Long-Term Evolution

Mobile Telecommunications Networks

WMNet Lab

Background

- Long-Term Evolution
  - Define a new packet-only wideband radio with flat architecture as part of 3GPP radio technology family
- 2004: identifying requirements from different players in the field
- 2005: feasibility study started
  - Key issues
    - Multiple access method
    - Network architecture in terms of functional split between radio access and core network

Background

- Key requirements
  - Packet-switched domain optimized
  - Server to UE round-trip time below 30ms and access delay below 300ms
  - Peak Rates UL/DL 50/100Mbps
  - Good level of mobility and security ensured
  - Improved terminal power efficiency
  - Frequency allocation flexibility
  - Higher Capacity compare with R6 HSDPA/HSUPA reference case

Evolution of network architecture

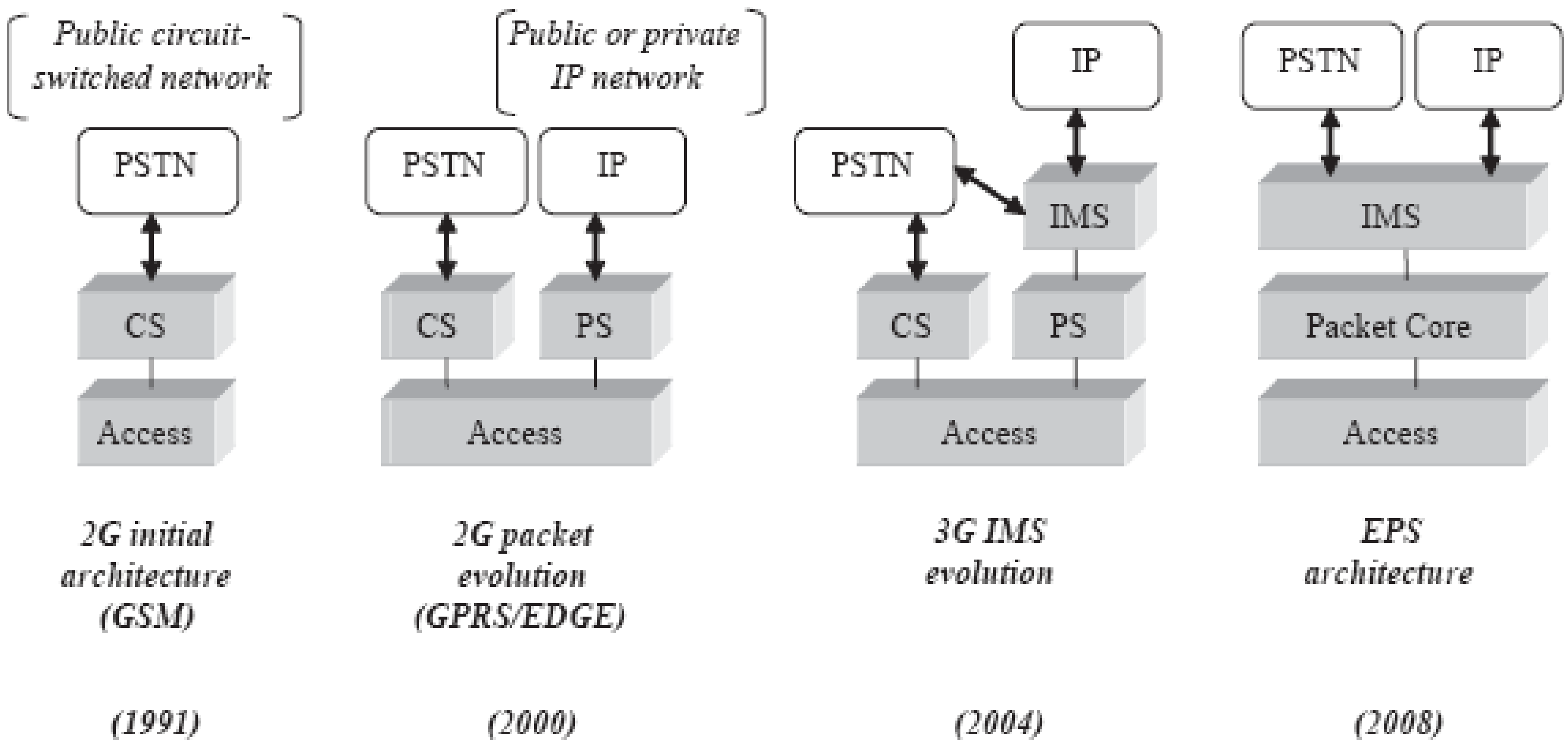


Figure 2.4 Evolution of network architecture (from circuit to packet).

Evolution of network architecture

- Flat architecture
  - More intelligence added to base station
  - UMTS architecture: hierarchical
    - Radio-related functionalities were located in RNC (radio network controller)
  - In the flat architecture the radio-related functionalities are located in BS
    - Packet scheduling
    - Frequency domain scheduling

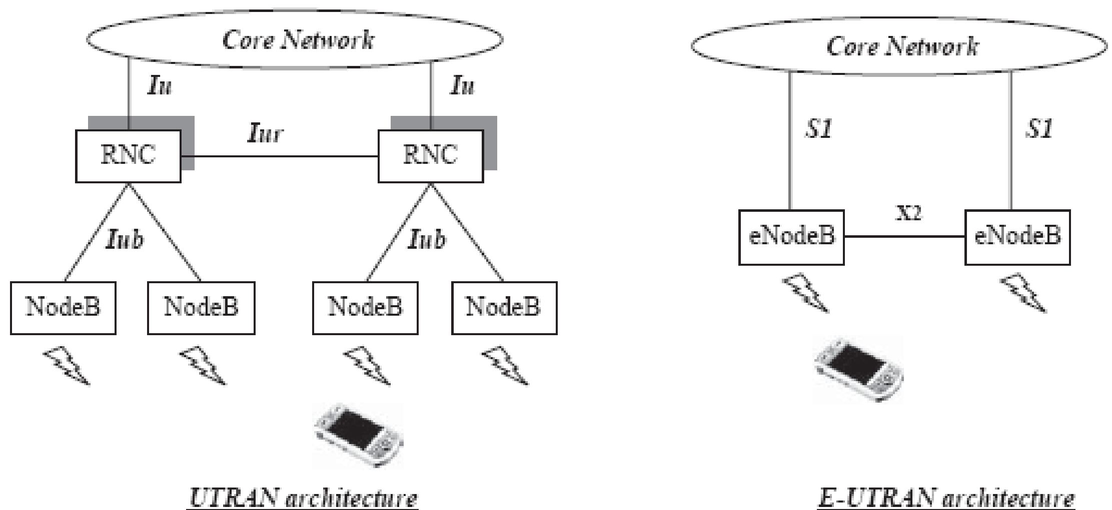


Figure 2.7 UTRAN and Evolved UTRAN architectures.

The overall EPS architecture

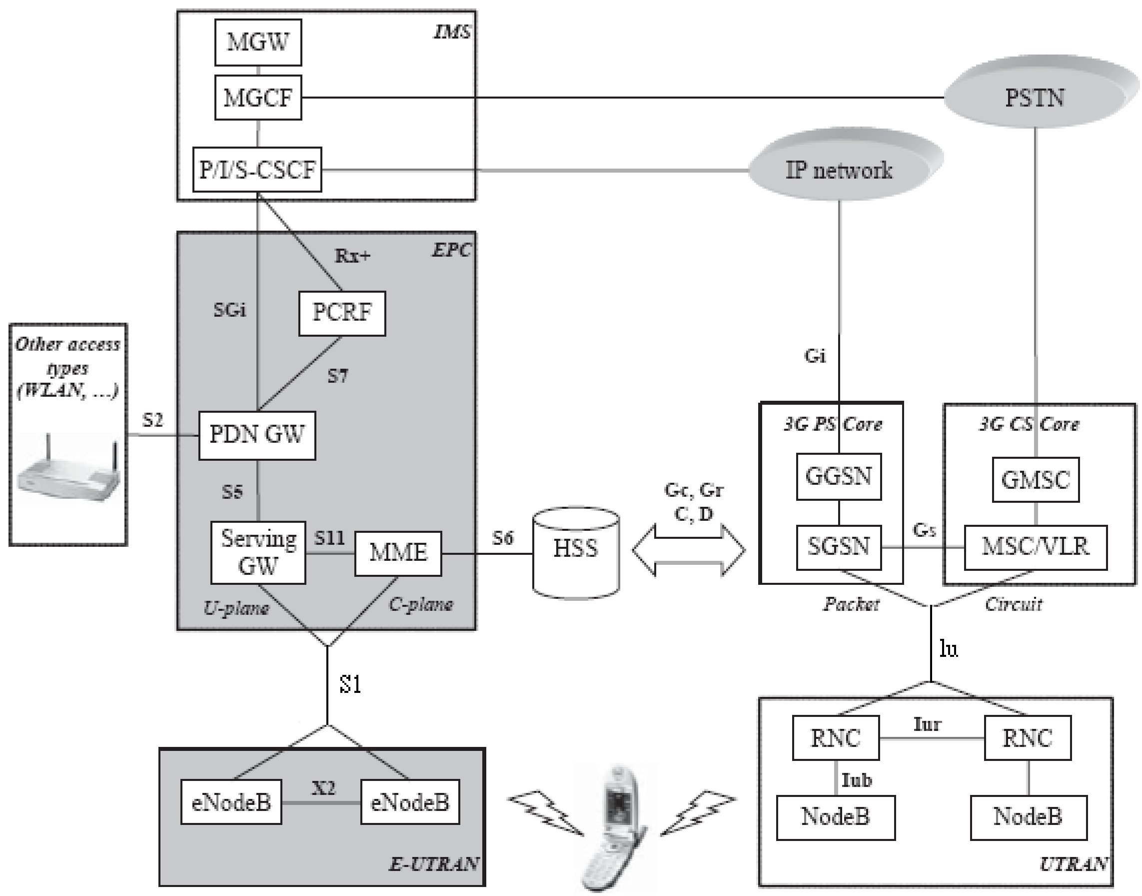


Figure 2.6 The overall EPS architecture.

EPC: functional entities

- MME (Mobility Management Entity)
  - Control plane functions
    - Security procedures
    - Terminal-to-network session handling
    - Idle terminal location management
- Serving GW (Serving Gateway)
  - Packets are routed through this point for intra E-UTRAN mobility and other 3GPP technologies
- PDN GW (Packet Data Network Gateway)
  - Sessions towards the external Packet Data Networks
  - Supports policy enforcement features, packet filtering and charging support

EPC: functional entities

- Home Subscriber Server (HSS)
  - Presents the registers, covering functionalities like the HLR and contains user-specific information on service priorities, data rates, etc.
- Policy and Charging Rules Function (PCRF)
  - Quality of service policy as well as on the charging policy applied

