are network-controlled. The eNB is responsible for configuring the gap pattern and providing it to the UE through RRC dedicated signalling. Terminals with a dual receiver perform measurements on cdma2000 1xRTT neighbour cells without tuning away from the E-UTRAN network. No DL gap patterns will be required for UEs which are capable of simultaneous reception on the involved frequency bands. No UL gap patterns will be required for UEs which are capable simultaneous transmission in one access and measuring on another access.

10.3.2.3.1.2.3 Active Mode Measurement

In RRC_CONNECTED mode, the UE measures the strengths of each of the cdma2000 1xRTT neighbour cells and reports them in an RRC Message.

10.3.2.3.1.3 E-UTRAN to cdma2000 1xRTT Cell Re-selection

UE performs Cell re-selection to cdma2000 1xRTT while in RRC_IDLE.

Cell reselection from E-UTRAN to 1xRTT should be aligned with 3GPP inter RAT cell reselection mechanism.

10.3.2.3.1.4 E-UTRAN to cdma2000 1xRTT Handover

In the high level procedure for handover from E-UTRAN to cdma2000 1xRTT, registration and handover is performed directly after the handover decision has been made. Based on measurement reports received from the UE the eNB initiates a handover by sending a RRC message to the UE to indicate to the UE that it should begin the handover procedure. This message shall include the specified target type and any cdma2000 specific 1xRTT access parameters needed by the UE to create the appropriate 1xRTT Origination Request message . The 1xRTT access parameters are transparent to E-UTRAN. The set of the required 1xRTT access parameters are out of scope of this specification.

10.3.2.3.2 Mobility from cdma2000 1xRTT to E-UTRAN

Mobility from cdma2000 1xRTT has no impact on E-UTRAN.

10.4 Area Restrictions

Information on which area restrictions to be applied during ECM-CONNECTED state is provided by the MME at context setup over the S1 interface.

The eNB shall store the UE restriction information and use it to determine whether the UE has access to radio resources in the E-UTRAN. The source eNB should apply restriction handling when selecting a target eNB.

The available UE restriction information shall be propagated by the source eNB over X2 at intra E-UTRAN handover.

10.5 Mobility to and from CSG cells

10.5.1 Inbound mobility to CSG cells

10.5.1.1 RRC_IDLE

Cell selection/reselection to CSG cells is based on a UE autonomous search function. The search function determines itself when/where to search.

It is FFS whether specific UE procedures or performance requirements will be specified.

UE checks the suitability of CSG cells (identified by the 1 bit indicator) based on the CSG whitelist in the UE (provided by upper layers). A CSG cell is only suitable for a UE if it belongs to its whitelist.

The automated searching for the CSG cells by the UE shall be disabled by the search function, if the CSG whitelist configured in the UE is empty.

In addition, manual selection of CSG cells is supported.

Cell selection/reselection to CSG cells does not require the network to provide neighbour cell information to the UE. The neighbour cell information can be provided to help the UE in specific cases, e.g. where the network wishes to trigger the UE to search for CSG cells.

10.5.1.2 RRC_CONNECTED

UE autonomously searches for CSG cells and can indicate the need for measurement gaps to the network (e.g. to check the suitability of the CSG cell). Upon network decision measurement gaps might be granted.

The automated searching for the CSG cells by the UE shall be disabled by the search function, if the CSG whitelist configured in the UE is empty.

UE checks the suitability of CSG cells (identified by the 1 bit indicator) based on the CSG whitelist in the UE (provided by upper layers). The UE shall report suitable CSG cells and/or any CSG cells including an indication that particular CSG cells are suitable to the serving cell.

Measurement reporting of CSG cells does not require the network to provide neighbour cell information to the UE. The neighbour cell information can be provided to help the UE in specific cases, e.g. where the network wishes to trigger the UE to search for CSG cells.

NOTE: in some case it might require that appropriate gaps are given to the UE.

10.5.2 Outbound mobility from CSG cells

10.5.2.1 RRC_IDLE

For a UE leaving a CSG cell in idle mode normal cell reselection based on configuration from the BCCH of the CSG cell applies.

10.5.2.2 RRC_CONNECTED

For a UE leaving a CSG cell in active mode normal network controlled mobility applies.

11 Scheduling and Rate Control

In order to utilise the SCH resources efficiently, a scheduling function is used in MAC. In this subclause, an overview of the scheduler is given in terms of scheduler operation, signalling of scheduler decisions, and measurements to support scheduler operation.

11.1 Basic Scheduler Operation

MAC in eNB includes dynamic resource schedulers that allocate physical layer resources for the DL-SCH and UL-SCH transport channels. Different schedulers operate for the DL-SCH and UL-SCH.

The scheduler should take account of the traffic volume and the QoS requirements of each UE and associated radio bearers, when sharing resources between UEs. Only "per UE" grants are used to grant the right to transmit on the UL-SCH (i.e. there are no "per UE per RB" grants).

Schedulers may assign resources taking account the radio conditions at the UE identified through measurements made at the eNB and/or reported by the UE.

Radio resource allocations can be valid for one or multiple TTIs.

Resource assignment consists of physical resource blocks (PRB) and MCS. Allocations for time periods longer than one TTI might also require additional information (allocation time, allocation repetition factor…).

11.1.1 Downlink Scheduling

In the downlink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on L1/L2 control channel(s). A UE always monitors the L1/L2 control channel(s) in order to find possible allocation when its downlink reception is enabled (activity governed by DRX).

In addition, E-UTRAN can allocate persistent downlink resources for the first HARQ transmissions to UEs. When required, retransmissions are explicitly signalled via the L1/L2 control channel(s). In the sub-frames where the UE has persistent resource, if the UE cannot find its C-RNTI on the L1/L2 control channel(s), a downlink transmission according to the persistent allocation that the UE has been assigned in the TTI is assumed. Otherwise, in the sub-frames where the UE has persistent resource, if the UE finds its C-RNTI on the L1/L2 control channel(s), the L1/L2 control channel allocation overrides the persistent allocation for that TTI and the UE does not decode the persistent resources.

11.1.2 Uplink Scheduling

In the uplink, E-UTRAN can dynamically allocate resources (PRBs and MCS) to UEs at each TTI via the C-RNTI on L1/L2 control channel(s). A UE always monitors the L1/L2 control channel(s) in order to find possible allocation for uplink transmission when its downlink reception is enabled (activity governed by DRX).

In addition, E-UTRAN can allocate a persistent uplink resource for the first HARQ transmissions and potentially retransmissions to UEs:

- RRC defines the periodicity of the persistent grant;
- PDCCH indicates whether the UL grant is a persistent one i.e. whether it can be implicitly reused in the following TTIs according to the periodicity defined by RRC.

In the sub-frames where the UE has persistent resource, if the UE cannot find its C-RNTI on the L1/L2 control channel(s), an uplink transmission according to the persistent allocation that the UE has been assigned in the TTI can be made. The network performs decoding of the pre-defined PRBs according to the pre-defined MCS. Otherwise, in the sub-frames where the UE has persistent resource, if the UE finds its C-RNTI on the L1/L2 control channel(s), the L1/L2 control channel allocation overrides the persistent allocation for that TTI and the UE's transmission follows the L1/L2 control, not the persistent allocation. Retransmissions are either implicitly allocated in which case the UE uses the persistent allocation, or explicitly allocated via L1/L2 control channel(s) in which case the UE does not follow the persistent allocation.

NOTE: there is no blind decoding in uplink and when the UE does not have enough data to fill the allocated resource, padding is used.

11.2 Void

11.3 Measurements to Support Scheduler Operation

Measurement reports are required to enable the scheduler to operate in both uplink and downlink. These include transport volume and measurements of a UEs radio environment.

Uplink buffer status reports (BSR) are needed to provide support for QoS-aware packet scheduling. In E-UTRAN uplink buffer status reports refer to the data that is buffered in for a group of radio bearer (RBG) in the UE. Four RBGs and two formats are used for reporting in uplink:

- A short format for which only one BSR (of one RBG) is reported;
- A long format for which all four BSRs (of all four RBGs) are reported.

Uplink buffer status reports are transmitted using MAC signalling.

11.4 Rate Control of GBR and AMBR

11.4.1 Downlink

The eNB guarantees the downlink GBR associated with a GBR bearer and enforces the downlink AMBR associated with a group of Non-GBR bearers.

11.4.2 Uplink

The UE has an uplink rate control function which manages the sharing of uplink resources between radio bearers. RRC controls the uplink rate control function by giving each bearer a priority and a prioritised bit rate (PBR). The values signalled may not be related to the ones signalled via S1 to the eNB.

The uplink rate control function ensures that the UE serves its radio bearer(s) in the following sequence:

1. All the radio bearer(s) in decreasing priority order up to their PBR;

2. All the radio bearer(s) in decreasing priority order for the remaining resources assigned by the grant.

NOTE1: In case the PBRs are all set to zero, the first step is skipped and the radio bearer(s) are served in strict priority order: the UE maximises the transmission of higher priority data.

NOTE2: By limiting the total grant to the UE, the eNB can ensure that the AMBR is not exceeded.

If more than one radio bearer has the same priority, the UE shall serve these radio bearers equally.

11.5 CQI reporting for Scheduling

The time and frequency resources used by the UE to report CQI are under the control of the eNB. CQI reporting can be either periodic or aperiodic. A UE can be configured to have both periodic and aperiodic reporting at the same time. In case both periodic and aperiodic reporting occurs in the same subframe, only the aperiodic report is transmitted in that subframe.

For efficient support of localized, distributed and MIMO transmissions, E-UTRA supports three types of CQI reporting:

- Wideband type: providing channel quality information of entire system bandwidth of the cell;

- Multi-band type: providing channel quality information of some subset(s) of system bandwidth of the cell;

- MIMO type: FFS.

Periodic CQI reporting is defined by the following characteristics:

- When the UE is allocated PUSCH resources in a subframe where a periodic CQI report is configured to be sent, the periodic CQI report is transmitted together with uplink data on the PUSCH. Otherwise, the periodic CQI reports are sent on the PUCCH.

Aperiodic CQI reporting is defined by the following characteristics:

- The report is scheduled by the eNB via the PDCCH;

- Transmitted together with uplink data on PUSCH.

When a CQI report is transmitted together with uplink data on PUSCH, it is multiplexed with the transport block by L1 (i.e. the CQI report is not part of the uplink the transport block).

The eNB configures a set of sizes and formats of the reports. Size and format of the report depends on whether it is transmitted over PUCCH or PUSCH and whether it is a periodic or aperiodic CQI report.

