LTE End to End System Part 1

• Procedures Release (RL50)

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1 Introduction

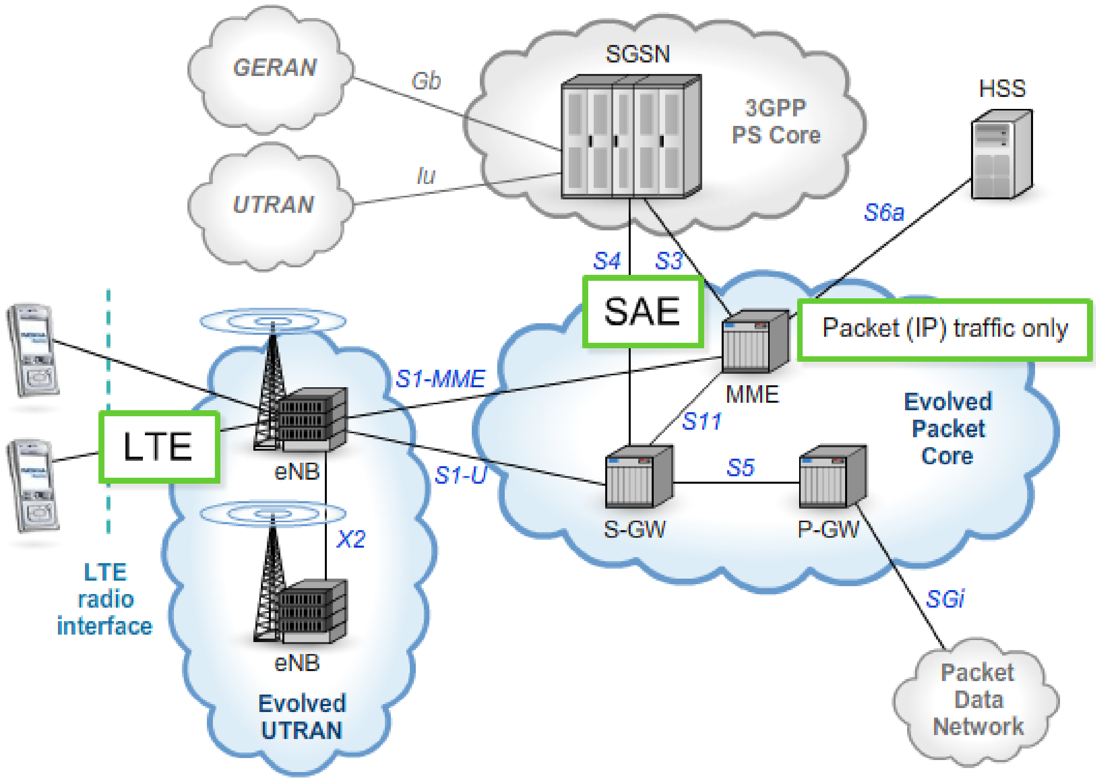
1.1 LTE / SAE Architecture

UTRAN Long Term Evolution (LTE) refers to the long term evolution of the 3GPP radio access technology and is considered the successor of the current UMTS system with the rollout anticipated to begin with trials in 2009.

The LTE work in 3GPP is closely aligned to the 3GPP system architecture evolution (SAE) framework which is concerned with the evolved core network architecture. The LTE/SAE framework defines the flat, scalable, IP-based architecture of the Evolved Packet System (EPS) consisting of a radio access network part (Evolved UTRAN) and the Evolved Packet Core (EPC).

Note that the Evolved Packet System is purely packet based. Voice transport is thus based on Voice over IP (VoIP) technology. Circuit-switched (CS) voice traffic is supported by either using the CS fallback (CSFB) or the single radio voice call continuity (SR-VCC) interworking solution.

Move your mouse pointer over the items in the architecture figure for a short introduction to each item.