Architecture model

- Non-roaming architecture

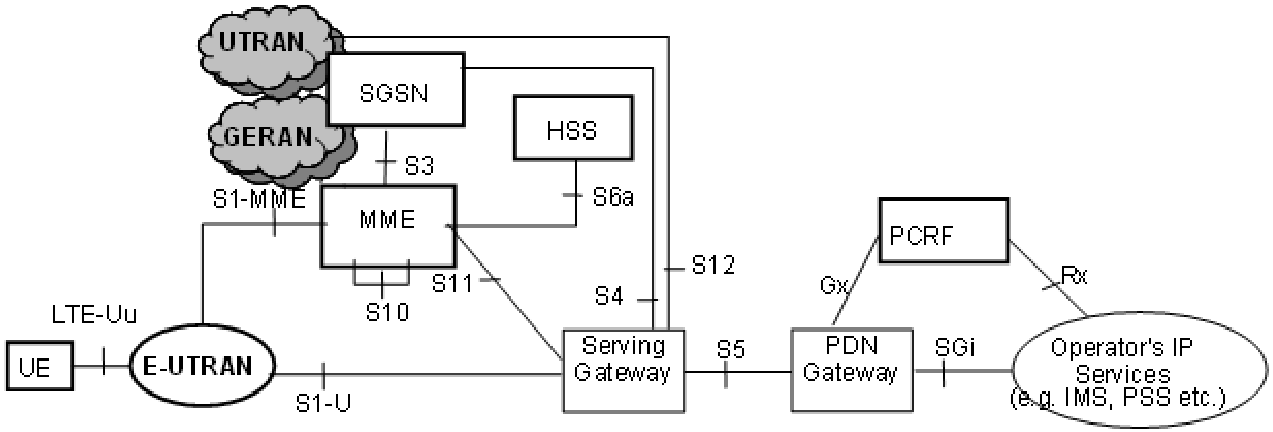


Figure 4.2.1-1: Non-roaming architecture for 3GPP accesses

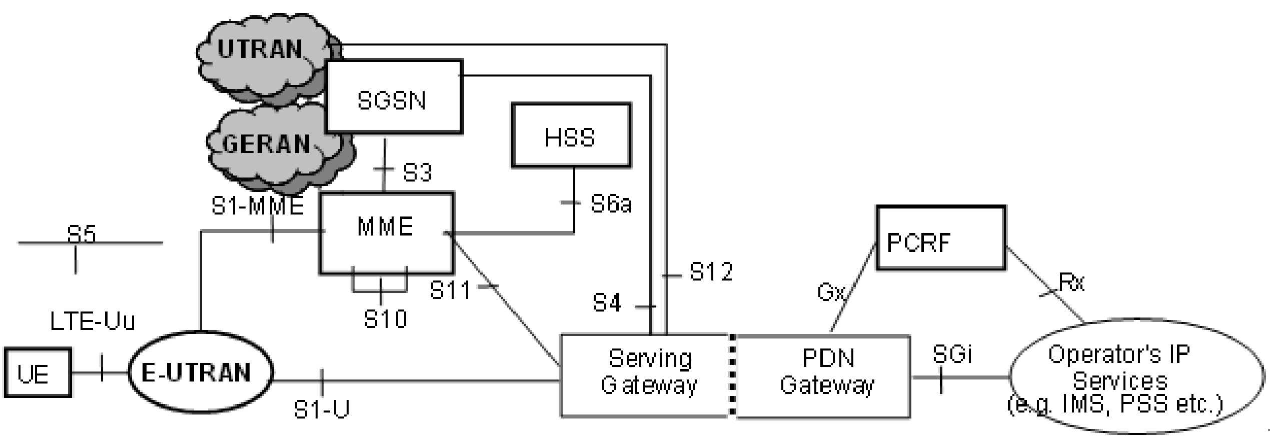


Figure 4.2.1-2: Non-roaming architecture for 3GPP accesses. Single gateway configuration option

Architecture model

- Roaming architecture

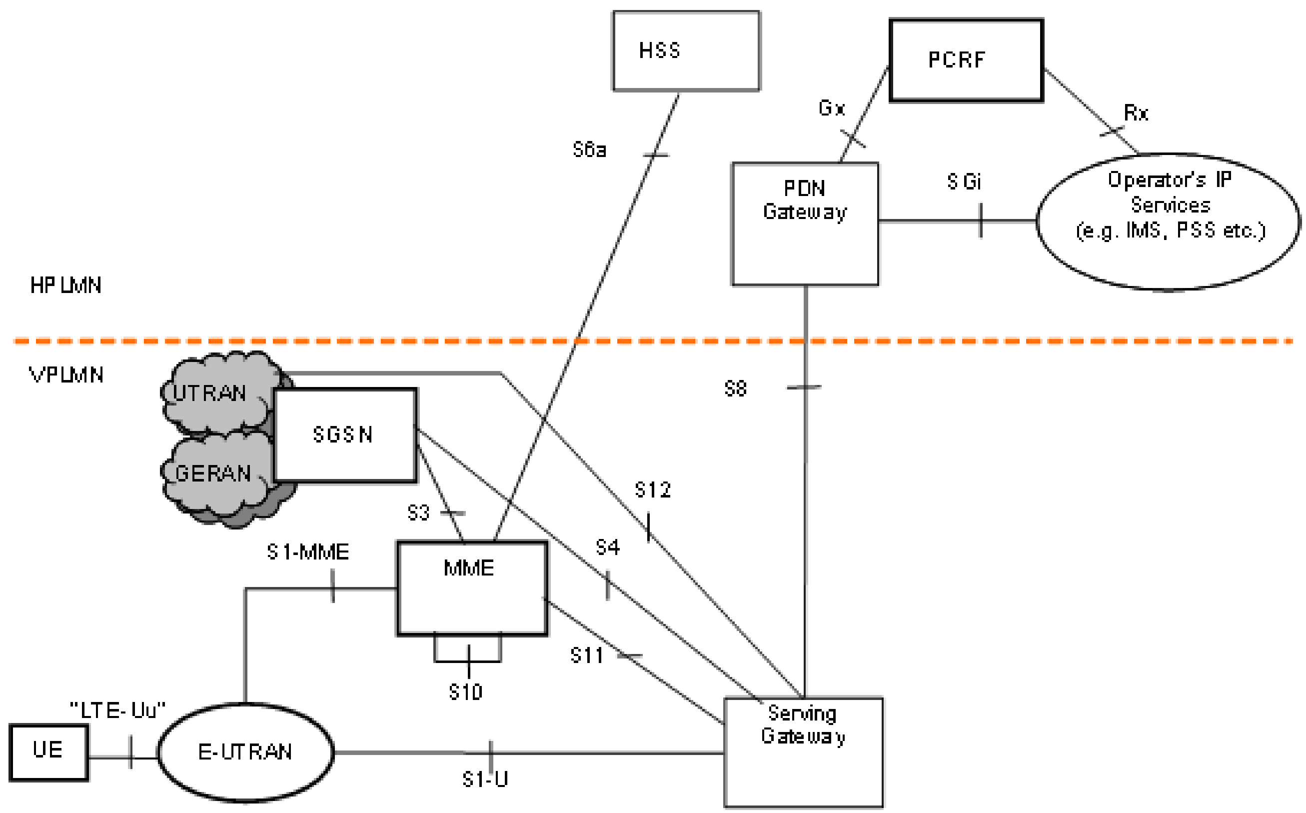


Figure 4.2.2-1: Roaming architecture for 3GPP accesses. Home routed traffic

Architecture model

- Roaming architecture

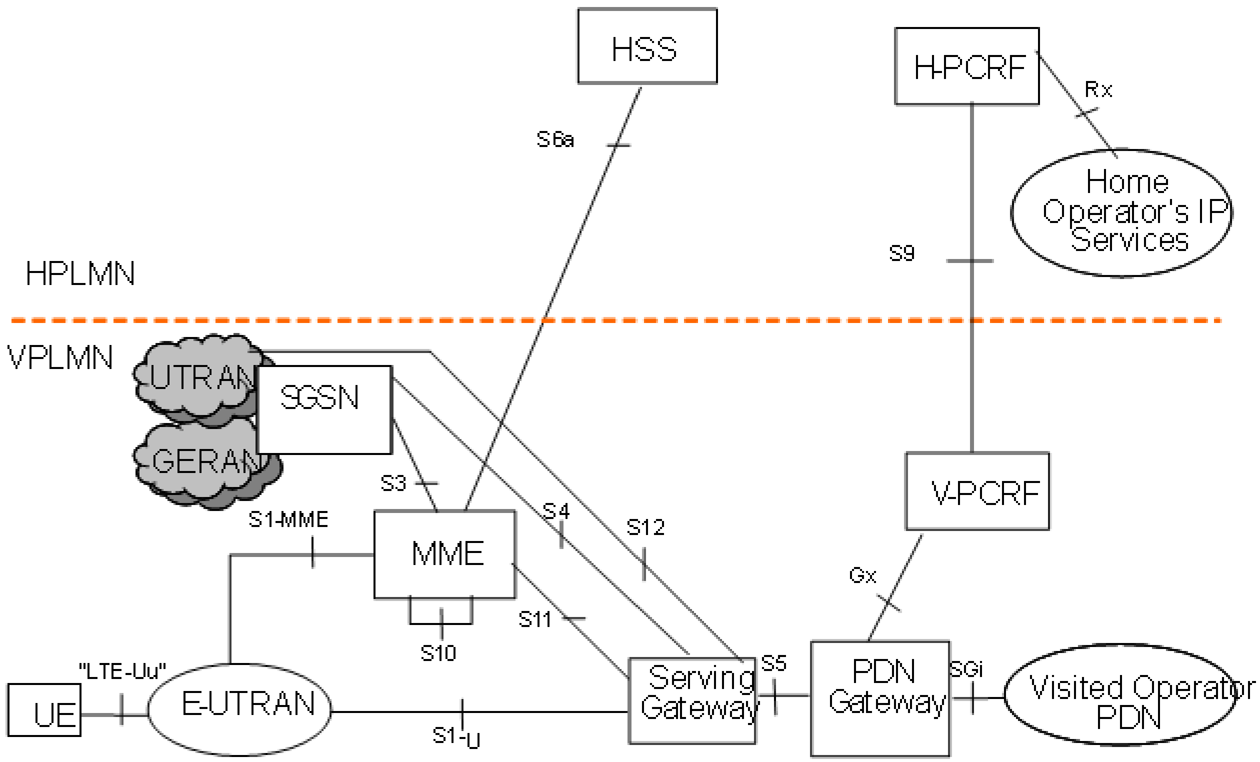
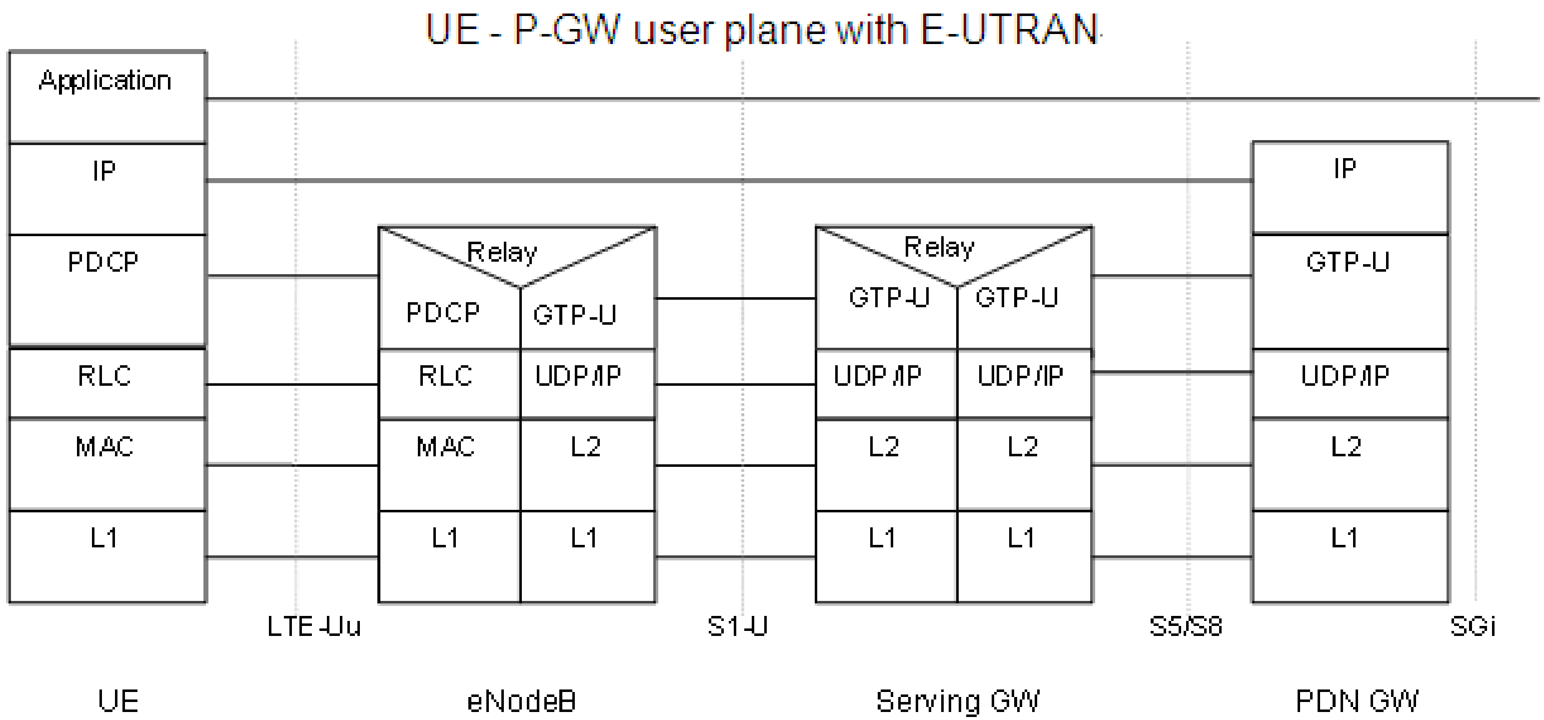


Figure 4.2.2-2: Roaming architecture for local breakout, with home operator's application functions only

Radio protocol architecture -- User Plane



Legend:

GPRS Tunnelling Protocol for the user plane (GTP-U): This protocol tunnels user data between eNodeB and the S-GW as well as between the S-GW and the P-GW in the backbone network. GTP shall encapsulate all end user IP packets.