12 DRX in RRC_CONNECTED

In order to enable reasonable UE battery consumption, DRX in E-UTRAN is characterised by the following:

- Per UE mechanism (as opposed to per radio bearer);

- No RRC or MAC substate to distinguish between different levels of DRX;

- Available DRX values are controlled by the network and start from non-DRX up to *x* seconds. Value *x* may be as long as the paging DRX used in ECM-IDLE;
- Measurement requirement and reporting criteria can differ according to the length of the DRX interval i.e. long DRX intervals may experience more relaxed requirements;
- The UE may omit measurements of neighbouring cells when the DRX interval is above a threshold and if the radio quality of the serving cell is above another threshold. To configure this behaviour in the UE, the two thresholds may be indicated by the eNB;
- Irrespective of DRX, UE may use first available RACH opportunity to send an UL measurement report;
- Immediately after sending a measurement report, the UE may change its DRX. This mechanism would be pre-configured by the eNB;
- HARQ operation related to data transmission is independent of DRX operation and the UE wakes up to read the PDCCH for possible retransmissions and/or ACK/NAK signalling regardless of DRX In the downlink, a timer is used to limit the time the UE stays awake awaiting for a retransmission;
- When DRX is configured, the UE may be further configured with an "on-duration" timer during which time the UE monitors the L1/L2 control channels for possible allocations;
- When DRX is configured, periodic CQI reports can only be sent by the UE during the “on-duration”;
- A timer in the UE is used to detect need for obtaining timing advance.

The following definitions apply to DRX in E-UTRAN:

- **on-duration**: duration in downlink subframes that the UE waits for, after waking up from DRX, to receive PDCCHs. If the UE successfully decodes a PDCCH, the UE stays awake and starts the inactivity timer;
- **inactivity-timer**: duration in downlink subframes (during wake time) that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH, failing which it re-enters DRX. The UE shall restart the inactivity timer following a single successful decoding of a PDCCH for a first transmission only (i.e. not for retransmissions).
- **active-time**: total duration that the UE is awake. This includes the “on-duration” of the DRX cycle, the time UE is performing continuous reception while the inactivity timer has not expired and the time UE is performing continuous reception while waiting for a DL retransmission after one HARQ RTT. Based on the above the minimum active time is of length equal to on-duration, and the maximum is undefined (infinite);

Of the above parameters the on-duration and inactivity-timer are of fixed lengths, while the active-time is of varying lengths based on scheduling decision and UE decoding success. Only on-duration and inactivity-timer duration are signalled to the UE by the eNB:

- There is only one DRX configuration applied in the UE at any time;
- UE shall apply an on-duration on wake-up from DRX sleep;

NOTE: this is also applicable for the case where the UE has only one service (e.g. Real Time) that is being handled through the allocation of predefined resources; this allows for other signalling such as RRC to be sent during the remaining portion of the active time.

- New transmissions can only take place during the active-time (so that when the UE is waiting for one retransmission only, it does not have to be “awake” during the RTT).
- If PDCCH has not been successfully decoded during the on-duration, the UE shall follow the DRX configuration (i.e. the UE can enter DRX sleep if allowed by the DRX configuration):
  - This applies also for the sub-frames where the UE has been allocated predefined resources.
- If it successfully decodes a PDCCH for a first transmission, the UE shall stay awake and start the inactivity timer (even if a PDCCH is successfully decoded in the sub-frames where the UE has also been allocated predefined resources) until a MAC control message tells the UE to re-enter DRX, or until the inactivity timer expires. In both cases, the DRX cycle that the UE follows after re-entering DRX is given by the following rules:

- If a short DRX cycle is configured; the UE first follows the short DRX cycle and after a longer period of inactivity the UE follows the long DRX cycle;
- Else the UE follows the long DRX cycle directly.

13 QoS

13.1 QoS concept and bearer service architecture

The EPS bearer service layered architecture is depicted in Figure 13.1-1 below, where:

- An UL TFT in the UE binds an SDF to an EPS bearer in the uplink direction. Multiple SDFs can be multiplexed onto the same EPS bearer by including multiple uplink packet filters in the UL TFT.
- A DL TFT in the PDN GW binds an SDF to an EPS bearer in the downlink direction. Multiple SDFs can be multiplexed onto the same EPS bearer by including multiple downlink packet filters in the DL TFT.
- A radio bearer transports the packets of an EPS bearer between a UE and an eNB. There is a one-to-one mapping between an EPS bearer and a radio bearer.
- An S1 bearer transports the packets of an EPS bearer between an eNodeB and a Serving GW.
- An S5/S8 bearer transports the packets of an EPS bearer between a Serving GW and a PDN GW.
- A UE stores a mapping between an uplink packet filter and a radio bearer to create the binding between an SDF and a radio bearer in the uplink.
- A PDN GW stores a mapping between a downlink packet filter and an S5/S8a bearer to create the binding between an SDF and an S5/S8a bearer in the downlink.
- An eNB stores a one-to-one mapping between a radio bearer and an S1 to create the binding between a radio bearer and an S1 bearer in both the uplink and downlink.
- A Serving GW stores a one-to-one mapping between an S1 bearer and an S5/S8a bearer to create the binding between an S1 bearer and an S5/S8a bearer in both the uplink and downlink.

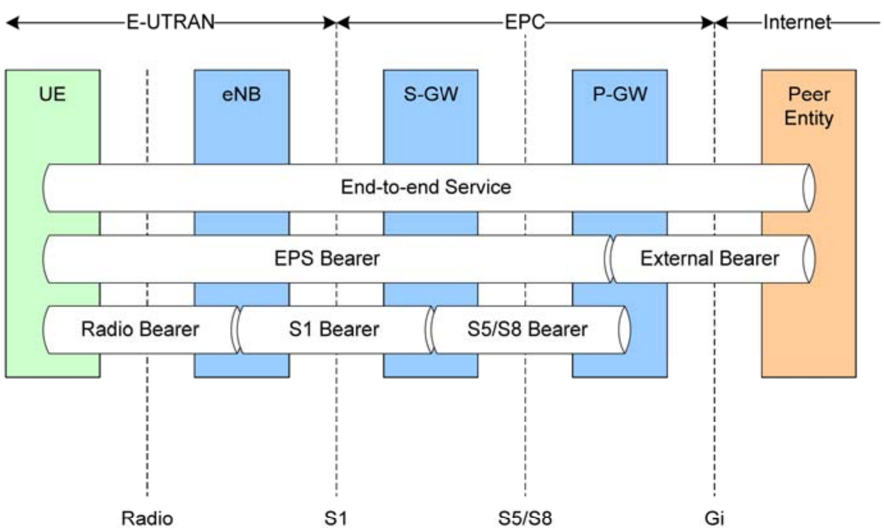

Figure 13.1-1: EPS Bearer Service Architecture

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13.2 Resource establishment and QoS signalling

14 Security

14.1 Overview and Principles

The following principles apply to E-UTRAN security:

- The keys used for NAS and AS protection shall be dependent on the algorithm with which they are used;
- The eNB keys are cryptographically separated from the EPC keys used for NAS protection (making it impossible to use the eNB key to figure out an EPC key).
- The AS (RRC and UP) and NAS keys are derived in the EPC/UE from key material that was generated by a NAS (EPC/UE) level AKA procedure (K_{ASME}) and identified with a key identifier (KSI_{ASME}).
- The eNB key (K_{eNB}) is sent from the EPC to the eNB when the UE is entering ECM-CONNECTED state (i.e. during RRC connection or S1 context setup).
- Separate AS and NAS level security mode command procedures are used. AS level security mode command procedure configures AS security (RRC and user plane) and NAS level security mode command procedure configures NAS security. Both integrity protection and ciphering for RRC are activated within the same AS SMC procedure, but not necessarily within the same message. User plane ciphering is activated at the same time as RRC ciphering.
- Keys stored inside eNBs shall never leave a secure environment within the eNB (except when done in accordance with this or other 3GPP specifications), and user plane data ciphering/deciphering shall take place inside the secure environment where the related keys are stored.
- Key material for the eNB keys is sent between the eNBs during ECM-CONNECTED intra-E-UTRAN mobility.
- A sequence number is used as input to the ciphering and integrity protection. A given sequence number must only be used once for a given eNB key (except for identical re-transmission). The same sequence number can be used for both ciphering and integrity protection.
- A hyper frame number (HFN) (i.e. an overflow counter mechanism) is used in the eNB and UE in order to limit the actual number of sequence number bits that is needed to be sent over the radio. The HFN needs to be synchronized between the UE and eNB.
- If corruption of keys is detected, UE has to restart radio level attachment procedure (e.g. similar radio level procedure to idle-to-connected mode transition or initial attachment).
- No integrity protection initialisation number (FRESH).

The MME invokes the AKA procedures by requesting authentication vectors to the HE (Home environment). The HE sends an authentication response back to the MME that contains a fresh authentication vector, including a base-key named K_{ASME}. Thus, as a result of an AKA run, the EPC and the UE share K_ASME. From K_ASME, the NAS, (and indirectly) K_eNB keys are derived. The K_ASME never leaves the EPC, but the K_eNB key is transported to the eNB from the EPC when the UE transitions to ECM-CONNECTED. From the K_eNB, the eNB and UE can derive the UP and RRC keys. When the UE goes into ECM-IDLE, the K_eNB, UP and RRC keys are deleted from the eNB. The key hierarchy is depicted on Figure 14.1-1 below, where:

- $\mathbf{K_{NASint}}$ is a key, which shall only be used for the protection of NAS traffic with a particular integrity algorithm This key is derived by UE and MME from K_{ASME} , as well as an identifier for the integrity algorithm.
- $\mathbf{K_{NASenc}}$ is a key, which shall only be used for the protection of NAS traffic with a particular encryption algorithm. This key is derived by UE and MME from K_{ASME}, as well as an identifier for the encryption algorithm.
- $\mathbf{K_{eNB}}$ is a key derived by UE and MME from K_{ASME}. K_{eNB} shall only be used for the derivation of keys for RRC traffic and the derivation of keys for UP traffic and the derivation of K_{eNB*} during HO.

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- K_{eNB*} is a key derived by UE and source eNB from K_{eNB}. K_{eNB*} shall only be used by UE and target eNB at handover for the derivation of a new K_{eNB} for RRC and UP traffic;
- K_{UPenc} is a key, which shall only be used for the protection of UP traffic with a particular encryption algorithm. This key is derived by UE and eNB from K_{eNB}, as well as an identifier for the encryption algorithm.
- K_{RRCint} is a key, which shall only be used for the protection of RRC traffic with a particular integrity algorithm. K_{RRCint} is derived by UE and eNB from K_{eNB}, as well as an identifier for the integrity algorithm.
- K_{RRCenc} is a key, which shall only be used for the protection of RRC traffic with a particular encryption algorithm. K_{RRCenc} is derived by UE and eNB from K_{eNB} as well as an identifier for the encryption algorithm.