- The LTE radio interface (air interface, LTE-Uu) is between the user equipment (UE) and the eNB.
- The evolved Node B (eNodeB, eNB) supports the LTE radio interface and provides the packet-switched functionality of a traditional radio network controller (RNC). As a result, the Evolved UTRAN does not require a separate RNC network element, in other words the architecture is “flat” (architecture contains fewer types of network entities and interfaces)
- The X2 interface between two eNB network elements is used during an inter-eNB handover.
- The S1-MME interface carries control plane signalling information between the eNodeB and Mobility Management Entity.
- The S1-U interface between the eNodeB and Serving Gateway carries the user plane data over a so-called GTP tunnel.
- The S4 interface between the S-GW and SGSN provides a GTP tunnel for the user plane during an inter-system handover.
- The S3 interface carries signalling between the MME and Serving GPRS Support Node (SGSN) located in a 2G/3G packet-switched core network.
- The S11 interface carries signalling messages between the Serving Gateway and the Mobility Management Entity.
- The S6a interface is used for transferring subscription and authentication data between the Home Subscriber Server (HSS) and MME.
- The SGi interface is between the PDN Gateway and the packet data network (PDN). The packet data network may be an operator-external public or private IP network, or an IP network belonging to the operator, for instance providing IP Multimedia Subsystem (IMS) services. Legacy Gn/Gp interface connectivity to the EPS is also supported.
- The Serving Gateway (S-GW) and PDN Gateway (P-GW) provide the user plane connectivity between the access network and the external packet data network (PDN). In the NSN LTE solution, it is possible to implement these functional entities within a single node.
- The Mobility Management Entity (MME) provides the basic control plane functionality in the Evolved Packet Core network. Note that user plane traffic does not go through the MME.

1.2 Evolution towards Flat Network Architecture

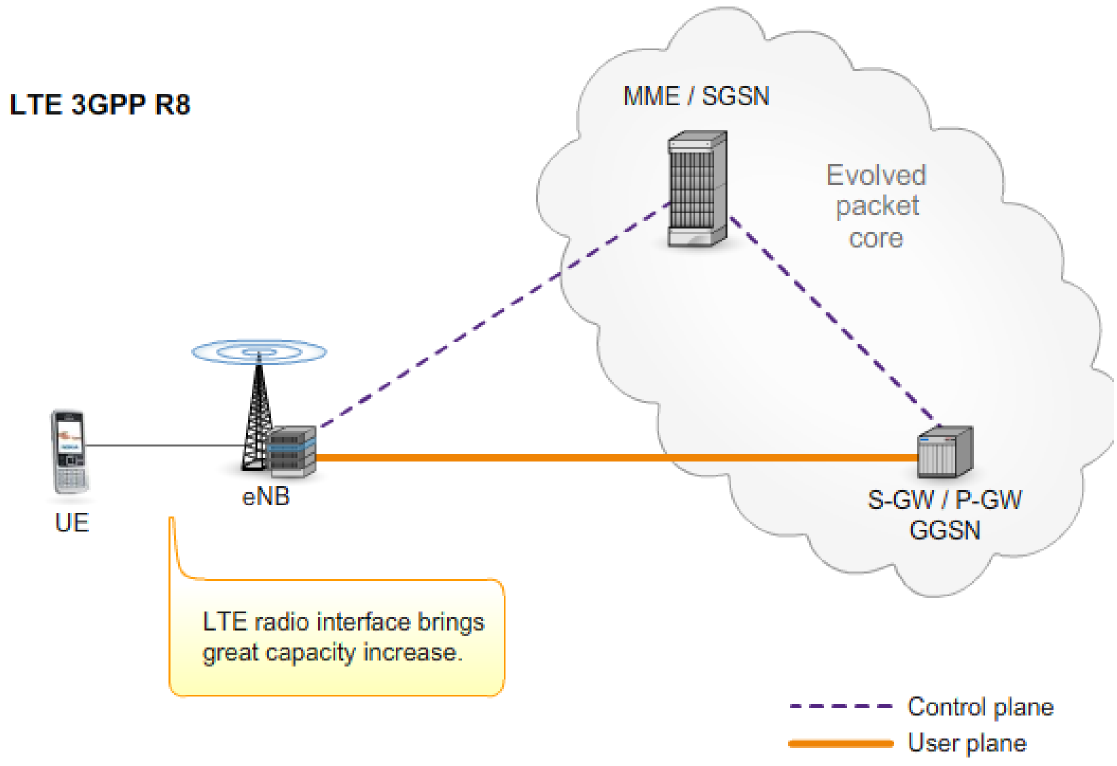
Closely associated with LTE is the evolution towards a flat network architecture.