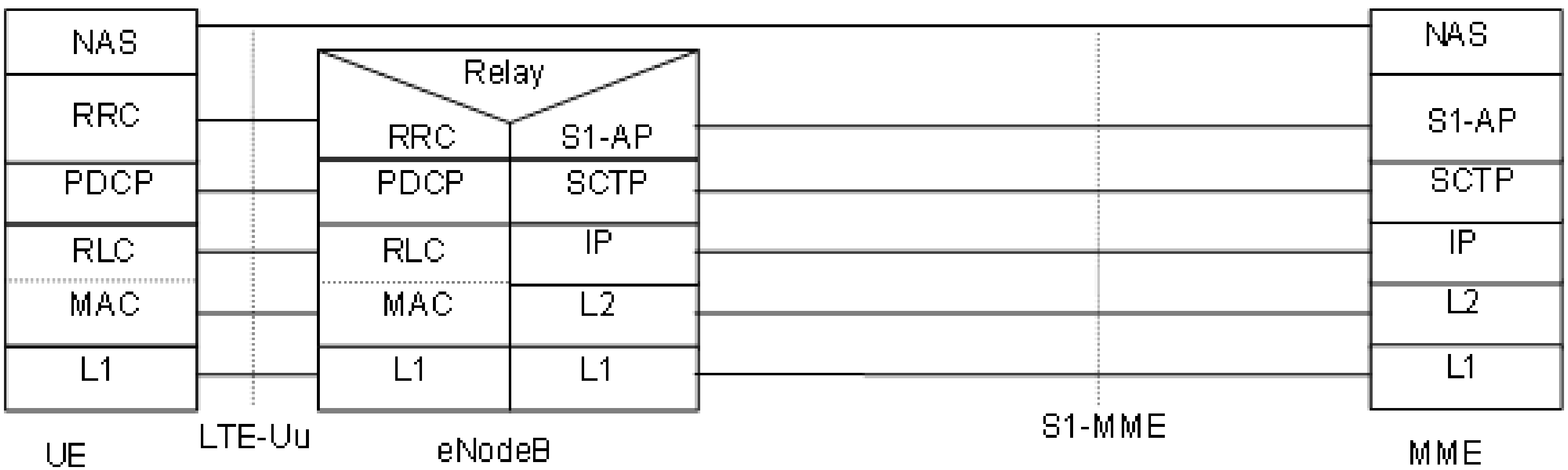
MME controls the user plane tunnel establishment and establishes User Plane Bearers between eNodeB and S-GW.

UDP/IP: These are the backbone network protocols used for routeing user data and control signalling.

LTE-Uu: The radio protocols of E-UTRAN between the UE and the eNodeB are specified in TS 36.300 [5].

Figure 5.1.2.1-1: User Plane

Radio protocol architecture -- Control Plane



Legend:

NAS: The NAS protocol supports mobility management functionality and user plane bearer activation, modification and deactivation. It is also responsible of ciphering and integrity protection of NAS signalling.
LTE-Uu: The radio protocol of E-UTRAN between the UE and the eNodeB is specified in TS 36.300 [5].

Figure 5.1.1.3-1: Control Plane UE - MME

Radio Resource Control

- RRC states are simplified to IDLE state and CONNECTED state

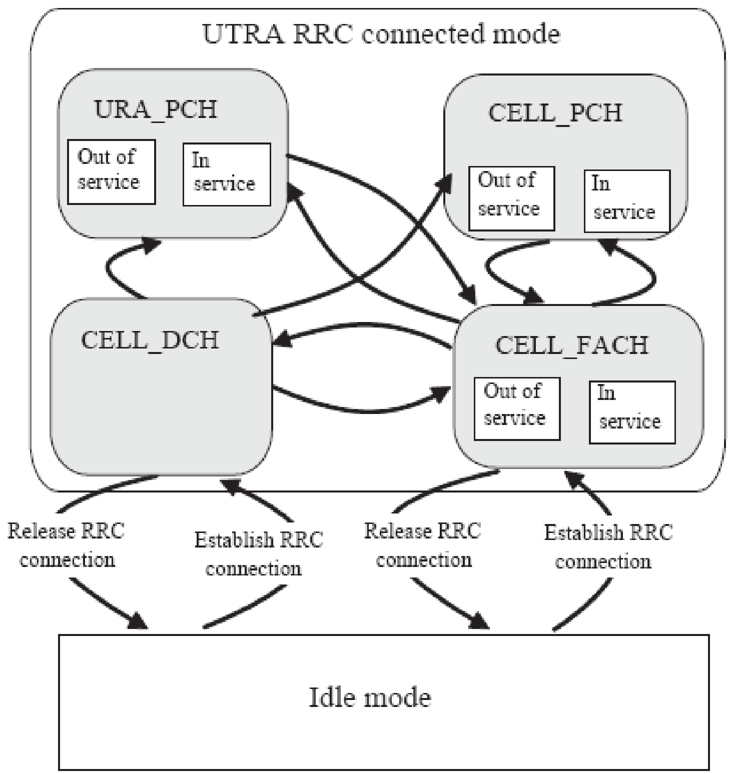


Figure 5.11 The 3G/UMTS RRC state machine (from 3GPP 25.331).

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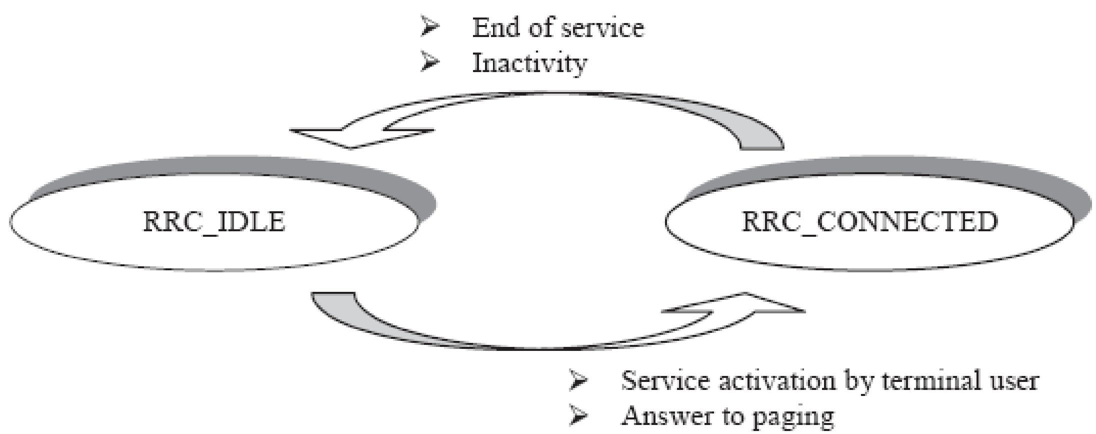


Figure 4.17 The RRC states.

Radio Resource Control

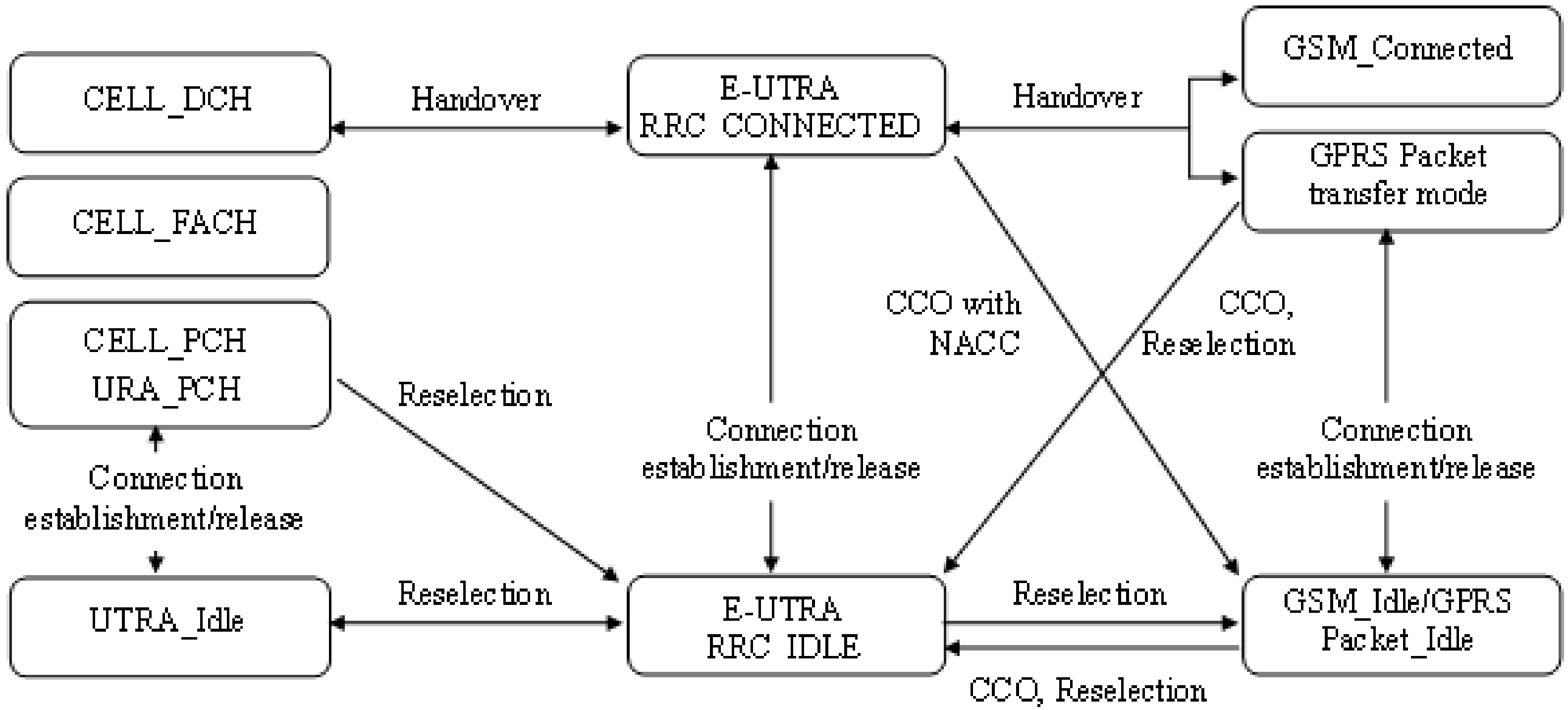
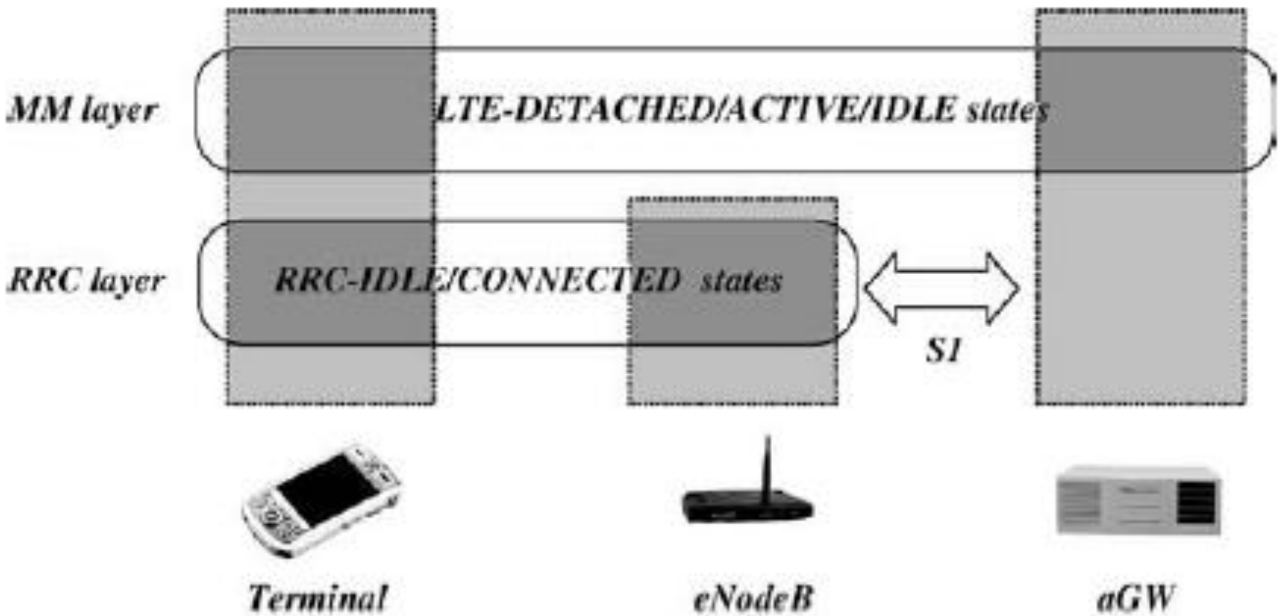


Figure 4.2.1-1: E-UTRA states and inter RAT mobility procedures, 3GPP

Radio Resource Control

- RRC states
  - RRC_CONNECTED
    - UE has an E-UTRAN-RRC connection
    - UE assist network controlled mobility
    - UE has context in E-UTRAN
    - Network can transmit and/or receive data to/from UE
    - E-UTRAN knows the cell which the UE belongs to
    - Neighbor cell measurements
    - UE reports channel quality information and feedback information to eNB
  - RRC_IDLE
    - UE has no E-UTRAN RRC connection
    - UE controlled mobility
    - No RRC context stored in the eNB
    - The UE shall have been allocated an id which uniquely identifies the UE in a tracking area
    - Decoding system information broadcast by E-UTRAN
    - Decoding of paging messages
    - Cell re-selection (based on system information)

Terminal States of RRC and MM Layer



= MME + S-GW + PDN-GW

Figure 5.8 RRC and MM state machines.