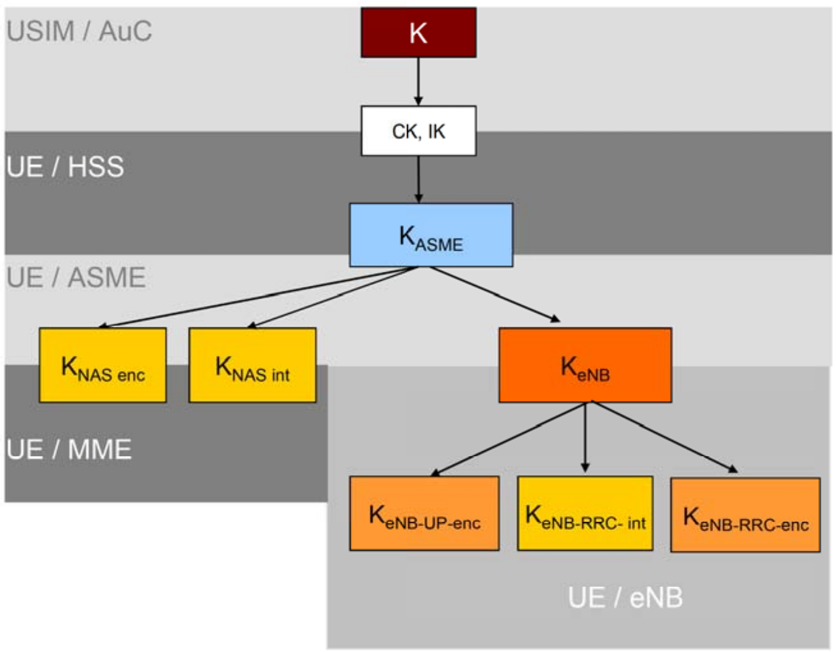

Figure 14.1-1: Key Hierarchy

COUNT-C reusing avoidance for the same radio bearer identity in RRC_CONNECTED mode without K_{eNB} change is left to eNB implementation e.g. by using intra-cell handover, smart management of radio bearer identities or triggering a transition to RRC_IDLE.

In case of HFN de-synchronisation in RRC_CONNECTED mode between the UE and eNB, the UE is pushed to IDLE.

14.2 Security termination points

The table below describes the security termination points.

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Table 14.2-1 Security Termination Points

	Ciphering	Integrity Protection
NAS Signalling	Required and terminated in MME	Required and terminated in MME
U-Plane Data	Required and terminated in eNB	Not Required (NOTE 1)
RRC Signalling (AS)	Required and terminated in eNB	Required and terminated in eNB
MAC Signalling (AS)	Not required (NOTE 2)	Not required (NOTE 2)
NOTE 1: Integrity protection for U-Plane is not required and thus it is not supported between UE and Serving Gateway or for the transport of user plane data between eNB and Serving Gateway on S1 interface. NOTE 2: SA3 needs to further study on whether buffer status reports from UEs to the eNBs in MAC layer need to be protected.		

14.3 State Transitions and Mobility

14.3.1 RRC_IDLE to RRC_CONNECTED

As a general principle, on RRC_IDLE to RRC_CONNECTED transitions, RRC protection keys and UP protection keys shall be generated while keys for NAS protection as well as higher layer keys are assumed to be already available in the MME. These higher layer keys may have been established in the MME as a result of an AKA run, or as a result of a transfer from another MME during handover or idle mode mobility.

14.3.2 RRC_CONNECTED to RRC_IDLE

On RRC_CONNECTED to RRC_IDLE transitions, eNBs shall delete the keys they store such that state for idle mode UEs only has to be maintained in MME. It is also assumed that eNB does no longer store state information about the corresponding UE and deletes the current keys from its memory. In particular, on connected to idle transitions:

- The eNB deletes K_{eNB} , K_{RRCenc} , K_{RRCint} and K_{UPenc}
- MME keeps K_{ASME} stored.

14.3.3 Intra E-UTRAN Mobility

The key hierarchy does not allow, as is, explicit key updates, but RRC and UP keys are derived based on the algorithm identifiers, K_{eNB}, and certain dynamic parameters (e.g. C-RNTI), which result as new RRC and UP keys at every handover (FFS for intra-eNB):.

- Source eNB and UE independently create K_{eNB*} from the current K_{eNB};
- K_{eNB*} is given to Target eNB during the HO preparation phase;
- Both Target eNB and UE derive the new K_{eNB} based on K_{eNB*} and C-RNTI allocated by the target eNB to UE.

The handling of HFN and PDCP SN at handover depends on the type of radio bearer:

- SRB: HFN and PDCP SN are reset.
- RLC-UM bearers: HFN and PDCP SN are reset.
- RLC-AM bearers: PDCP SN and HFN are maintained (10.1.2.3).

NOTE: COUNT-C reusing avoidance is left to network implementation.

14.4 AS Key Change in RRC_CONNECTED

If AS Keys (K_{UPenc}, K_{RRCint} and K_{RRCenc}) need to be changed in RRC_CONNECTED, something along the line of an intra-cell handover is used (FFS).

14.5 Security Interworking

If user plane ciphering is activated in the source RAN, it shall remain activated in the target RAN.

For E-UTRAN to UTRAN/GERAN mobility, the MME shall derive and transfer to the SGSN a confidentially key and an integrity key from K_{ASME}. Based on this information, the SGSN can in turn derive appropriate keys to be used in the target RAN.

Similarly for UTRAN/GERAN to E-UTRAN mobility, the SGSN shall derive and transfer to the MME a confidentially key and an integrity key. Based on this information, the MME can in turn derive K_{ASME}.

15 MBMS

For MBMS, the following definitions are introduced:

MBSFN Synchronization Area: an area of the network where all NodeBs/eNodeBs can be synchronized and perform MBSFN transmissions. MBSFN Synchronization Areas are capable of supporting one or more MBSFN Areas. On a given frequency layer, a NodeB/eNodeB can only belong to one MBSFN Synchronization Area. MBSFN Synchronization Areas are independent from the definition of MBMS Service Areas

MBSFN Transmission or a transmission in MBSFN mode: a simulcast transmission technique realised by transmission of identical waveforms at the same time from multiple cells. An MBSFN Transmission from multiple cells within the MBSFN Area is seen as a single transmission by a UE.

MBSFN Area: a MBSFN Area consists of a group of cells within an MBSFN Synchronization Area of a network, which are co-ordinated to achieve a MBSFN Transmission. A cell within an MBSFN Synchronization Area may form part of multiple MBSFN Areas, each characterized by different transmitted content and participating set of cells.

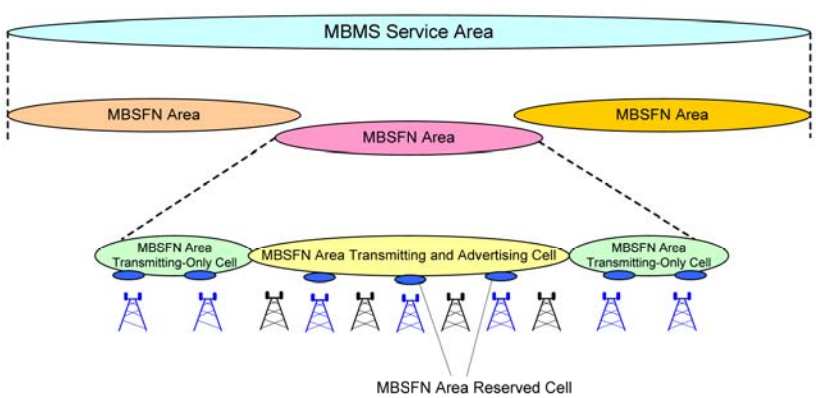

Figure 15-1: MBMS Definitions

MBSFN Area Transmitting and Advertising Cell: A cell within a MBSFN Area which is contributing to the MBSFN Transmission and advertises within the cell the availability of the MBSFN Transmission.

MBSFN Area Transmitting-Only Cell: A cell within a MBSFN Area which is contributing to the MBSFN Transmission but does not advertise within the cell the availability of the MBSFN Transmission. The need for this type of cell is FFS.

MBSFN Area Reserved Cell: A cell within a MBSFN Area which does not contribute to the MBSFN Transmission. The cell may be allowed to transmit for other services but at restricted power on the resource allocated for the MBSFN transmission e.g. PTP for users at the centre of the cell.

15.1 General

In E-UTRAN, MBMS can be provided on a frequency layer dedicated to MBMS (set of cells dedicated to MBMS transmission i.e. set of "MBMS dedicated cells") and/or on a frequency layer shared with non-MBMS services (set of cells supporting both unicast and MBMS transmissions i.e. set of "Unicast/MBMS mixed cells"). In both cases, single frequency network mode of operation is possible for MBMS transmission (MBSFN).

MBMS reception is possible for UEs in RRC_CONNECTED or RRC_IDLE states. Whenever receiving MBMS services, a user shall be notified of an incoming call, and originating calls shall be possible.

15.1.1 E-MBMS Logical Architecture

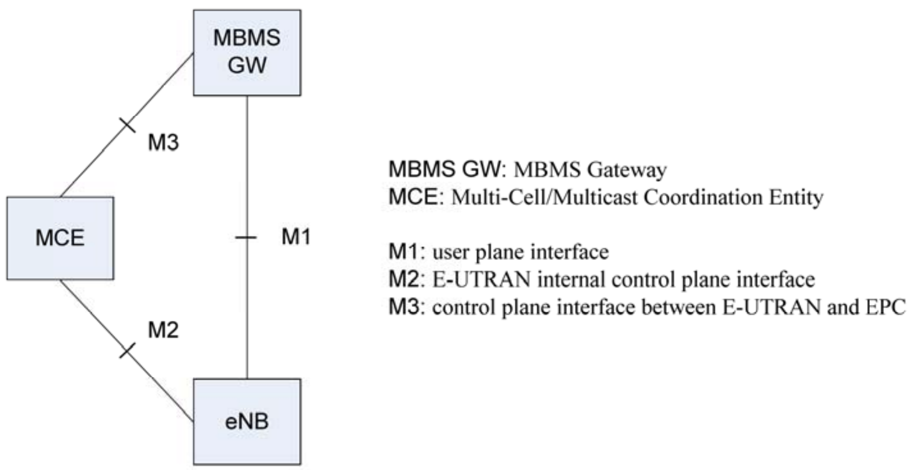

Figure 15.1.1-1: E-MBMS Logical Architecture

Figure 15.1.1-1 depicts the E-MBMS Logical Architecture.

NOTE: Additional horizontal interfaces e.g. MCE to MCE is FFS.

Multi-cell/multicast Coordination Entity (MCE)

The MCE is a logical entity – this does not preclude the possibility that it may be part of another network element – whose functions are the allocation of the radio resources used by all eNBs in the MBSFN area for multi-cell MBMS transmissions using MBSFN operation. Besides allocation of the time/ frequency radio resources this also includes deciding the further details of the radio configuration e.g. the modulation and coding scheme. The MCE is involved in MBMS Session Control Signalling. The MCE does not perform UE - MCE signalling.

E-MBMS Gateway (MBMS GW)

The MBMS GW is a logical entity – this does not preclude the possibility that it may be part of another network element – that is present between the BMSC and eNBs whose principal functions is the sending/broadcasting of MBMS packets with the SYNC protocol to each eNB transmitting the service. The MBMS GW hosts the PDCP layer of the user plane and uses IP Multicast as the means of forwarding MBMS user data to the eNB. The MBMS GW performs MBMS Session Control Signalling (Session start/stop) towards the E-UTRAN.