In a traditional 3GPP network both the user plane data and control plane signalling is carried between the UE and GGSN via the BTS, RNC and SGSN. The high-speed packet access (HSPA) solution in 3GPP release 6 provides greatly increased radio access capacity when compared to earlier solutions.

As a next step in the network architecture evolution, 3GPP release 7 offers the possibility of implementing a direct GTP tunnel for carrying user data between the RNC and GGSN. The control plane signalling still takes place via the SGSN.

The basic idea of the Internet HSPA (I-HSPA) solution is to integrate the RNC packet switched functionality into the base stations. At the same time, the GTP tunnel for the user plane traffic is extended to the I-HSPA adapter in the BTS. The direct tunnel solution offers high bitrates in a very cost efficient manner and reduces the round trip time (RTT) in the user plane.

The LTE network architecture is similar to the I-HSPA architecture, although the functionality and names of the network elements have changed. Also, the LTE radio interface provides greatly increased radio access capacity when compared to HSPA.



1.3 EPS Bearer

In the Evolved Packet System (EPS), so-called EPS bearers are employed for carrying the user data between the UE and the PDN Gateway, or between the UE and the Serving Gateway.

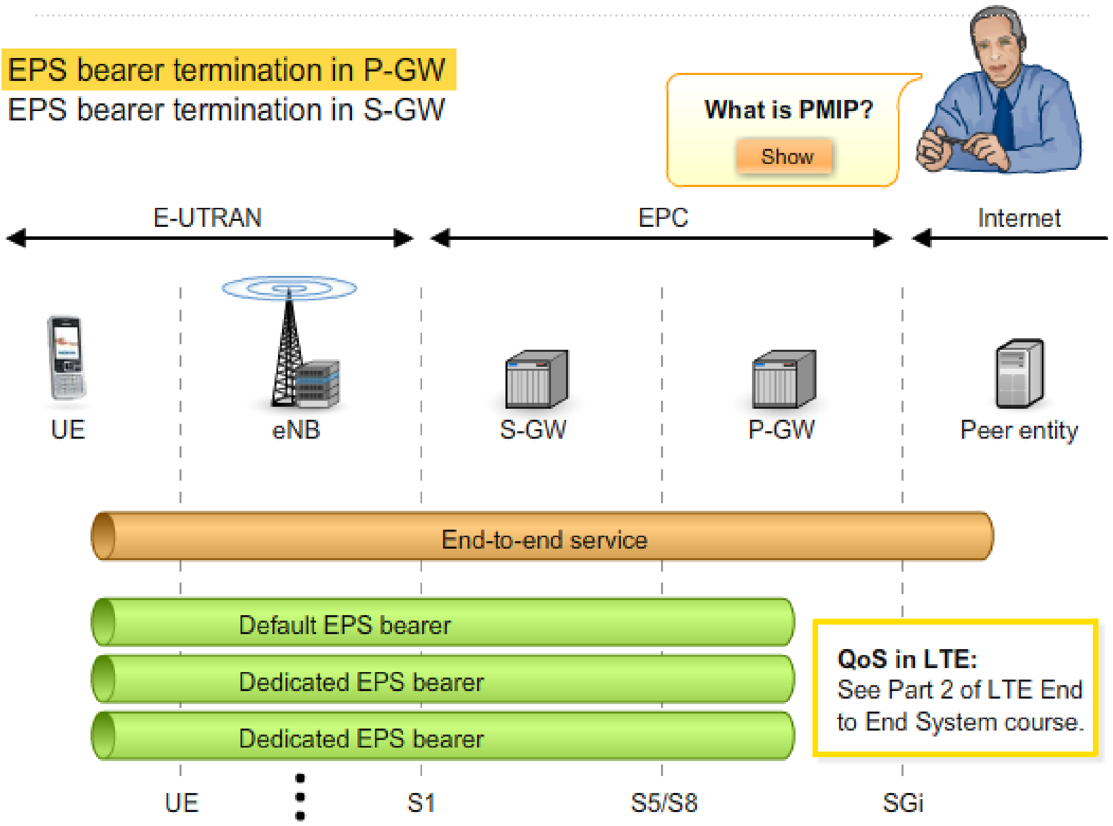
In the first option, the EPS bearer consists of a radio bearer, an S1 bearer and an S5/S8 bearer. Between the eNodeB and PDN Gateway, the transport of the user data takes place within a GPRS Tunnelling Protocol (GTP) tunnel.