Terminal States of RRC and MM Layer

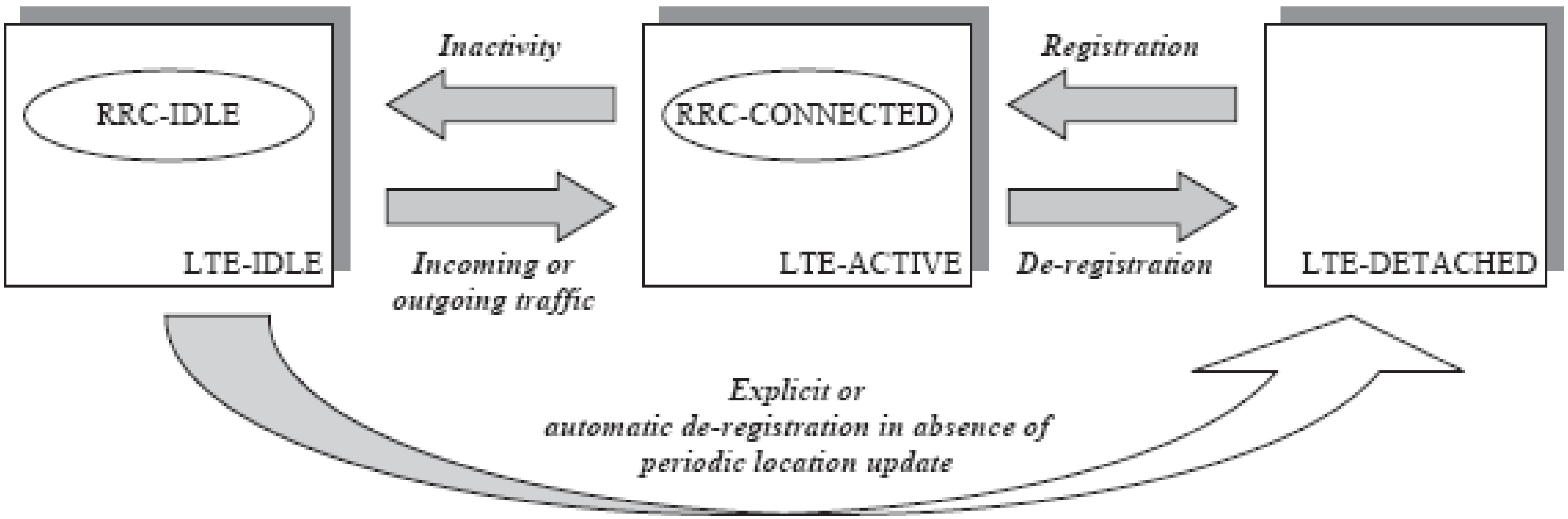


Figure 5.9 Evolved UMTS Terminal states and transitions.

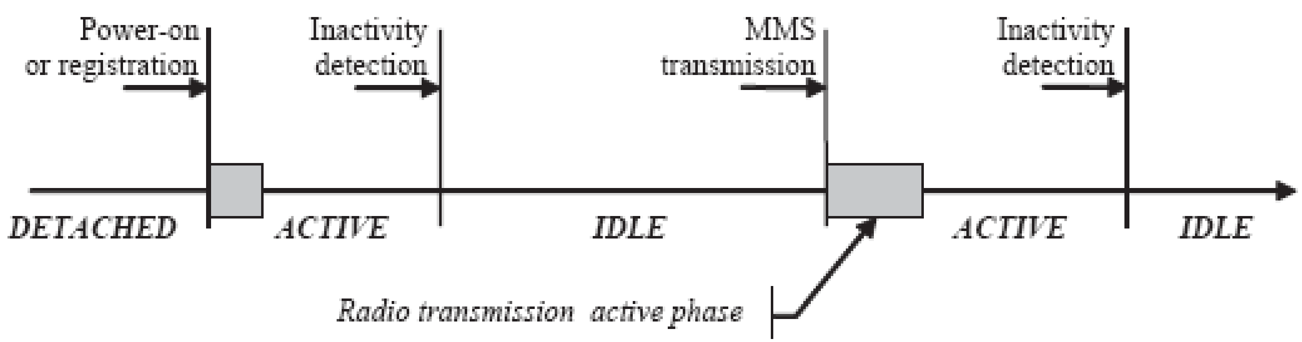


Figure 5.12 Example of MM state transition.

Terminal States of MM Layer

- LTE-DETACHED
  - The mobile is not registered to the network
- LTE-IDLE
  - The mobile is registered to the network, but not active
    - Low power consumption mode
    - Location management at the Tracking Area level
    - Resume a previously active data session without having to
      - Set up the EPC bearers
      - Renegotiate the associated Quality of Service attributes
- LTE-ACTIVE
  - The only real active state
    - The terminal is exchanging data and signaling information with the network (RRC connection being set up)

Registration Procedure

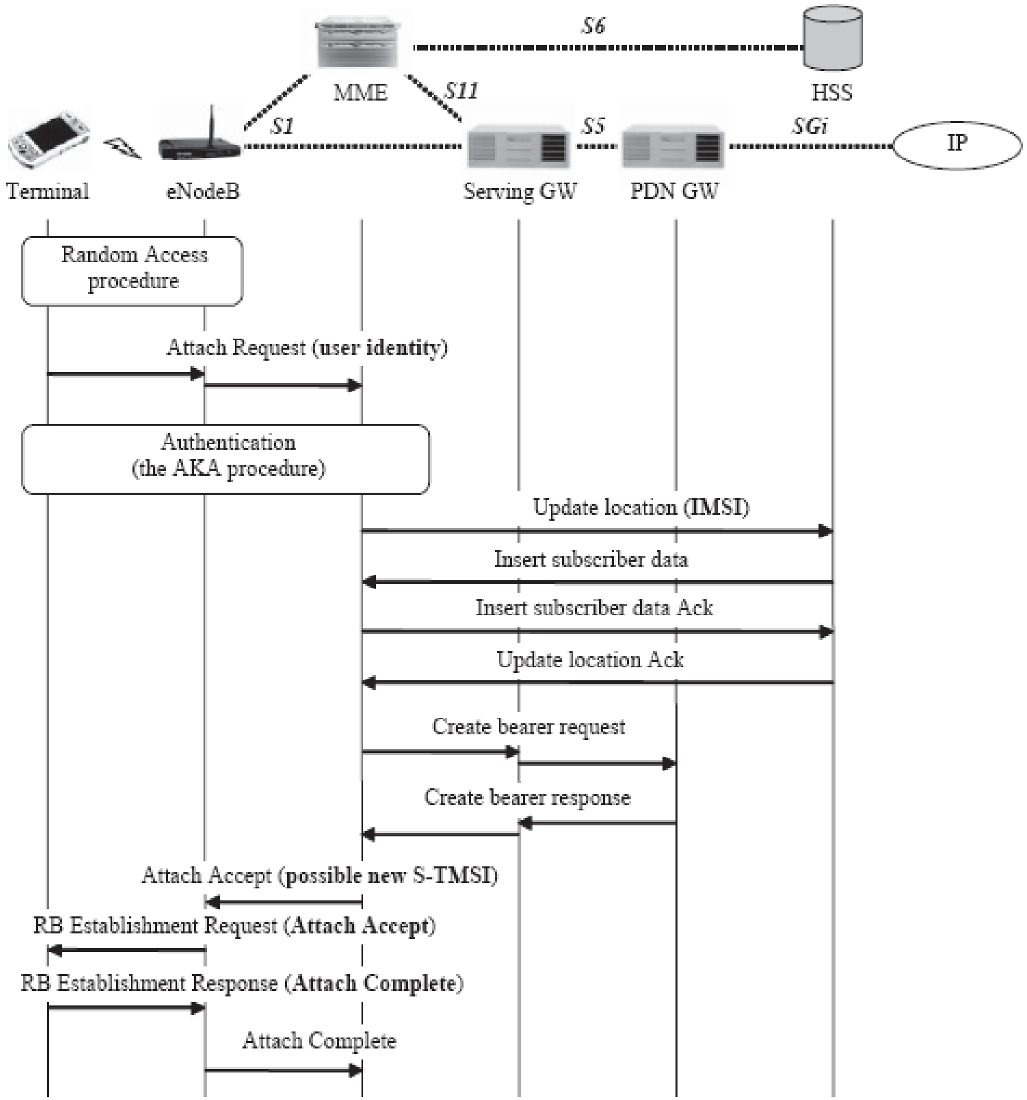


Figure 5.5 An example of subscriber registration.

Deregistration Procedure

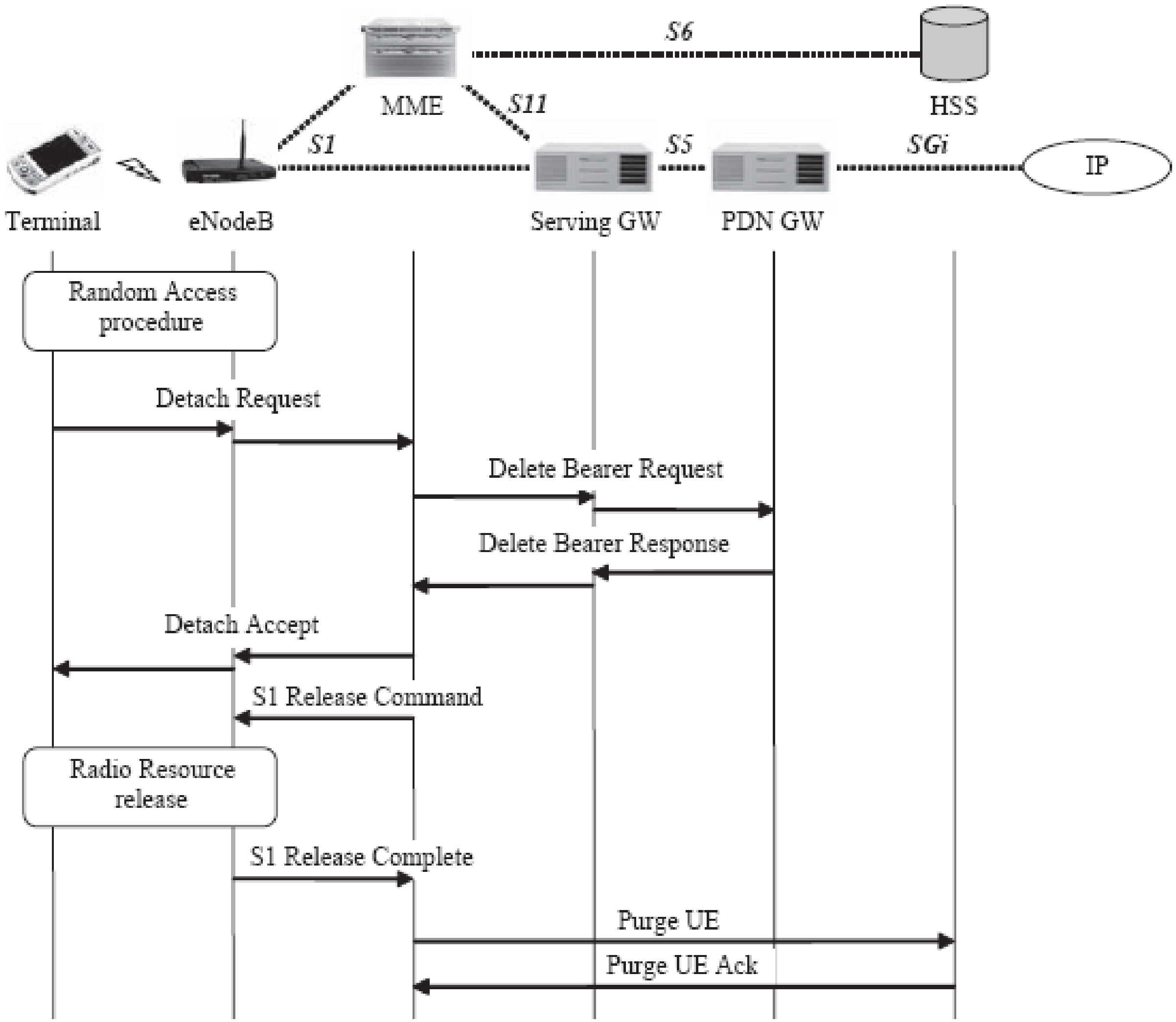


Figure 5.7 An example of terminal-initiated de-registration.