Control Plane Interfaces

"M3" Interface: MCE – MBMS GW

An Application Part is defined for this interface between E-MBMS Gateway and MCE. This application part allows for MBMS Session Control Signalling on EPS bearer level (i.e. does not convey radio configuration data). The procedures comprise e.g. MBMS Session Start and Stop. SCTP is used as signalling transport i.e. Point-to-Point signalling is applied.

"M2" Interface: MCE – eNB

An Application Part is defined for this interface, which conveys at least radio configuration data for the multi-cell transmission mode eNBs and Session Control Signalling. SCTP is used as signalling transport i.e. Point-to-Point signalling is applied.

User Plane Interface

"M1" Interface: MBMS GW – eNB

This interface is a pure user plane interface. Consequently no Control Plane Application Part is defined for this interface. IP Multicast is used for point-to-multipoint delivery of user packets for both single cell and multi-cell transmission.

Deployment consideration

It is not precluded that M3 interface can be terminated in eNBs. In this case MCE is considered as being part of eNB. Therefore M2 does not exist in this scenario. This is depicted in Figure 15.1.1-2 which depicts two envisaged deployment alternatives. In the scenario depicted on the left MCE is deployed in a separate node. In the scenario on the right MCE is part of the eNBs. These eMBMS architecture deployment alternatives shall be applicable to both multi-cell and single cell transmission mode.

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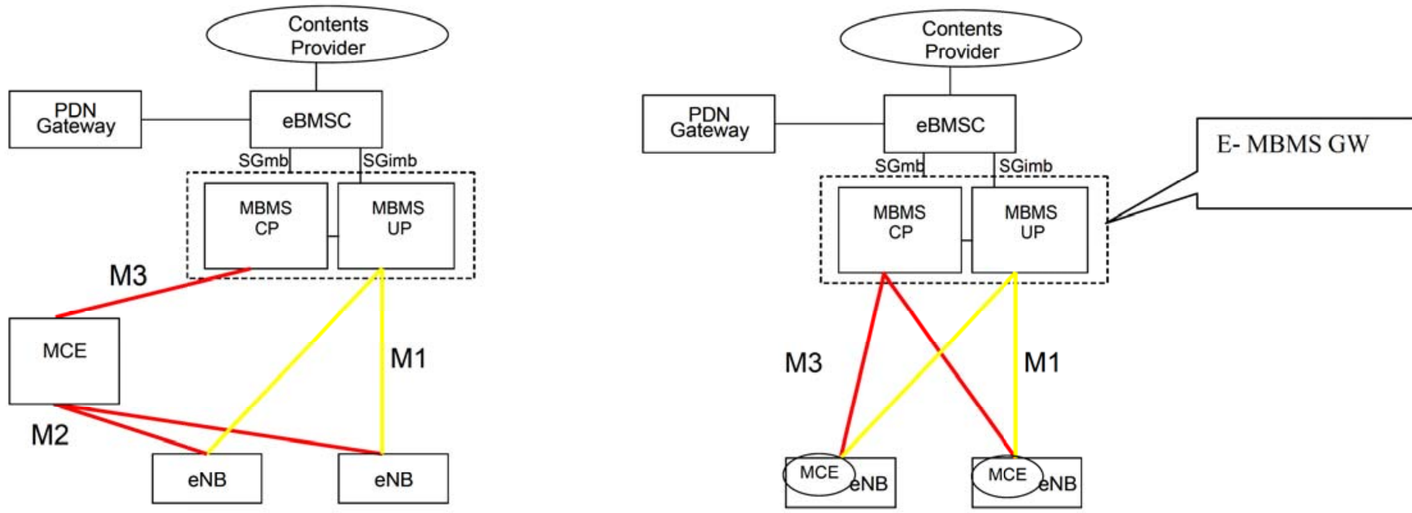

Figure 15.1.1-2: eMBMS Architecture deployment alternatives

15.1.2 E-MBMS User Plane Protocol Architecture

The overall U-plane architecture of content synchronization is shown in Figure 15.1-1. This architecture is based on the functional allocation for Unicast and the SYNC protocol layer is defined additionally on transport network layer to support content synchronization mechanism.

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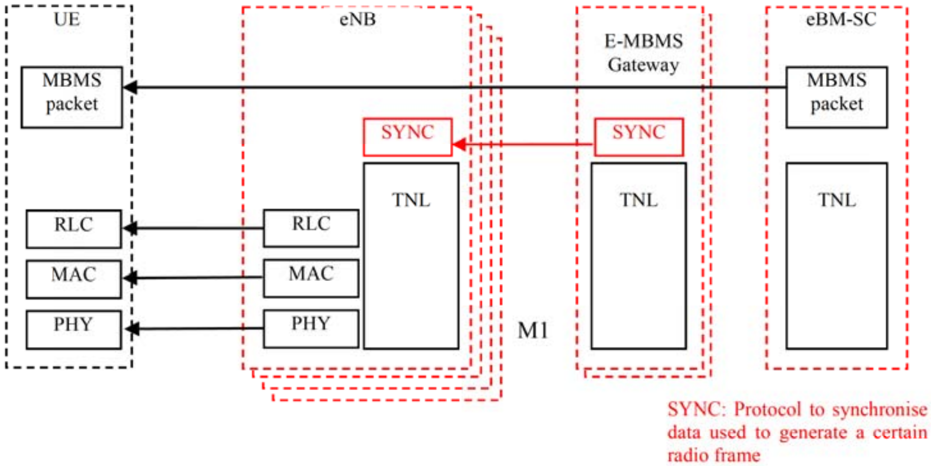

Figure 15.1.2-1: The overall u-plane architecture of the MBMS content synchronization

The SYNC protocol is defined as a protocol to carry additional information that enable eNBs to identify the timing for radio frame transmission and detect packet loss. The SYNC protocol is applicable to DL and may be specified as a part of GTP-U, or as an independent protocol.

If PDCP (Header Compression) is used, it is located in the E-MBMS GW for both multi-cell and single-cell transmission.

Complying with the content synchronization mechanism is required for an eNB distributing a MBMS service for Multi-Cell transmission. An eNB transmitting a service in single cell only should not be required to comply with the stringent timing requirements indicated by SYNC protocol.

15.2 MBMS Cells

An E-UTRAN cell supporting MBMS is either an MBMS-dedicated cell or an MBMS/Unicast-mixed cell.

15.2.1 MBMS-dedicated cell

When a cell belongs to a frequency layer dedicated to MBMS transmission:

- MTCH and MCCH are mapped on MCH or DL-SCH (FFS) for p-t-m transmission;
- No uplink;
- No counting mechanism in another (unicast) cell supported;
- No support for unicast data transfer in the cell;
- The occurrence of paging messages on the frequency layer dedicated to MBMS transmission is FFS:
  - If paging messages were allowed, the UE could answer in a non-E-UTRA cell e.g. UTRA cell (FFS);

15.2.2 MBMS/Unicast-mixed cell

When a cell does not belong to a frequency layer dedicated to MBMS transmission:

- MTCH and MCCH are mapped on MCH or DL-SCH for p-t-m transmission;
- Transmission of both unicast and MBMS in the cell is done in a co-ordinated manner.

15.3 MBMS Transmission

15.3.1 General

Transmission of MBMS in E-UTRAN is either a single-cell transmission or a multi-cell transmission. In both cases, MCCH terminates at the eNB.

15.3.2 Single-cell transmission

Single-cell transmission of MBMS is characterized by:

- MBMS is transmitted only on the coverage of a specific cell;
- Combining of MBMS transmission from multiple cells is not supported;
- MTCH and MCCH are mapped on DL-SCH for p-t-m transmission;
- Scheduling is done by the eNB;
- Multiple UEs can be allocated dedicated uplink feedback channels identical to those used in unicast transmission, which enables them to report HARQ Ack/Nack and CQI. Where such a feedback mechanism is configured, AMC is applied, and HARQ retransmissions are made on DL-SCH using a group (service specific) RNTI in a time frame that is co-ordinated with the original MTCH transmission. All UEs are able to receive the retransmissions and combine them with the original transmissions at the HARQ level.
- UEs that are allocated a dedicated uplink feedback channel are in RRC_CONNECTED state.
- To avoid unnecessary MBMS transmission on MTCH in a cell where there is no MBMS user, MCCH may announce only the availability of MBMS service(s) and the network can detect the presence in a cell of at least one MBMS user interested in the MBMS service (e.g. by polling or through UE service request) before starting the transmission on MTCH. It is FFS whether or not it is needed to count to a greater granularity the number of UEs in a cell interested in an MBMS service.

For single-cell transmission, an eNB is not required to comply with the stringent timing requirements indicated by SYNC protocol. The following principles still applies for the single transmission:

1. An E-MBMS GW sends/broadcasts MBMS packet with the SYNC protocol to each eNB transmitting the service.
2. The SYNC protocol provides additional information so that the eNBs identify the transmission radio frame(s). The E-MBMS GW does not need accurate knowledge of radio resource allocation in terms of exact time division (e.g. exact start time of the radio frame transmission).
3. The segmentation/concatenation is needed for MBMS packets and should be totally up to the RLC/MAC layer in eNB, without taking into account any indication in the SYNC protocol.

15.3.3 Multi-cell transmission

Multi-cell transmission of MBMS is characterized by:

- Synchronous transmission of MBMS within its MBSFN Area;
- Combining of MBMS transmission from multiple cells is supported;
- MTCH and MCCH are mapped on MCH for p-t-m transmission;
- The MBSFN Synchronization Area, the MBSFN Area, and the MBSFN Transmitting, Advertising, and Reserved cells are semi-statically configured e.g. by O&M.
- Scheduling of each MCH is done by the MCE.
- AMC based on non-AS level feedback is FFS.

A carrier frequency may support more than one MCH, where the physical resource allocation to a specific MCH is made by specifying a pattern of subframes, not necessarily adjacent in time, to that MCH. This pattern is called a MCH Subframe Allocation Pattern (MSAP). Multiple MBMS services can be mapped to the same MCH and one MCH contains data belonging to only one MBSFN Area. Whether there is a 1-to-1 mapping between MCH and MBSFN Area is FFS. The MSAP for every MCH carrying MTCH is signalled on MCCH. At such an MSAP occasion:

- The eNB applies MAC multiplexing of different MTCH's to be transmitted on this MCH. The transmission order of MTCHs is signalled (FFS whether implicitly or explicitly) in the MCCH;
- Dynamic scheduling information can be provided in the MSAP occasion to assist the UE in choosing which subframes it needs to receive, both when services are multiplexed onto the MCH and when only a single service is transmitted on the MCH. It is FFS how the scheduling information is carried (e.g. in a MAC control element, or a separate logical channel MSCH). The dynamic scheduling information carries the mapping of MTCHs to the sub-frames of the associated MSAP occasion. This mapping is based on the indexing of sub-frames belonging to one MSAP occasion.