Session Setup Procedure

- Session Setup
  - There are two types of procedures in session setup
    - Service Request
      - An IDLE to ACTIVE terminal state transition because the user is resuming a data session or activating a new service
    - Dedicated Bearer activation
      - A new application service activation while the terminal is in ACTIVE mode

Session Setup Procedure

- Session Setup
  - IDLE → resume service

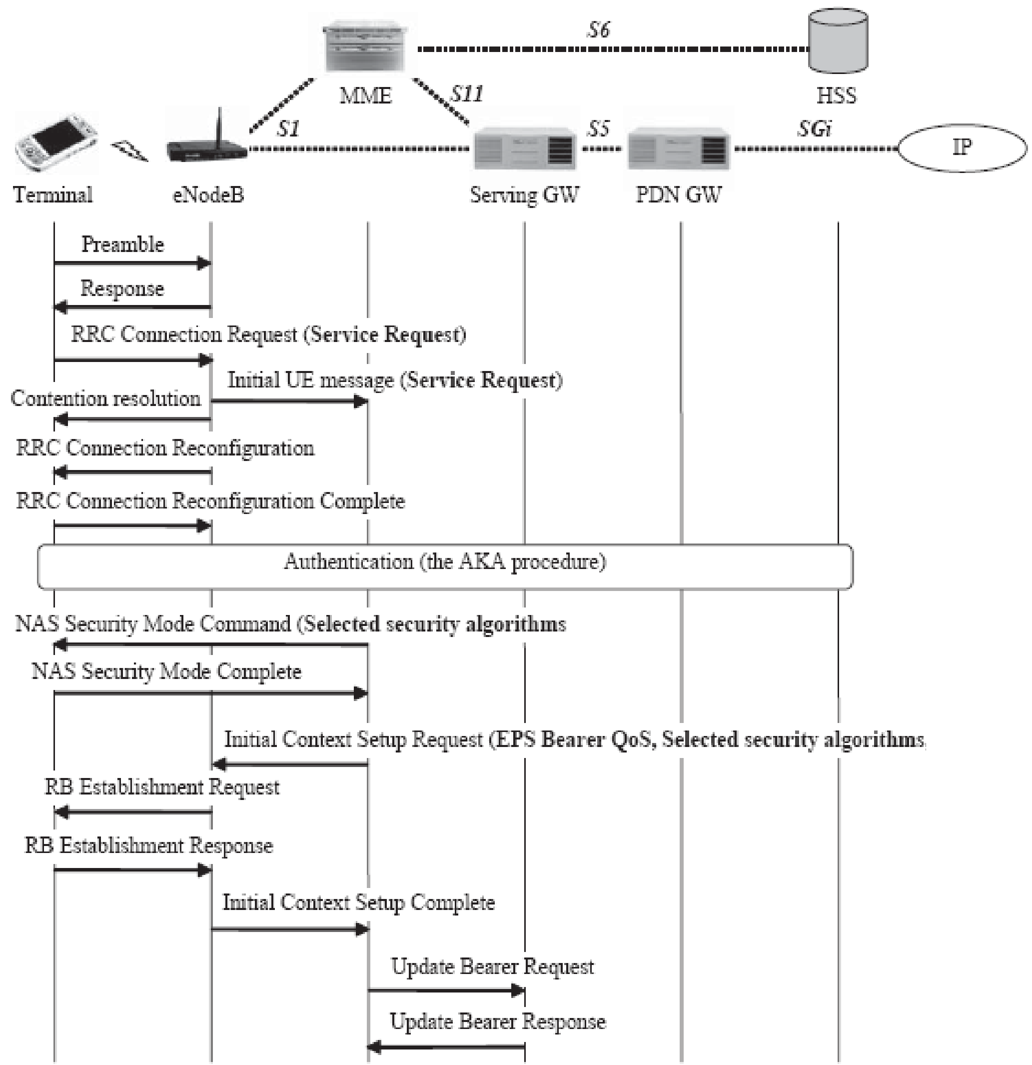


Figure 5.23 An example of a user-initiated Service Request.

Session Setup Procedure

- Session Setup

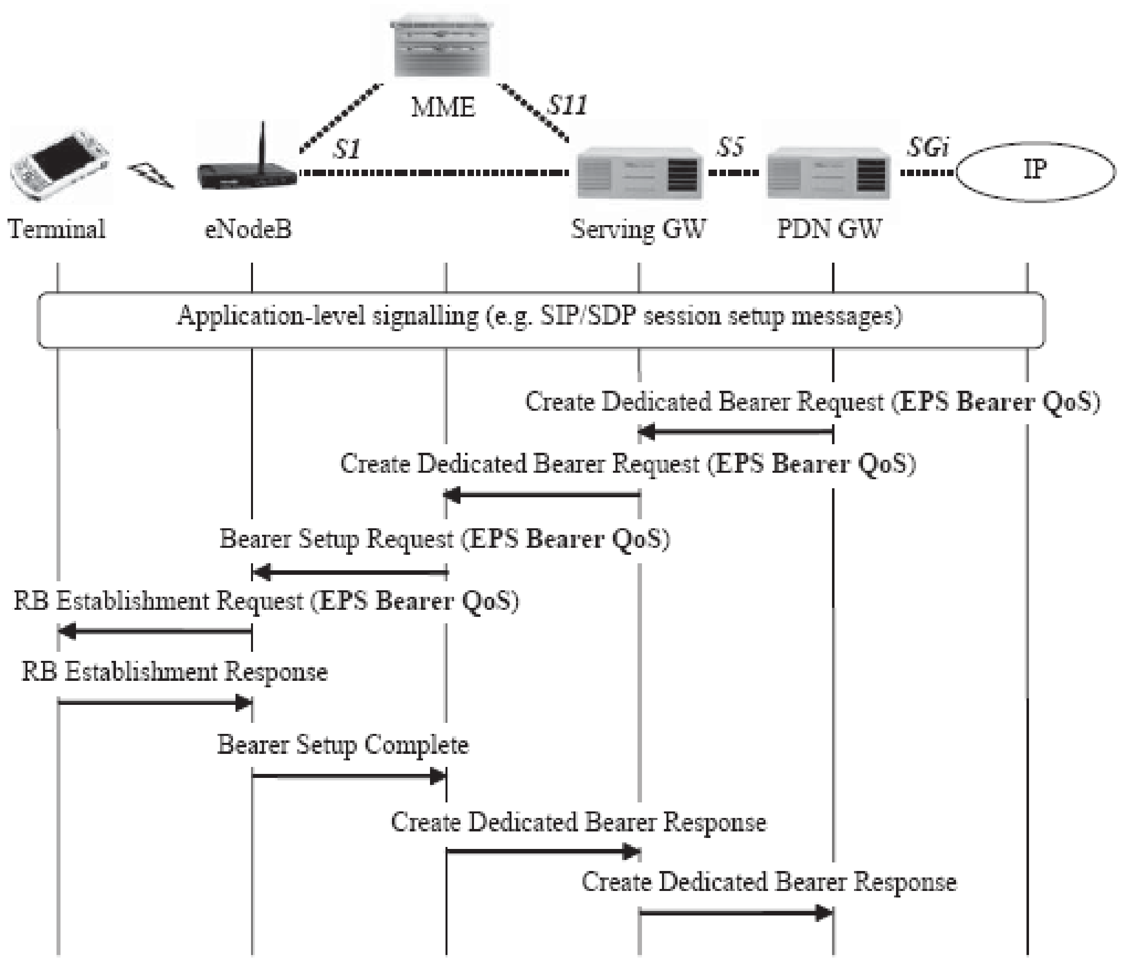


Figure 5.24 An example of Dedicated Bearer activation.

Mobility Management

- Mobility in ACTIVE mode
  - UE assisted network controlled handover
  - The decision to move / choice for the target cell is made by the current serving eNodeB

Mobility in ACTIVE mode

- Intra E-UTRAN mobility with X2 support

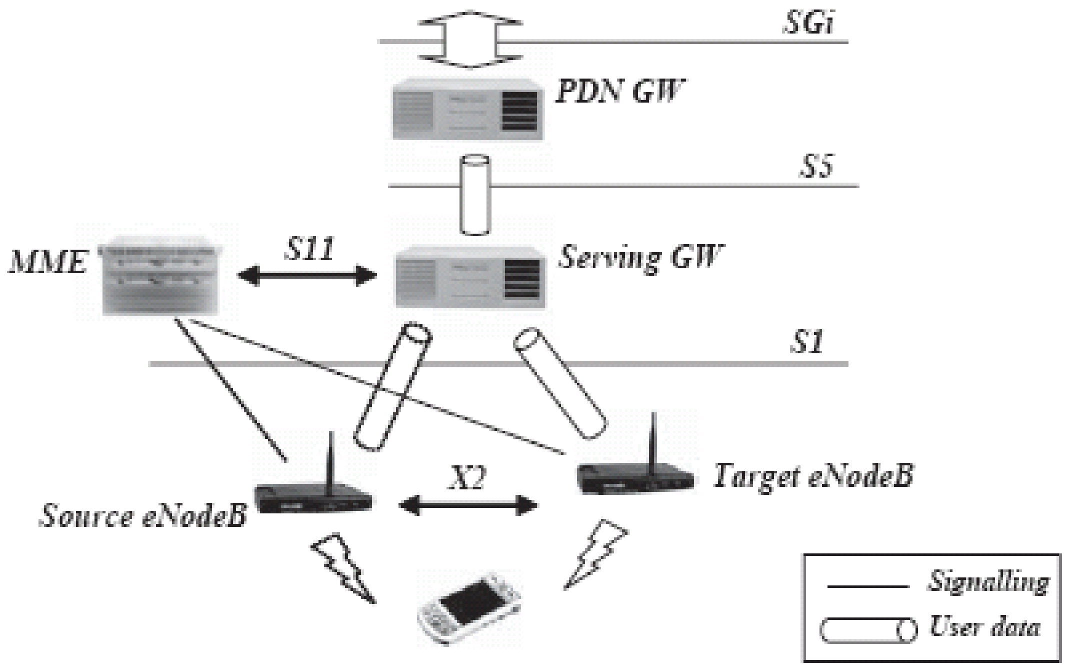


Figure 5.30 Overview of intra E-UTRAN mobility with X2 support.

Intra E-UTRAN mobility with X2 support

- The HO procedure is performed without EPC involvement
  - Preparation messages are directly exchanged between the eNBs
  - Handover command from the target eNB and is transparently forwarded to the UE by the source eNB
  - Source eNB passes all necessary information to the target eNB, e.g. EPC bearer attributes and RRC context
    - Both the source eNB and UE keep some context to enable the return of the UE in case of HO failure
  - The release of the resources at the source side during the HO completion phase is triggered by the eNB

Intra E-UTRAN mobility with X2 support

The source eNodeB sends a Handover Request message over the X2 interface to the target eNodeB, which allocates all needed resources to accept the incoming terminal and associated bearers

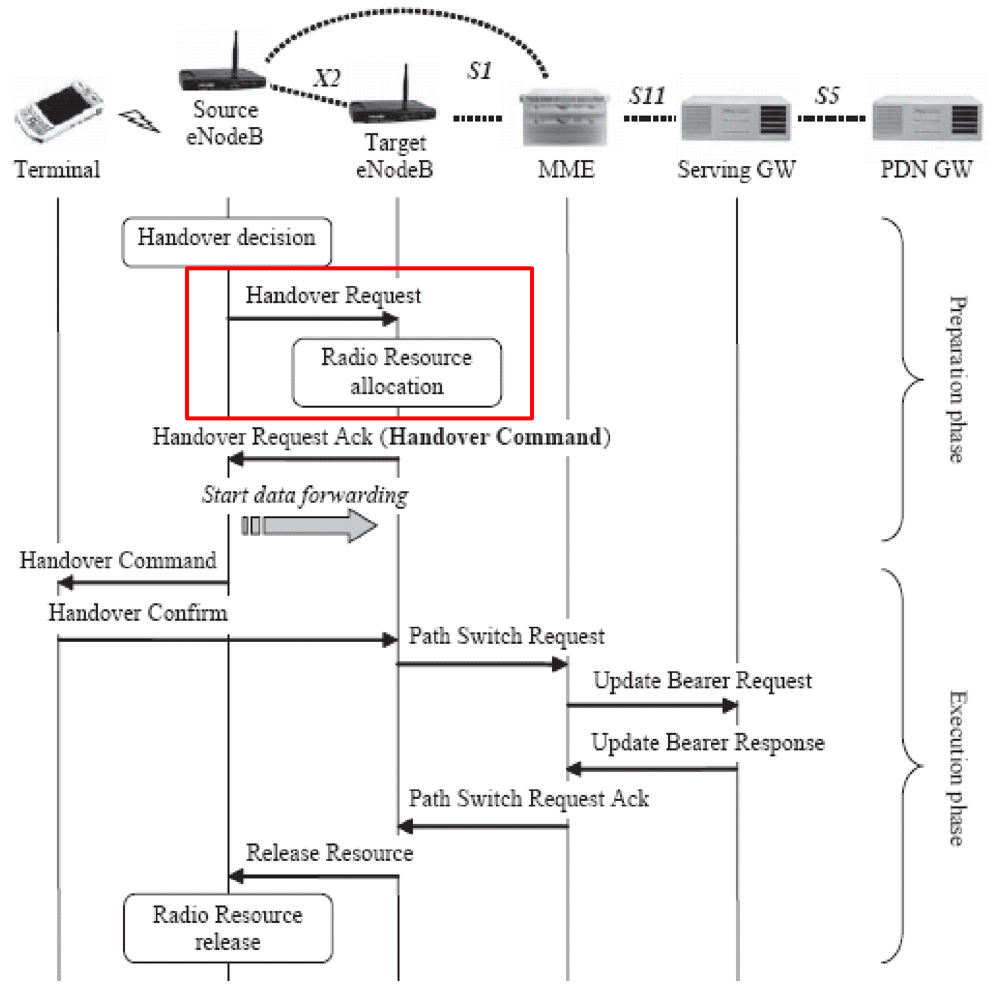


Figure 5.31 Intra-E-UTRAN mobility with X2 support – message flow.

Intra E-UTRAN mobility with X2 support

On reception of the Handover Request Ack, the source eNodeB forwards all buffered downlink RLC SDUs that have not been acknowledged by the terminal to the target eNodeB

Those packets will be stored by the target eNodeB until the terminal is able to receive them

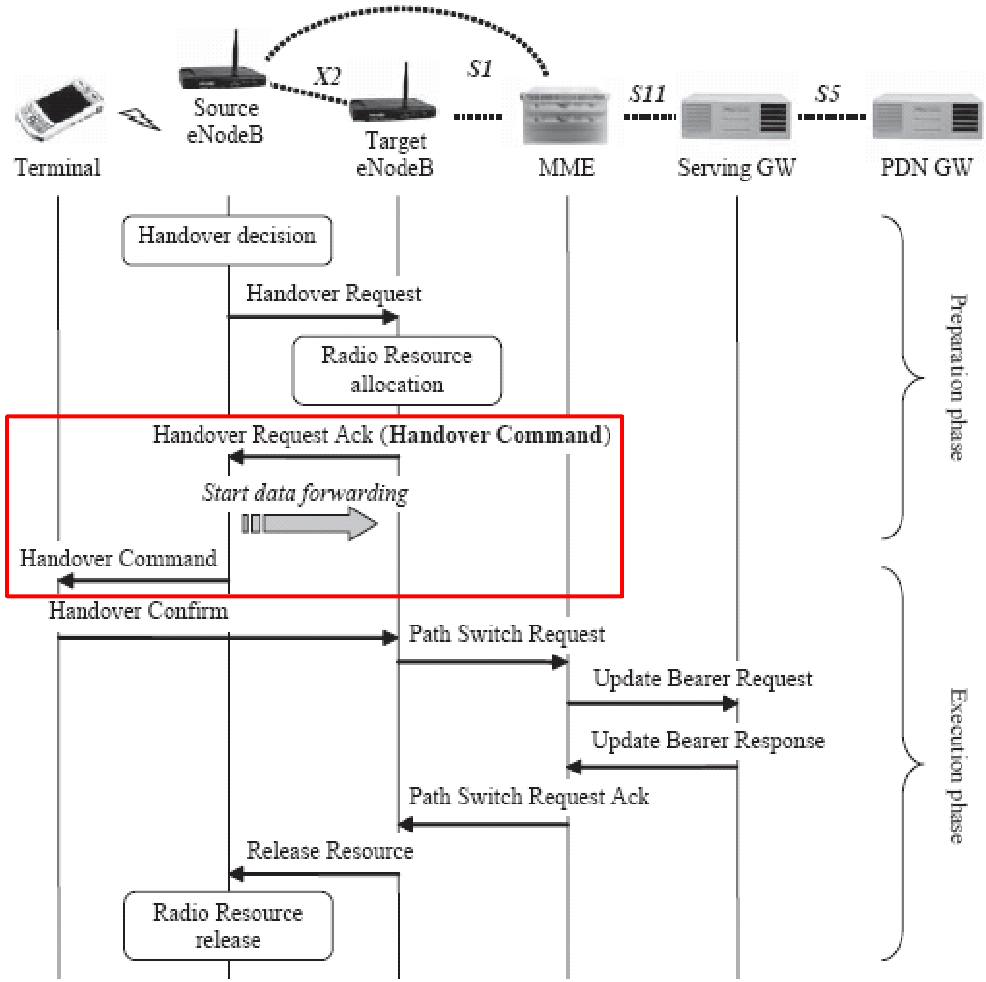


Figure 5.31 Intra-E-UTRAN mobility with X2 support – message flow.

Intra E-UTRAN mobility with X2 support

Path Switch Request message is to inform the MME about the successful completion of an intra EUTRAN handover and request a path switch of the user plane data towards the new eNodeB

The MME is now aware that the terminal has successfully changed eNodeB and can therefore update the ServingGW about the new data path

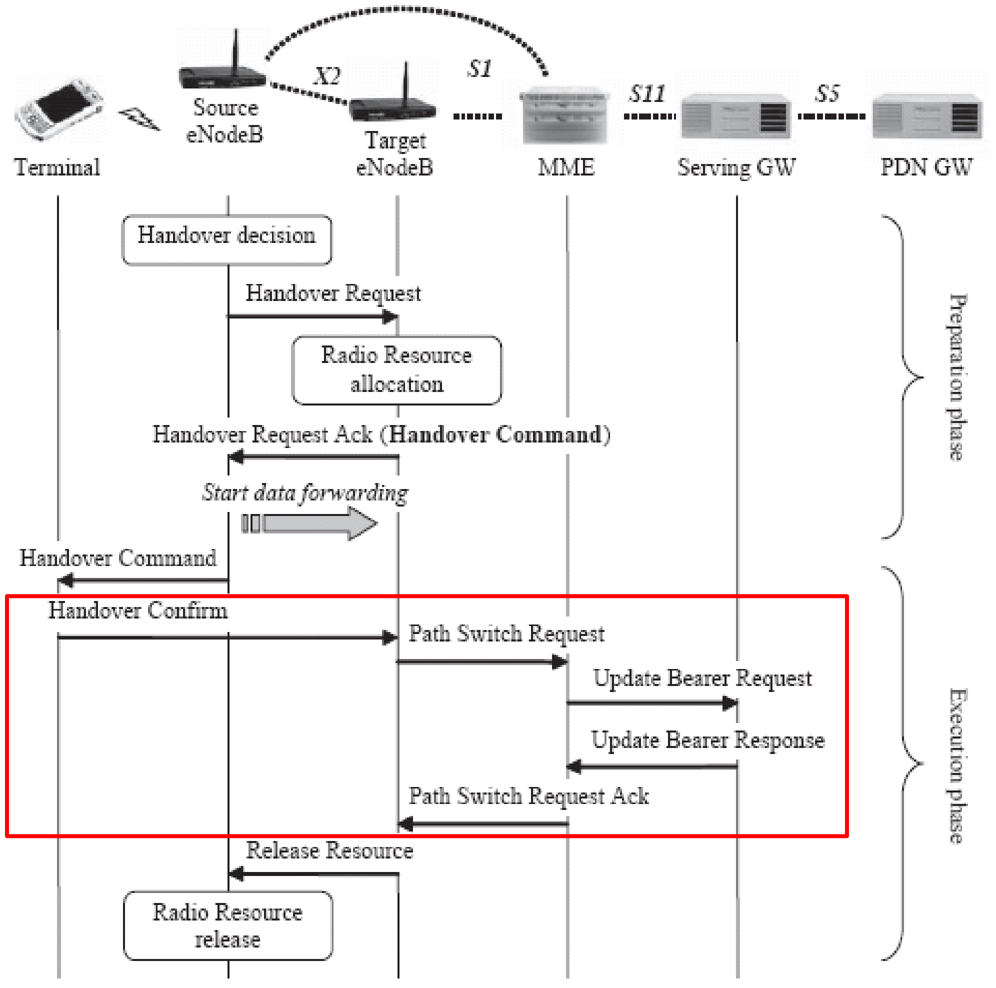


Figure 5.31 Intra-E-UTRAN mobility with X2 support – message flow.

Intra E-UTRAN mobility with X2 support

Once the Handover Confirm is received, the target eNodeB can transmit over the radio the buffered packets for the downlink

Eventually, the Release Resource is sent by the target eNodeB over X2, which has the effect of releasing old resources allocated in the Source eNodeB

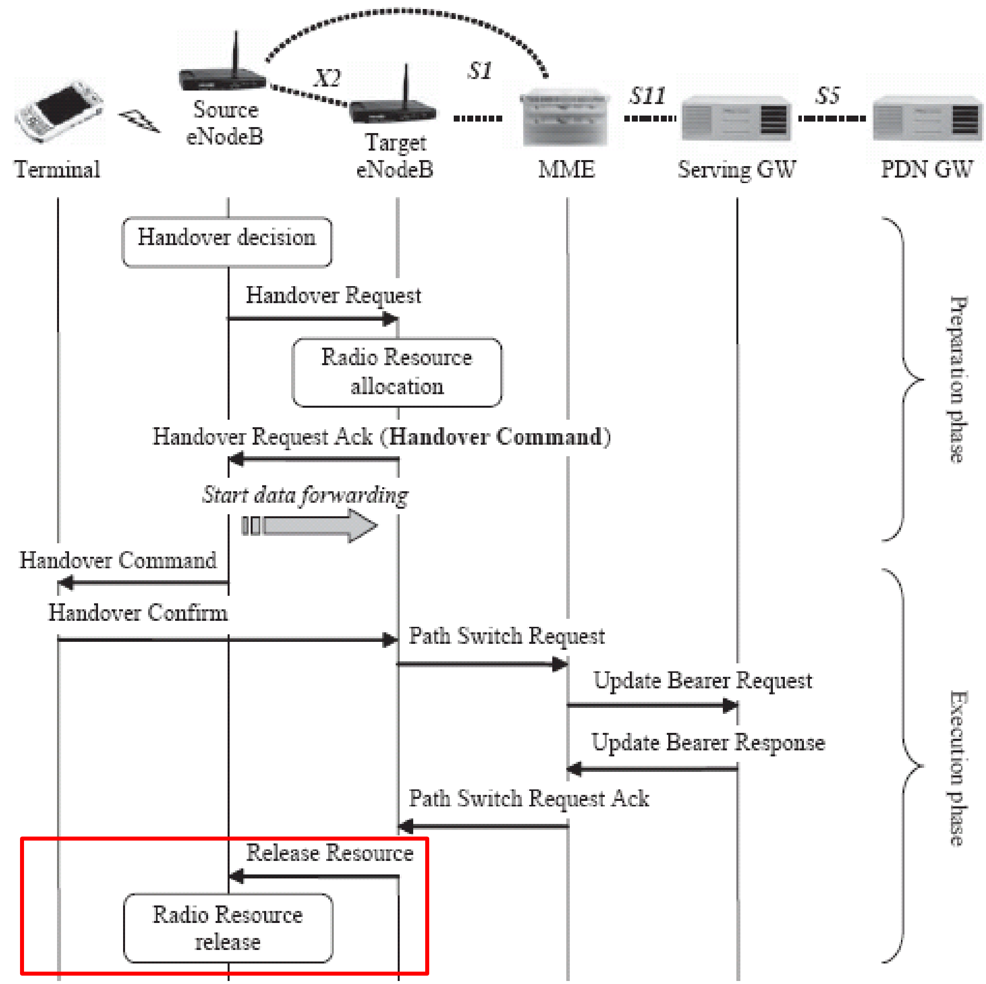


Figure 5.31 Intra-E-UTRAN mobility with X2 support – message flow.