The content synchronization for multi-cell transmission is provided by the following principles:

1. All eNBs in a given MBSFN Synchronization Area have a synchronised radio frame timing such that the radio frames are transmitted at the same time.
2. All eNBs have the same configuration of RLC/MAC/PHY for each MBMS service, and identical information (e.g. time information, transmission order/priority information) such that synchronized dynamic scheduling in the eNBs is ensured. These are indicated in advance by the MCE.
3. An E-MBMS GW sends/broadcasts MBMS packet with the SYNC protocol to each eNB transmitting the service.
4. The SYNC protocol provides additional information so that the eNBs identify the transmission radio frame(s). The E-MBMS GW does not need accurate knowledge of radio resource allocation in terms of exact time division (e.g. exact start time of the radio frame transmission).
5. eNB buffers MBMS packet and waits for the transmission timing indicated in the SYNC protocol.
6. The segmentation/concatenation is needed for MBMS packets and should be totally up to the RLC/MAC layer in eNB.
7. The SYNC protocol provides means to detect packet loss(es) and supports a recovery mechanism robust against loss of consecutive PDU packets (MBMS Packets with SYNC Header).
8. For the packet loss case the transmission of radio blocks potentially impacted by the lost packet should be muted.
9. The mechanism supports indication or detection of MBMS data burst termination (e.g. to identify and alternately use available spare resources related to pauses in the MBMS PDU data flow).

15.3.4 MBMS Reception States

UEs that are receiving MTCH transmissions and are taking part in at least one MBMS feedback scheme will be in RRC_CONNECTED state. UEs receiving MTCH transmissions without taking part in an MBMS feedback mechanism can be in RRC_IDLE or RRC_CONNECTED state.

For the reception of single-cell transmission of MTCH, an eNB can require a UE to be in RRC_CONNECTED state. The signalling by which a UE is triggered to move to RRC_CONNECTED state solely for single-cell reception purposes is carried on MCCH.

15.3.5 MCCH Structure

The following principles govern the MCCH structure:

- BCCH indicates the scheduling of one or two Primary MCCH (one for single cell transmission on DL-SCH, one for multi-cell transmission on MCH) where the Primary MCCH on MCH can also point to additional Secondary MCCH(s) on MCH if any.

NOTE: the need for Secondary MCCH(s) when the Primary MCCH is mapped on DL-SCH is FFS.

- BCCH only points to the resources where the Primary MCCH(s) can be found i.e. it does not indicate the availability of the services.
- The primary MCCH is sent on DL-SCH for single cell transmission and on MCH for multi-cell transmission on an MBSFN area.
- Multiple overlapping MTCH-MBSFN areas can result in multiple MCCHs, for which using different MBSFN areas should be possible (using Secondary MCCHs).
- The MCCH-MBSFN area is not necessarily the same as the MTCH-MBSFN area i.e. MCCH can be either on a different MCH than the MCH carrying "advertised" MTCH, or multiplexed on the same MCH as the one carrying "advertised" MTCH.

15.4 Service Continuity

As combinations of the possible MBMS cell types and transmission modes, various deployment scenarios come into question. Among them, E-UTRAN provides the necessary optimization mechanisms to support seamless MBMS continuity between:

1) MBSFN and single-cell transmission on a shared frequency layer;
2) MBSFN on a dedicated frequency layer and single-cell transmission on a shared frequency layer;
3) Cells providing single-cell transmission on a shared frequency layer.

For the reception of single-cell transmission of MTCH, UEs that are receiving MBMS service(s) in RRC_CONNECTED state (either directed to the state to receive the MBMS service or in the state already for other reasons and the eNB is aware that the UE is receiving the particular MBMS service(s)), can be provided with target cell MTCH information for these services via the handover related signalling. The serving eNB will trigger the target eNB to prepare for the handover e.g. to obtain the MBMS service if necessary.

UEs that are receiving MBMS service(s) in RRC_IDLE state performing cell reselection or are in RRC_CONNECTED state and which do not receive target cell information as part of handover signalling, should obtain target cell MTCH information from the target cell MCCH or, if supported, serving cell MCCH information (FFS). If the UE was in RRC_CONNECTED state and the source eNB was aware that it is receiving the particular MBMS service(s) the serving eNB could trigger the target eNB to prepare for the handover e.g. to obtain the MBMS service if necessary.

15.5 Network sharing

Network sharing of MBMS resources among multiple operators of the same country is supported, with focus on, but not limited to, sharing of a dedicated-carrier MBSFN. MBMS network sharing shall not require unicast network sharing. Unicast mobility shall not be affected by the sharing of MBMS resources by operators.

NOTE: it is FFS whether this is based on dual-receiver solutions.

15.6 Network Functions for Support of Multiplexing

Considerable gain in radio resource efficiency can be achieved by multiplexing several E-MBMS services on a single MCH. The services that share the resources are called E-MBMS Service Multiplex. The amount of common radio resources allocated to such an E-MBMS Service Multiplex can be smaller than the sum of radio resources, which would need to be allocated for the individual services without multiplexing. This represents the statistical multiplexing gain.

The entity managing the E-MBMS Service Multiplex e.g. deciding which services are to be multiplexed is FFS. The duration of each E-MBMS service may be different, so there is may be a need to manage the Service Multiplex dynamically, i.e. addition or removal of services into/from the E-MBMS Service Multiplex. The MCE allocates the optimal amount of resources to multiplexed services, using service related information. MBSFN transmission is ensured by identical multiplexing of the services within the MBMS-GW or different eNBs. The location of the multiplexing function is FFS.

These functions are supported by respective signalling and by the SYNC protocol on M1, the details are FFS.

15.7 Procedures

15.7.1 Procedures for Broadcast mode

15.7.1.1 Session Start procedure

The purpose of the MBMS Session Start procedure is to request the E-UTRAN to notify UEs about an upcoming MBMS Session of a given MBMS Bearer Service and to establish an MBMS SAE bearer for this MBMS Session. The MBMS Session Start procedure is triggered by the EPC.

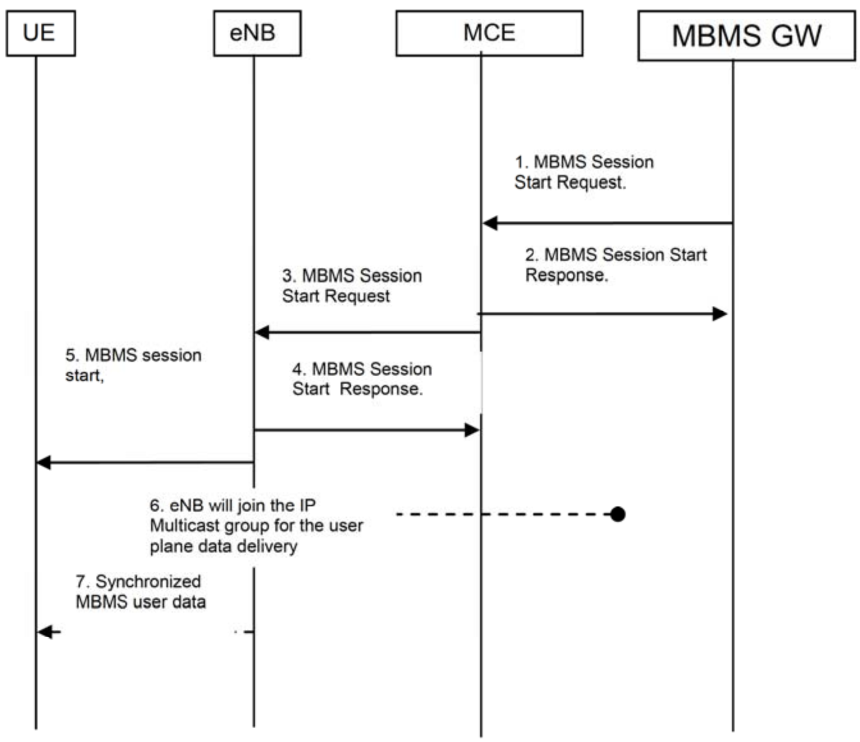

Figure 15.7.1.1-1. Session Start procedure

1. The MBMS GW entity sends MBMS session start request message to the MCE(s) controlling eNBs in the targeted MBMS service area. The message includes the IP multicast address and session attributes.
2. MCE confirms the reception of the MBMS Session Start request to the MBMS GW. It is FFS whether this message is transmitted after message 4.
3. MCE sends the MBMS Session Start message to the eNBs in the targeted MBMS service area. In addition to the session attributes this message provides radio bearer configuration for MBSFN transmission.
4. eNB confirms the reception of the MBMS Session Start message.
5. eNB sends the MBMS Session Start message to UEs. The location of the message is FFS, other positions are after messages 6 or 7. The message details are FFS.
6. eNB joins the IP multicast group to receive the MBMS User Plane data.
7. eNB sends the MBMS data to radio interface at the determined time.

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15.7.1.2 Session Stop procedure

The MBMS Session Stop procedure is to request the E-UTRAN to notify UEs about the end of a given MBMS Session and to release the corresponding MBMS SAE bearer this MBMS Session. The MBMS Session Stop procedure is triggered by the EPC.

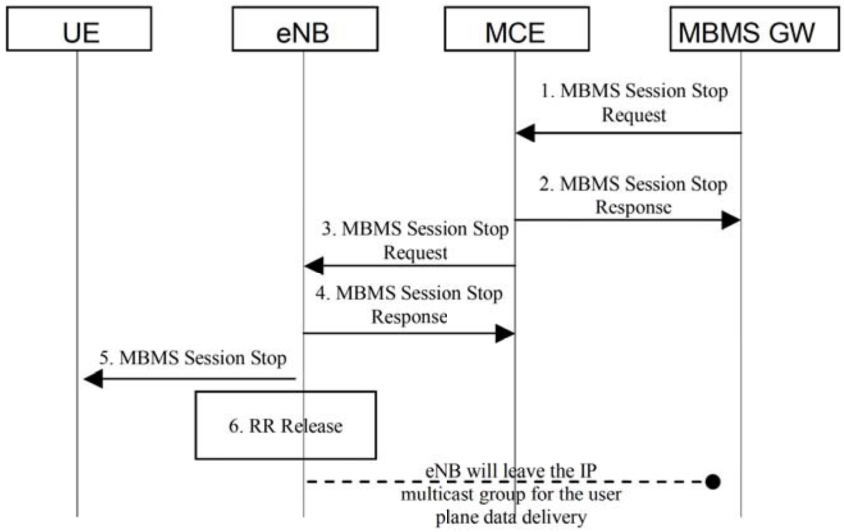

Figure 15.7.1.2-1. Session Stop procedure

1. The MBMS GW entity sends MBMS session stop request message to the MCE(s) controlling eNBs in the targeted MBMS service area.
2. MCE confirms the reception of the MBMS Session stop request to the MBMS GW.
3. MCE forwards the MBMS Session stop message to the eNBs in the targeted MBMS service area.
4. eNB confirms the reception of the MBMS Session stop message.
5. eNB sends the MBMS Session stop message to UEs. The message details are FFS.
6. The corresponding SAE bearer is released, and eNB leaves the the IP multicast group.

16 Radio Resource Management aspects

The purpose of radio resource management (RRM) is to ensure the efficient use the available radio resources and to provide mechanisms that enable E-UTRAN to meet radio resource related requirements identified in sub-clause 10 of 3GPP TR 25.913 [2]. In particular, RRM in E-UTRAN provides means to manage (e.g. assign, re-assign and release) radio resources taking into account single and multi-cell aspects.

16.1 RRM functions

16.1.1 Radio Bearer Control (RBC)

The establishment, maintenance and release of Radio Bearers involve the configuration of radio resources associated with them. When setting up a radio bearer for a service, radio bearer control (RBC) takes into account the overall resource situation in E-UTRAN, the QoS requirements of in-progress sessions and the QoS requirement for the new service. RBC is also concerned with the maintenance of radio bearers of in-progress sessions at the change of the radio resource situation due to mobility or other reasons. RBC is involved in the release of radio resources associated with radio bearers at session termination, handover or at other occasions.

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RBC is located in the eNB.

16.1.2 Radio Admission Control (RAC)

The task of radio admission control (RAC) is to admit or reject the establishment requests for new radio bearers. In order to do this, RAC takes into account the overall resource situation in E-UTRAN, the QoS requirements, the priority levels and the provided QoS of in-progress sessions and the QoS requirement of the new radio bearer request. The goal of RAC is to ensure high radio resource utilization (by accepting radio bearer requests as long as radio resources available) and at the same time to ensure proper QoS for in-progress sessions (by rejecting radio bearer requests when they cannot be accommodated).

RAC is located in the eNB.

16.1.3 Connection Mobility Control (CMC)

Connection mobility control (CMC) is concerned with the management of radio resources in connection with idle or connected mode mobility. In idle mode, the cell reselection algorithms are controlled by setting of parameters (thresholds and hysteresis values) that define the best cell and/or determine when the UE should select a new cell. Also, E-UTRAN broadcasts parameters that configure the UE measurement and reporting procedures. In connected mode, the mobility of radio connections has to be supported. Handover decisions may be based on UE and eNB measurements. In addition, handover decisions may take other inputs, such as neighbour cell load, traffic distribution, transport and hardware resources and Operator defined policies into account.

CMC is located in the eNB.

16.1.4 Dynamic Resource Allocation (DRA) - Packet Scheduling (PS)

The task of dynamic resource allocation (DRA) or packet scheduling (PS) is to allocate and de-allocate resources (including buffer and processing resources and resource blocks (i.e. chunks)) to user and control plane packets. DRA involves several sub-tasks, including the selection of radio bearers whose packets are to be scheduled and managing the necessary resources (e.g. the power levels or the specific resource blocks used). PS typically takes into account the QoS requirements associated with the radio bearers, the channel quality information for UEs, buffer status, interference situation, etc. DRA may also take into account restrictions or preferences on some of the available resource blocks or resource block sets due to inter-cell interference coordination considerations.

DRA is located in the eNB.

16.1.5 Inter-cell Interference Coordination (ICIC)

Inter-cell interference coordination has the task to manage radio resources (notably the radio resource blocks) such that inter-cell interference is kept under control. ICIC is inherently a multi-cell RRM function that needs to take into account information (e.g. the resource usage status and traffic load situation) from multiple cells. The preferred ICIC method may be different in the uplink and downlink.

ICIC is located in the eNB.

16.1.6 Load Balancing (LB)

Load balancing has the task to handle uneven distribution of the traffic load over multiple cells. The purpose of LB is thus to influence the load distribution in such a manner that radio resources remain highly utilized and the QoS of in-progress sessions are maintained to the extent possible and call dropping probabilities are kept sufficiently small. LB algorithms may result in hand-over or cell reselection decisions with the purpose of redistribute traffic from highly loaded cells to underutilized cells.

LB is located in the eNB.

16.1.7 Inter-RAT Radio Resource Management

Inter-RAT RRM is primarily concerned with the management of radio resources in connection with inter-RAT mobility, notably inter-RAT handover. At inter-RAT handover, the handover decision may take into account the involved RATs resource situation as well as UE capabilities and Operator policies. The importance of Inter-RAT RRM may depend on the specific scenario in which E-UTRAN is deployed. Inter-RAT RRM may also include functionality for inter-RAT load balancing for idle and connected mode UEs.

16.1.8 Subscriber Profile ID for RAT/Frequency Priority

The RRM strategy in E-UTRAN may be based on user specific information.

The Subscriber Profile ID for RAT/Frequency Priority (SPID) parameter received by the eNB via the S1 interface is an index referring to user information (e.g. mobility profile, service usage profile and roaming restrictions). The information is UE specific and applies to all its Radio Bearers.

This index is mapped by the eNB to locally defined configuration in order to apply specific RRM strategies (e.g. to define RRC_IDLE mode priorities and control inter-RAT/inter frequency handover in RRC_CONNECTED mode).

16.2 RRM architecture

16.2.1 Centralised Handling of certain RRM Functions

16.2.2 De-Centralised RRM

Historical information about the UE is transferred between the eNBs over the X2 interface during the handover preparation procedure. For instance, an activity level description of the UE in the source eNB is transferred to the target eNB.

16.2.3 Load balancing control

17 RF aspects

17.1 Spectrum deployments

18 UE capabilities

RRC signalling carries RRC capability and NAS signalling carries NAS capability. Some capability information may be stored in the EPC. In the uplink, some capability information may be sent early in e.g. RRC_CONNECTION_REQUEST. In the downlink, inquiry procedure of the UE capability may be supported.

For emergency services, a minimum MBMS UE capability is defined. Whether such a minimum capability should be a mandatory UE capability is FFS.

19 S1 Interface

19.1 S1 User plane

The S1 user plane interface (S1-U) is defined between the eNB and the S-GW. The S1-U interface provides non guaranteed delivery of user plane PDUs between the eNB and the S-GW. The user plane protocol stack on the S1 interface is shown in Figure 19.1-1. The transport network layer is built on IP transport and GTP-U is used on top of UDP/IP to carry the user plane PDUs between the eNB and the S-GW.

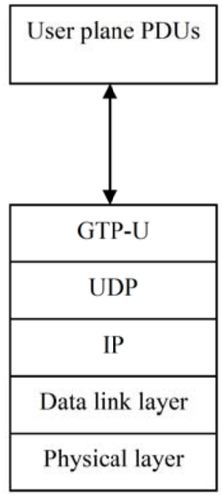

Figure 19.1-1: S1 Interface User Plane (eNB - S-GW)

19.2 S1 Control Plane

The S1 control plane interface (S1-MME) is defined between the eNB and the MME. The control plane protocol stack of the S1 interface is shown on Figure 19.2-1. The transport network layer is built on IP transport, similarly to the user plane but for the reliable transport of signalling messages SCTP is added on top of IP. The application layer signalling protocol is referred to as S1-AP (S1 Application Protocol).

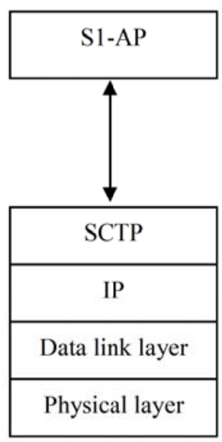

Figure 19.2-1: S1 Interface Control Plane (eNB-MME)

The SCTP layer provides the guaranteed delivery of application layer messages.

In the transport IP layer point-to-point transmission is used to deliver the signalling PDUs.

A single SCTP association per S1-MME interface instance shall be used with one pair of stream identifiers for S1-MME common procedures. Only a few pairs of stream identifiers should be used for S1-MME dedicated procedures. The upper limit for the number of stream identifiers for dedicated procedures is FFS and will be decided during the stage 3 work.

MME communication context identifiers that are assigned by the MME for S1-MME dedicated procedures and eNB communication context identifiers that are assigned by the eNB for S1-MME dedicated procedures shall be used to distinguish UE specific S1-MME signalling transport bearers. The communication context identifiers are conveyed in the respective S1-AP messages.

19.2.1 S1 Interface Functions

Note: The following list of S1 functions reflects the status of agreements in RAN3, might be extended in forthcoming meetings.

- EPS Bearer Service Management function:
  - Setup, Modify, release.
- Mobility Functions for UEs in ECM-CONNECTED:
  - Intra-LTE Handover;
  - Inter-3GPP-RAT Handover.
- S1 Paging function:
- NAS Signalling Transport function;
- S1-interface management functions:
  - Error indication;
  - Reset.
- Network Sharing Function;
- Roaming and Area Restriction Support function;
- NAS Node Selection Function;
- Initial Context Setup Function;
- UE Context Modification Function.

19.2.1.1 S1 Paging function

The paging function supports the sending of paging requests to all cells of the TA(s) the UE is registered.

Paging requests are sent to the relevant eNBs according to the mobility information kept in the UE's MM context in the serving MME.

19.2.1.2 S1 UE Context Management function

In order to support UEs in ECM-CONNECTED, UE contexts need to be managed, i.e. established and released in the eNodeB and in the EPC to support user individual signalling on S1.

19.2.1.3 Initial Context Setup Function

The Initial Context Setup function supports the establishment of the necessary overall initial UE Context including EPS Bearer context, Security context, roaming restriction, UE capability information, Subscriber Profile ID for RAT/Frequency Priority, UE S1 signalling connection ID, etc. in the eNB to enable fast Idle-to-Active transition.

In addition to the setup of overall initial UE Contexts, Initial Context Setup function also supports the piggy-backing of the corresponding NAS messages. Initial Context Setup is initiated by the MME.

19.2.1.3a UE Context Modification Function

The UE Context Modification function supports the modification of UE Context in eNB for UEs in active state.

19.2.1.4 Mobility Functions for UEs in ECM-CONNECTED

19.2.1.4.1 Intra-LTE Handover

The Intra-LTE-Handover function supports mobility for UEs in ECM-CONNECTED and comprises the preparation, execution and completion of handover via the X2 and S1 interfaces.

19.2.1.4.2 Inter-3GPP-RAT Handover

The Inter-3GPP-RAT Handover function supports mobility to and from other 3GPP-RATs for UEs in ECM-CONNECTED and comprises the preparation, execution and completion of handover via the S1 interface.

19.2.1.5 EPS Bearer Service Management function

The EPS Bearer Service management function is responsible for establishing, modifying and releasing E-UTRAN resources for user data transport once a UE context is available in the eNB. The establishment and modification of E-UTRAN resources is triggered by the MME and requires respective QoS information to be provided to the eNB. The release of E-UTRAN resources is triggered by the MME either directly or following a request received from the eNB (optional).

NOTE: Whether EPS bearer related NAS messages are included in S1AP EPS Bearer Management procedures piggybacking or if NAS messages are sent with S1-AP Direct Transfer is FFS:

19.2.1.6 NAS Signalling Transport function

The NAS Signalling Transport function provides means to transport a NAS message (e.g. for NAS mobility management) for a specific UE on the S1 interface.

19.2.1.7 NAS Node Selection Function

The interconnection of eNBs to multiple MME/Serving S-GWs is supported in the LTE/SAE architecture. Therefore a NAS node selection function is located in the eNB to determine the MME association of the UE, based on the UE's temporary identifier, which was assigned to the UE by the MME.