Mobility in ACTIVE mode

- Intra E-UTRAN mobility without X2 support
  - In some cases, it may happen that the X2 interface is not available between eNodeBs
  - This may result from
    - network equipment failure
    - operator is not willing to deploy X2 connectivity between eNodeB for cost reasons
  - The MME is no longer transparent to the handover process
    - it acts as a signaling relay between the two eNodeBs

Intra E-UTRAN mobility without X2 support

The request for handover is transmitted from the source eNodeB via the MME, using the Handover Required and Handover Request S1 messages

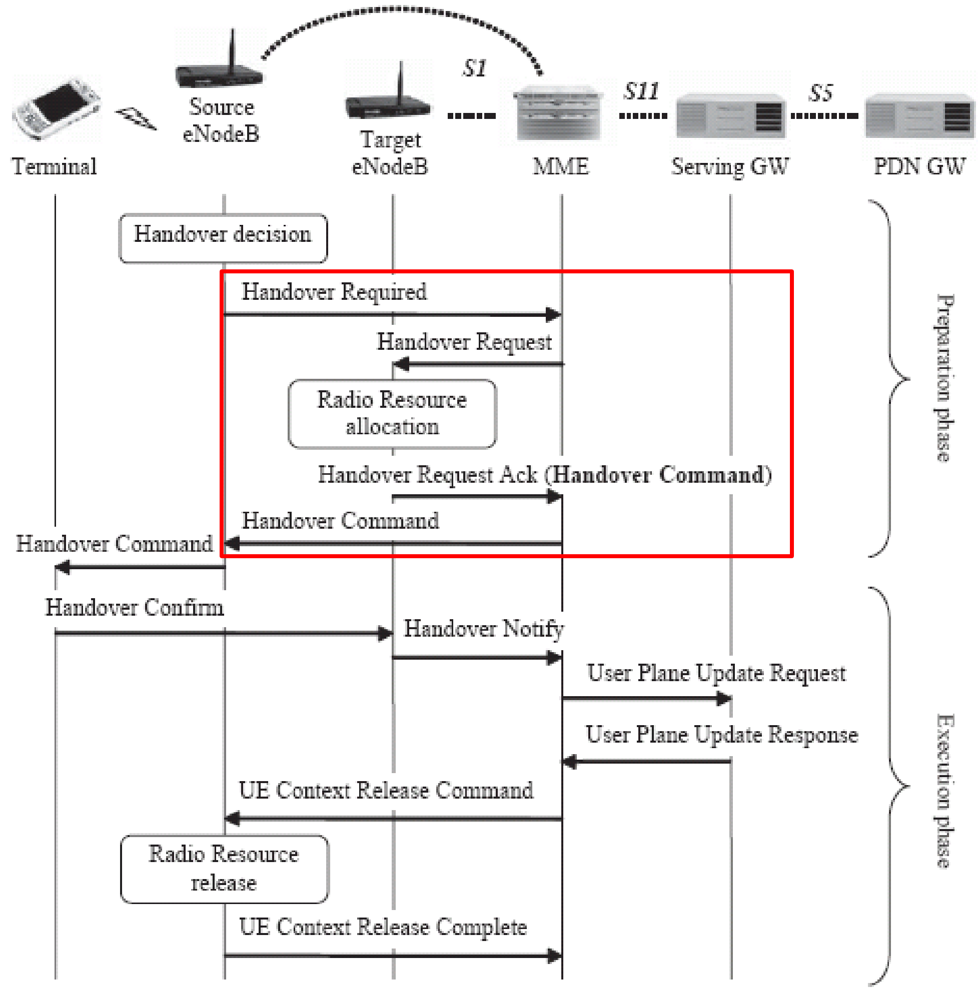


Figure 5.32 Intra-E-UTRAN mobility without X2 support – message flow.

Mobility in ACTIVE mode

- Intra E-UTRAN mobility with EPC node relocation
  - The target eNodeB has no connectivity with the current MME and Serving GW
  - From the terminal and eNodeB perspective, this handover is not different from the previous no X2 support case
  - The only real difference relies on the fact that the session needs also to be handed over from one MME to the other

Intra E-UTRAN mobility with EPC node relocation

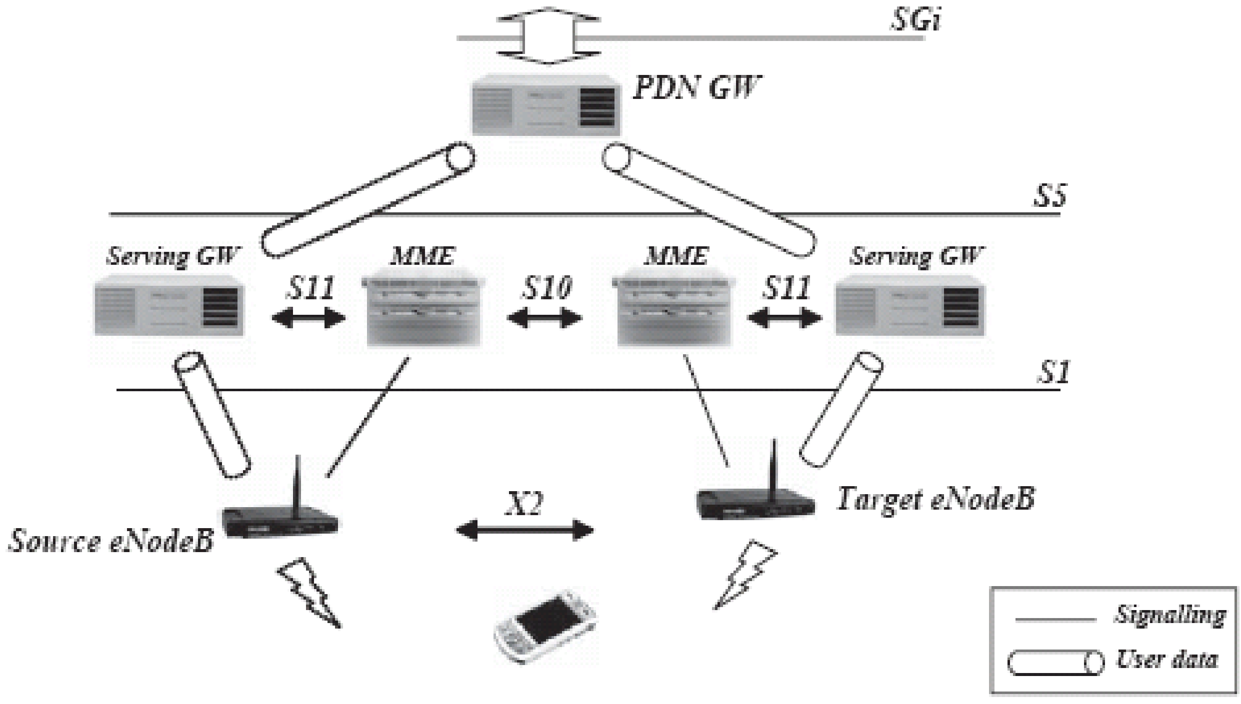


Figure 5.33 Overview of intra-E-UTRAN mobility with EPC relocation.

Intra E-UTRAN mobility with EPC node relocation

The main difference is that the source and target MME are different nodes, which requires the transfer of the user context between the two MME using the Forward Relocation Response / Request exchange

In addition, a new User plane bearer is created between the PDN GW and the new Serving GW

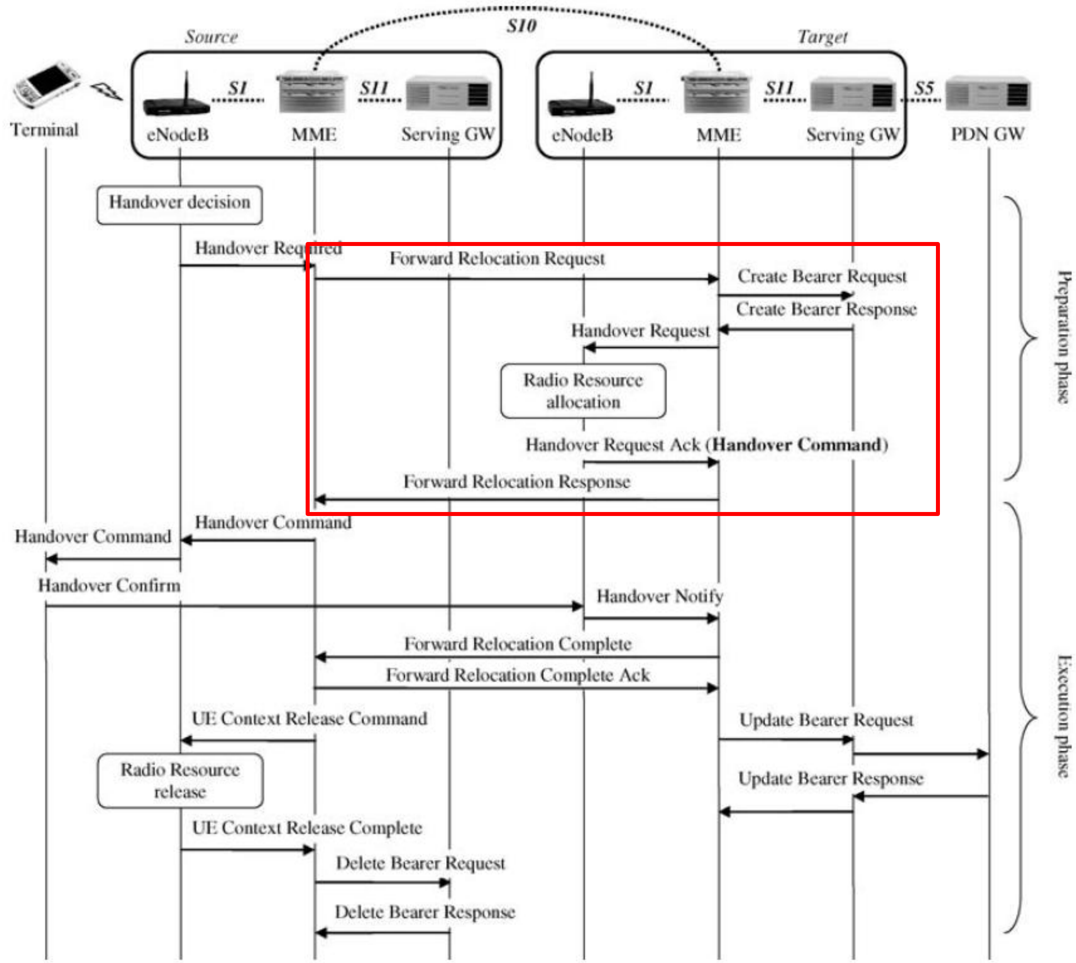


Figure 5.34 Intra-E-UTRAN mobility with EPC relocation – message flow.