This functionality is located in the eNB only and enables proper routing via the S1 interface. On S1, no specific procedure corresponds to the NAS Node Selection Function.

19.2.1.8 S1-interface management functions

The S1-interface management functions provide

- means to ensure a defined start of S1-interface operation (reset)
- means to handle different versions of application part implementations and protocol errors (error indication)

19.2.2 S1 Interface Signalling Procedures

Note: The following list of S1 procedures reflects the status of agreements in RAN3, might be extended in forthcoming meetings.

- EPS Bearer signalling procedures:
  - EPS Bearer Setup procedure;
  - EPS Bearer Modification procedure;
  - EPS Bearer Release procedure (MME initiated);
  - EPS Bearer Release procedure (eNB initiated).
- Handover signalling procedures;

    - Handover Preparation procedure;
    - Handover Resource Allocation procedure;
    - Handover Completion procedure;
    - Handover Cancellation procedure.
- Paging procedure;
- NAS transport procedure:
    - UL direction (Initial UE Message);
    - UL direction (Uplink NAS transport);
    - DL direction (Downlink NAS transport).
- Error Indication procedure:
    - eNB initiated error indication procedure;
    - MME initiated error indication procedure.
- Reset procedure:
    - eNB initiated Reset procedure;
    - MME initiated Reset procedure.
- Initial Context Setup procedure;
- UE Context Modification procedure.

19.2.2.1 Paging procedure

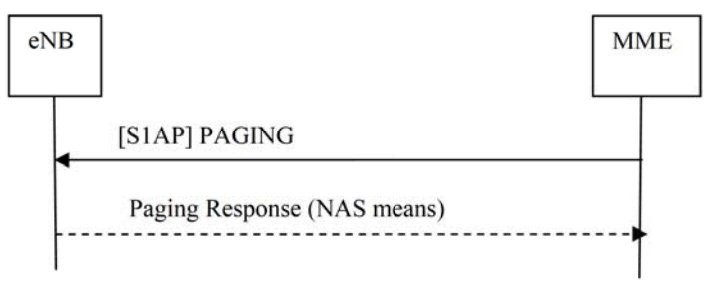

Figure 19.2.2.1-1: Paging procedure

The MME initiates the paging procedure by sending the PAGING message to each eNB with cells belonging to the tracking area(s) in which the UE is registered. Each eNB can contain cells belonging to different tracking areas, whereas each cell can only belong to one TA.

The paging response back to the MME is initiated on NAS layer and is sent by the eNB based on NAS-level routing information.

19.2.2.2 S1 UE Context Release procedure

The S1 UE Context Release procedure causes the eNB to remove all UE individual signalling resources and the related user data transport resources. This procedure is initiated by the EPC and may be triggered on request of the serving eNB.

19.2.2.2.1 S1 UE Context Release (EPC triggered)

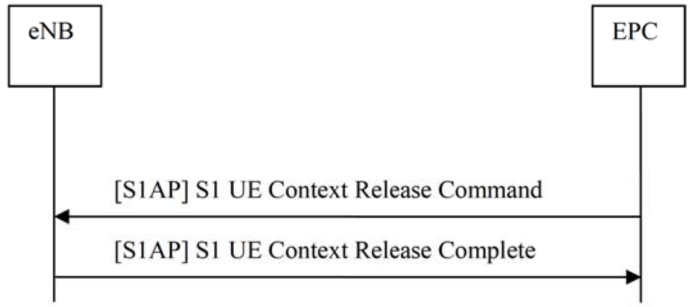

Figure 19.2.2.2.1-1: S1 UE Context Release procedure (EPC triggered)

- The EPC initiates the UE Context Release procedure by sending the S1 UE Context Release Command towards the E-UTRAN. The eNodeB releases all related signalling and user data transport resources.
- The eNB confirms the S1 UE Context Release activity with the S1 UE Context Release Complete message.
- In the course of this procedure the EPC releases all related resources as well, except context resources in the EPC for mobility management and the default EPS Bearer configuration.

19.2.2.2.2 S1 UE Context Release Request (eNB triggered)

The S1 UE Context Release Request procedure is initiated for E-UTRAN internal reasons and comprises the following steps:

- The eNB sends the S1 UE Context Release Request message to the EPC.
- The EPC triggers the EPC initiated UE context release procedure.

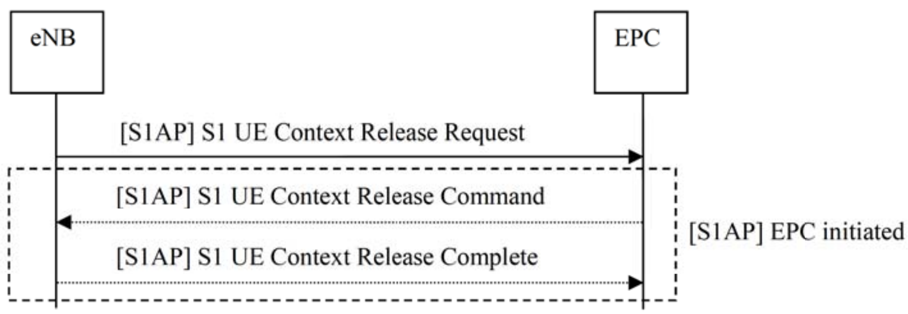

Figure 19.2.2.2.2-1: S1 UE Context Release Request procedure (eNB triggered) and subsequent S1 UE Context Release procedure (EPC triggered)

19.2.2.3 Initial Context Setup procedure

The Initial Context Setup procedure establishes the necessary overall initial UE context in the eNB in case of an Idle-to Active transition. The Initial Context Setup procedure is initiated by the MME.

The Initial Context Setup procedure comprises the following steps:

- The MME initiates the Initial Context Setup procedure by sending INITIAL CONTEXT SETUP REQUEST to the eNB. This message may include general UE Context (e.g. security context, roaming restrictions, UE capability information, UE S1 signalling connection ID, etc.), EPS bearer context (Serving GW TEID, QoS information), and may be piggy-backed with the corresponding NAS message.
- Upon receipt of INITIAL CONTEXT SETUP REQUEST, the eNB setup the context of the associated UE, and perform the necessary RRC signalling towards the UE, e.g. Radio Bearer Setup procedure.

- The eNB responds with INITIAL CONTEXT SETUP COMPLETE to inform a successful operation, and with INITIAL CONTEXT SETUP FAILURE to inform an unsuccessful operation.

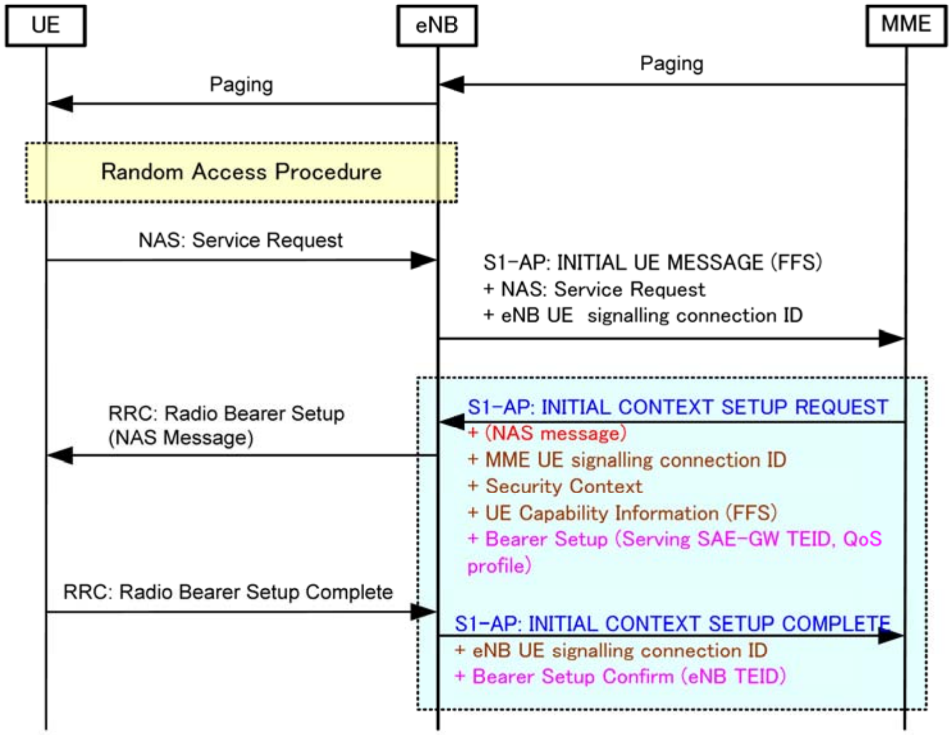

Figure 19.2.2.3-1: Initial Context Setup procedure (highlighted in blue) in Idle-to-Active procedure

19.2.2.3a UE Context Modification procedure

The UE Context Modification procedure enables the MME to modify the UE context in the eNB for UEs in active state. The UE Context Modification procedure is initiated by the MME.

The UE Context Modification procedure comprises the following steps:

- The MME initiates the UE Context Modification procedure by sending UE CONTEXT MODIFICATION REQUEST to the eNB to modify the UE context in the eNB for UEs in active state.

- The eNB responds with UE CONTEXT MODIFICATION RESPONSE to inform a successful operation, and with UE CONTEXT MODIFICATION FAILURE to inform an unsuccessful operation.

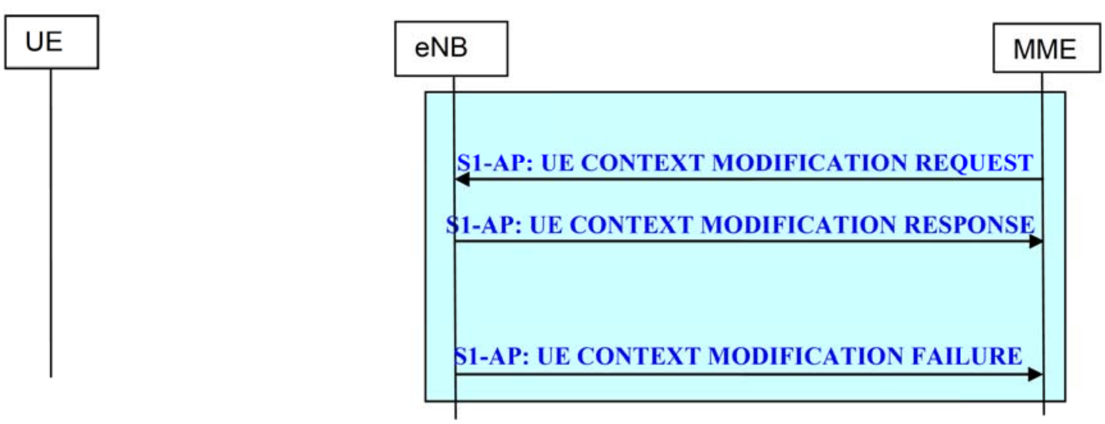

Figure 19.2.2.3a-1: UE Context Modification procedure

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19.2.2.4 EPS Bearer signalling procedures

19.2.2.4.1 EPS Bearer Setup procedure

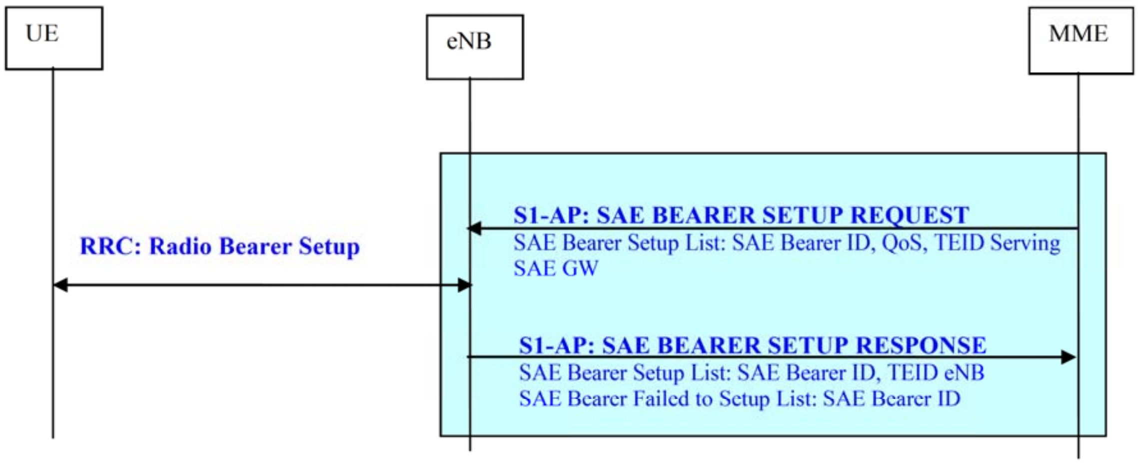

Figure 19.2.2.4.1-1: EPS Bearer Setup procedure

The EPS Bearer Setup procedure is initiated by the MME to support:

- Assignment of resources to a dedicated EPS bearer.
- Assignment of resources for a default EPS bearer (FFS)
- Setup of S1 Bearer (on S1) and Radio Bearer (on Uu)

The EPS Bearer Setup procedure comprises the following steps:

- The EPS BEARER SETUP REQUEST is sent by the MME to the eNB to setup resources on S1 and Uu for one or several EPS Bearer(s). The EPS BEARER SETUP REQUEST message contains the Serving GW TEID and QoS indicator(s) per EPS bearer within the EPS Bearer Setup List.
- Upon receipt of the EPS BEARER SETUP REQUEST the eNB establishes the Radio Bearer(s) (RRC: Radio Bearer Setup) and resources for S1 Bearers.
- The eNB responds with a EPS BEARER SETUP RESPONSE messages to inform whether the setup of resources and establishment of an EPS Bearer was successful or unsuccessful, with the EPS bearer Setup (EPS Bearer ID , eNB TEID) and the EPS Bearer Failed to Setup list (EPS bearer ID). The eNB also creates the binding between the S1 bearer(s) (DL/UL TEID) and the Radio Bearer(s).

19.2.2.4.2 EPS Bearer Modification procedure

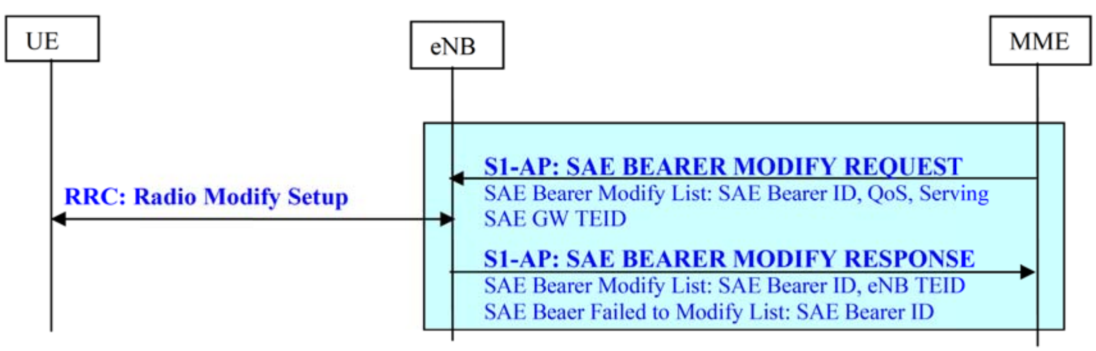

Figure 19.2.2.4.2-1: EPS Bearer Modification procedure

The EPS Bearer Modification procedure is initiated by the MME to support the modification of already established EPS Bearer configurations:

- Modify of S1 Bearer (on S1) and Radio Bearer (on Uu)

The EPS Bearer Modification procedure comprises the following steps:

- The EPS BEARER MODIFY REQUEST is sent by the MME to the eNB to modify one or several EPS Bearer(s). The EPS BEARER MODIFY REQUEST message contains the QoS indicator(s) and Serving GW TEID per EPS bearer in the EPS Bearer Modify List.
- Upon receipt of the EPS BEARER MODIFY REQUEST the eNB modifies the Radio Bearer configuration (RRC procedure to modify the Radio bearer).
- The eNB responds with an EPS BEARER MODIFY RESPONSE message to inform whether the EPS Bearer modification has succeeded or not indicating with the EPS bearer Modify list and EPS bearer Failed to Modify list. With EPS Bearer ID(s) in the EPS Bearer Modify List the eNB identifies the EPS bearer(s) successfully modified or failed to modify.

19.2.2.4.3 EPS Bearer Release procedure (MME initiated)

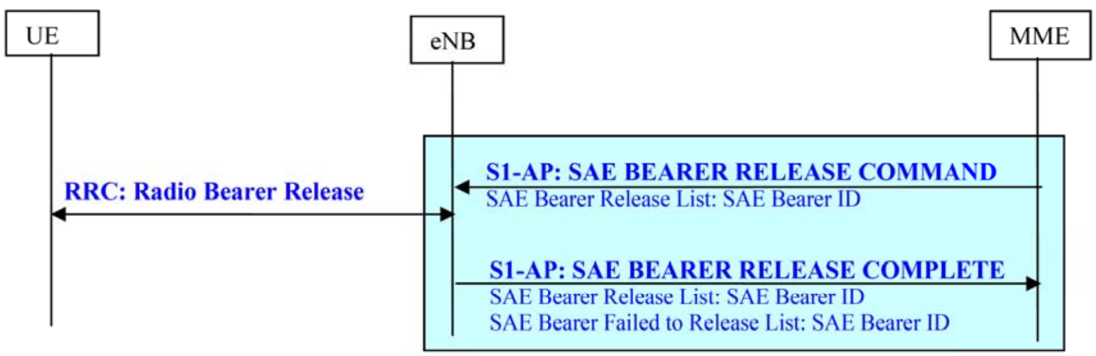

Figure 19.2.2.4.3-1: EPS Bearer Release procedure (MME initiated)

The EPS Bearer Release procedure is initiated by the MME to release resources for the indicated EPS Bearers.

The EPS Bearer Release procedure comprises the following steps:

- The EPS BEARER RELEASE COMMAND is sent by the MME to the eNB to release resources on S1 and Uu for one or several EPS Bearer(s). With the EPS Bearer ID(s) in the EPS bearer Release List contained in EPS BEARER RELEASE COMMAND the MME identifies, the EPS Access Bearer(s) to be released.
- Upon receipt of the EPS BEARER RELEASE COMMAND the eNB releases the Radio Bearers (RRC: Radio bearer release) and S1 Bearers.
- The eNB responds with an EPS BEARER RELEASE COMPLETE message containing EPS bearer Release list and EPS bearer Failed to Release list. With the EPS Bearer IDs in the EPS Bearer Release List/EPS Bearer Failed to Release List the eNB identifies the EPS bearer(s) successfully released or failed to release.

19.2.2.4.4 EPS Bearer Release procedure (eNB initiated)

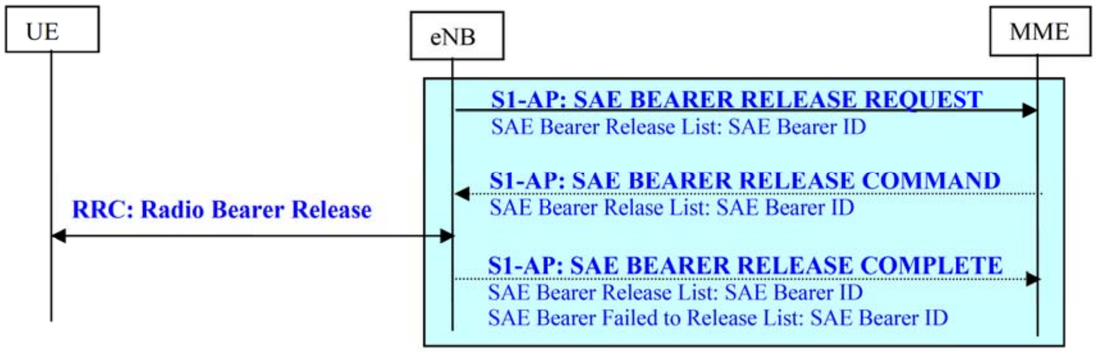

Figure 19.2.2.4.4-1: EPS Bearer Release (eNB initiated) procedure

The EPS Bearer Release function enables the E-UTRAN to request the release of resources for one or several EPS Bearers. The eNB initiated EPS Bearer Release procedure comprises the following steps:

- The eNB initiates the EPS Bearer Release procedure by sending the EPS BEARER RELEASE REQUEST message to the MME in order to release of one or more EPS Bearer(s). With the EPS Bearer ID(s) in the EPS Bearer Release List the eNB identifies the EPS bearer(s) requested to be released. The EPS BEARER RELEASE REQUEST message shall include the reason to release the resources for the EPS bearer, for example user inactivity.

- Upon receipt the MME initiates the EPS Bearer Release procedure (EPS BEARER RELEASE COMMAND/ EPS BEARER RELEASE COMPLETE) to request release of resources for the EPS Bearer(s).

19.2.2.5 Handover signalling procedures

Handover signalling procedures support both, inter-eNB handover and inter-RAT handover.

Inter-RAT handovers shall be initiated via the S1 interface.

Inter-eNB handovers shall be initiated via the X2 interface except if any of the following conditions are true:

- there is no X2 between source and target eNB.

- the source eNB has been configured to initiate handover to the particular target eNB via S1 interface in order to enable the change of an EPC node (MME and/or Serving GW).

- the source eNB has attempted to start the inter-eNB HO via X2 but receives a negative reply from the target eNB with a specific cause value.

NOTE: Handling of cases where the target eNB does not reply is FFS.

Inter-eNB handovers shall be initiated via the S1 interface, if one of the above conditions applies.

NOTE: Affects on Home eNBs should be looked at.

It is foreseen to re-use Handover principles from the Iu interface for inter-eNB handovers which are initiated via the S1 interface.

19.2.2.5.1 Handover Preparation procedure

The Handover preparation procedure is initiated by the source eNB if it determines the necessity to initiate the handover via the S1 interface.