Intra E-UTRAN mobility with EPC node relocation

The new MME informs the old one about the successful outcome using the Forward Relocation Complete, so that the old radio resources and bearer path can be released

In addition, the bearer path is updated using the Update Bearer procedure, so that the PDN GW can transmit the downlink packet to the relevant new Serving GW

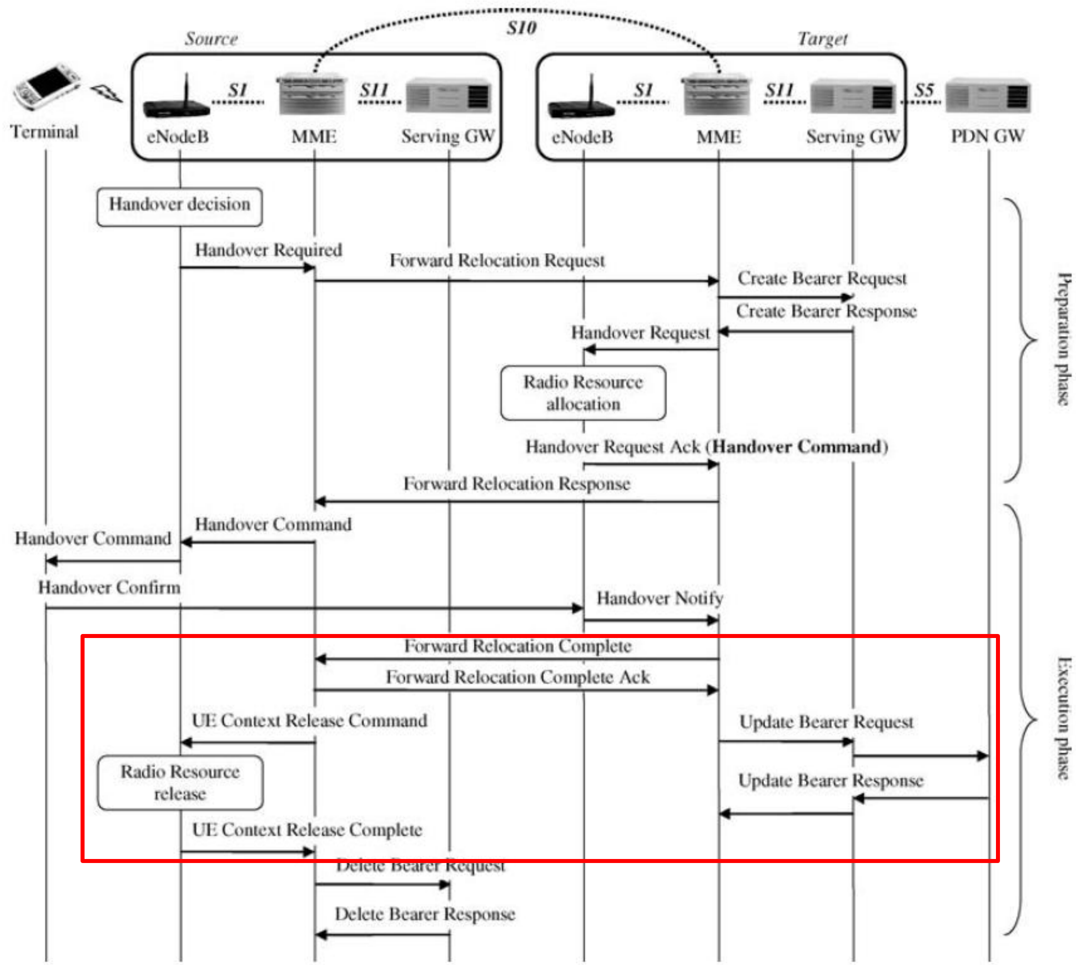


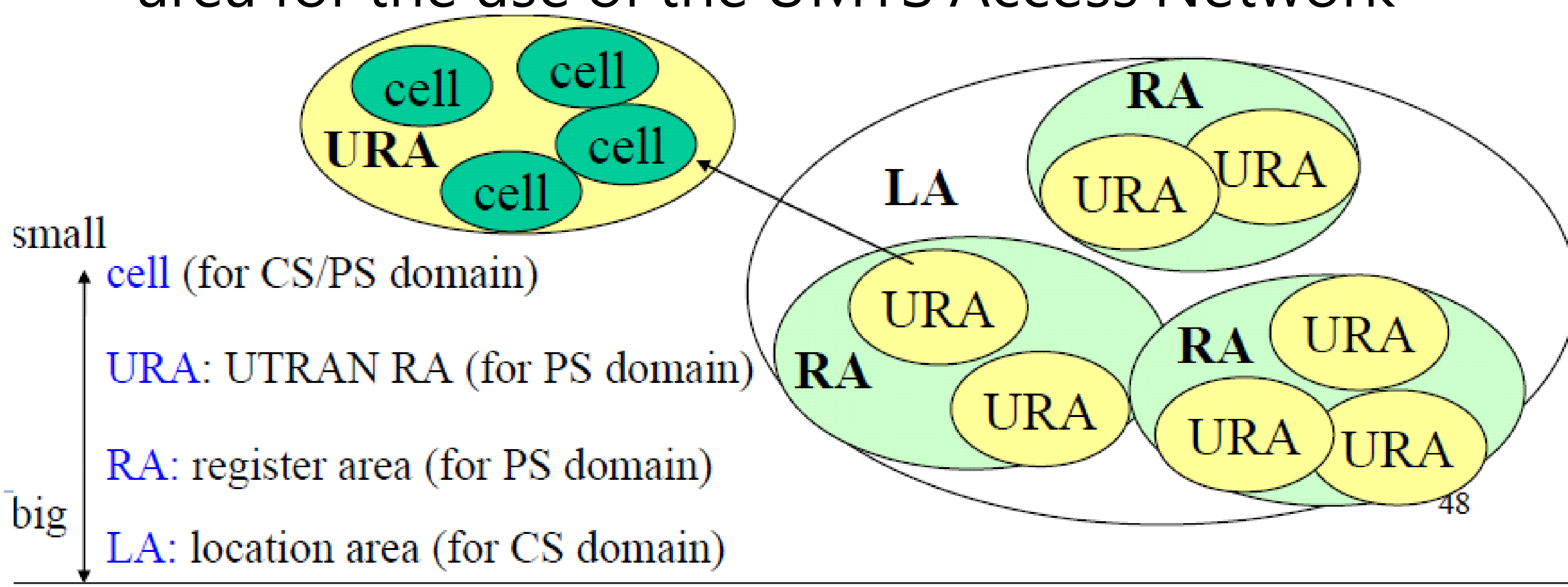
Figure 5.34 Intra-E-UTRAN mobility with EPC relocation – message flow.

Mobility Management

- Mobility in IDLE mode
  - UE controlled handover
  - Tracking Area
    - Similar to Routing Area or UTRAN Registration Area
    - Defined as a set of contiguous cells

Mobility in IDLE mode

- Comparison with 2G/GPRS and UMTS
  - LA (Location Area), which is the type of area supported by the Circuit Core network domain MSC/VLR
  - RA (Routing Area), which is the equivalent of the LA for the Packet Core network domain
  - URA (UTRAN Registration Area), which is a registration area for the use of the UMTS Access Network



Mobility in IDLE mode – Tracking area update

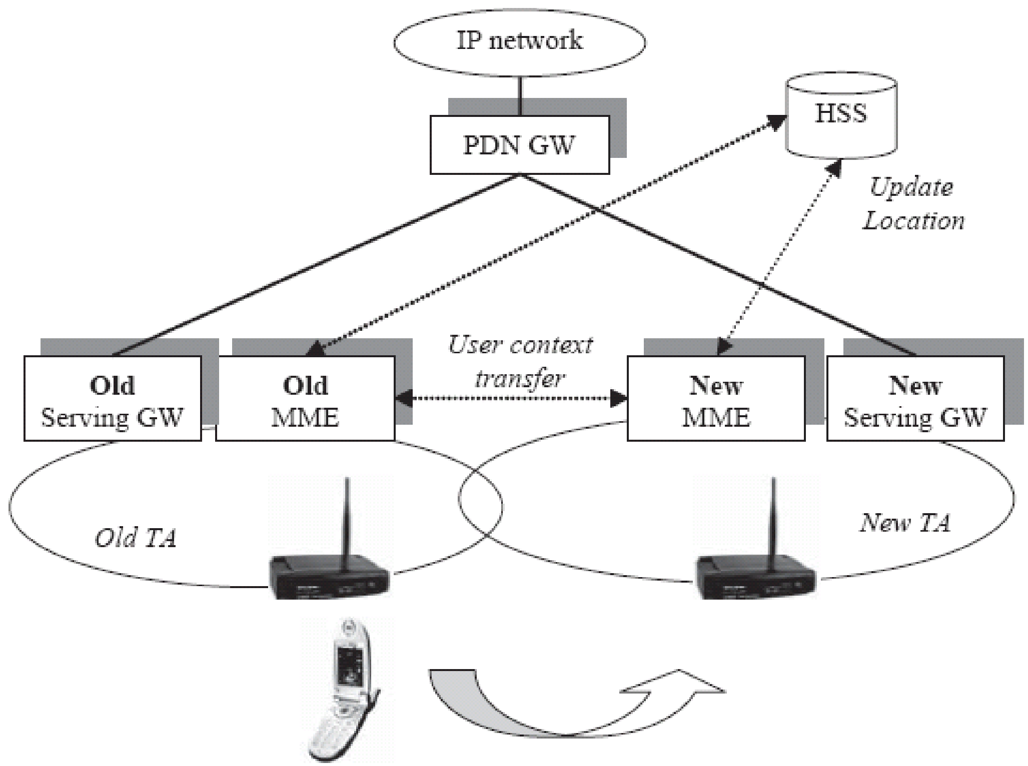


Figure 5.28 An example of a Tracking Area Update.

Mobility in IDLE mode – Tracking area update

- Tracking area update
  - User context transfer from old to new MME
    - Subscriber context
      - user IMSI
      - subscriber data
  - Bearer path update
    - PDN-GW
    - S-GW
  - HSS database update
    - new serving MME id
    - IP address

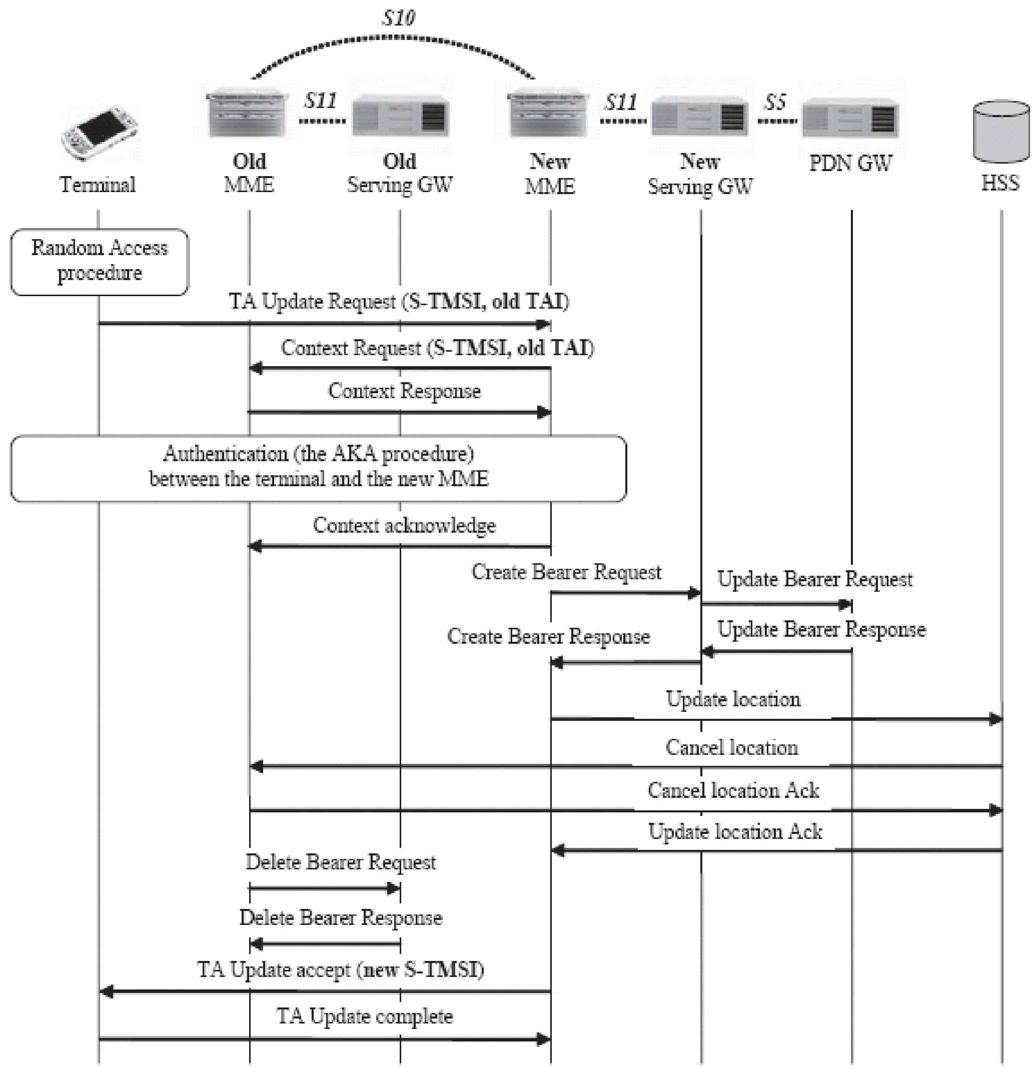


Figure 5.29 Inter-MME Tracking Area Update – message flow.