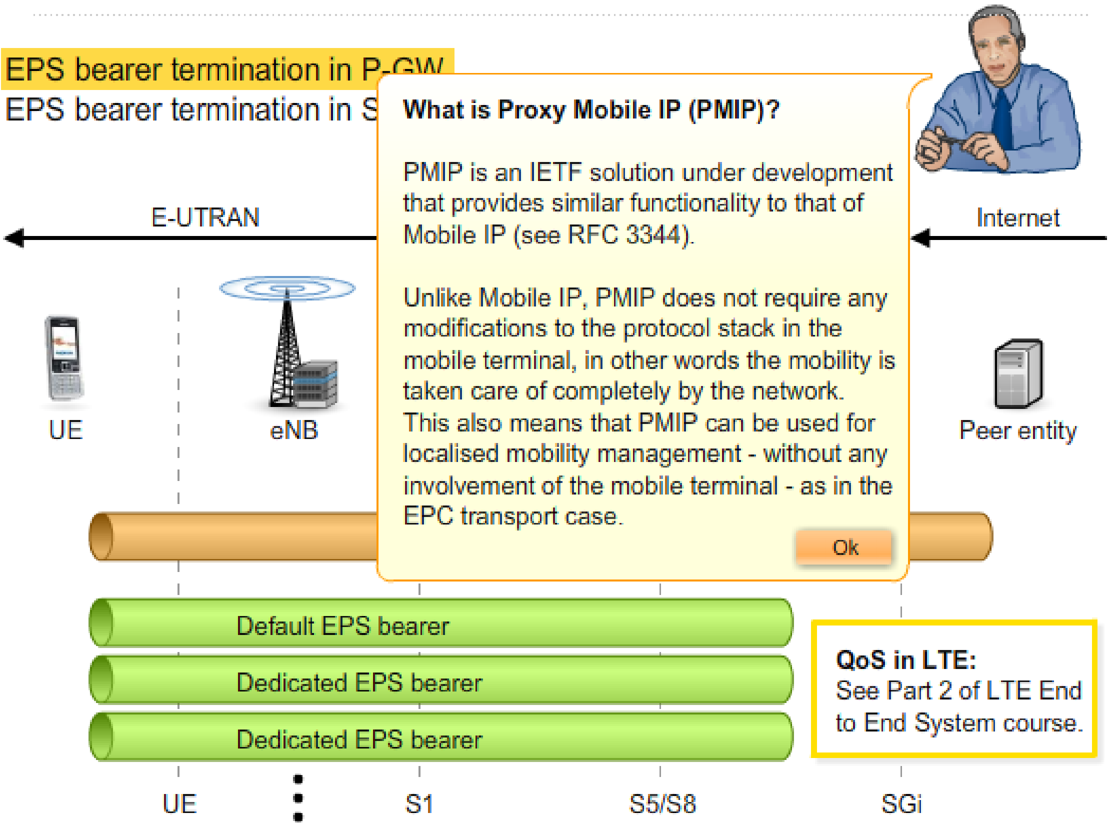
In the second option, the GTP tunnel extends to the Serving Gateway only. Over the S5/S8 interface the IETF Proxy Mobile IP (PMIP) solution is used instead for carrying the user data traffic.

Each EPS bearer is associated with a certain Quality of Service (QoS) profile. Thus, different packet flows with different QoS requirements will be associated with different EPS bearers, and the network can prioritise packets accordingly.

When a UE connects to a packet data network (PDN), one EPS bearer is permanently established for the lifetime of the PDN connection to provide always-on IP connectivity with that PDN. This bearer is referred to as the default bearer. Additional dedicated EPS bearers may or may not be allocated for the transport of user data.

The QoS concept will be explained in more detail in Part 2 of the LTE End to End System course.





1.4 EMM and ECM States

There are two sets of states defined for each UE based on the information held by the Mobility Management Entity.

The two EPS Mobility Management (EMM) states, EMM-DEREGISTERED and EMM-REGISTERED, describe whether or not the UE is registered in the MME and can be reached by paging.

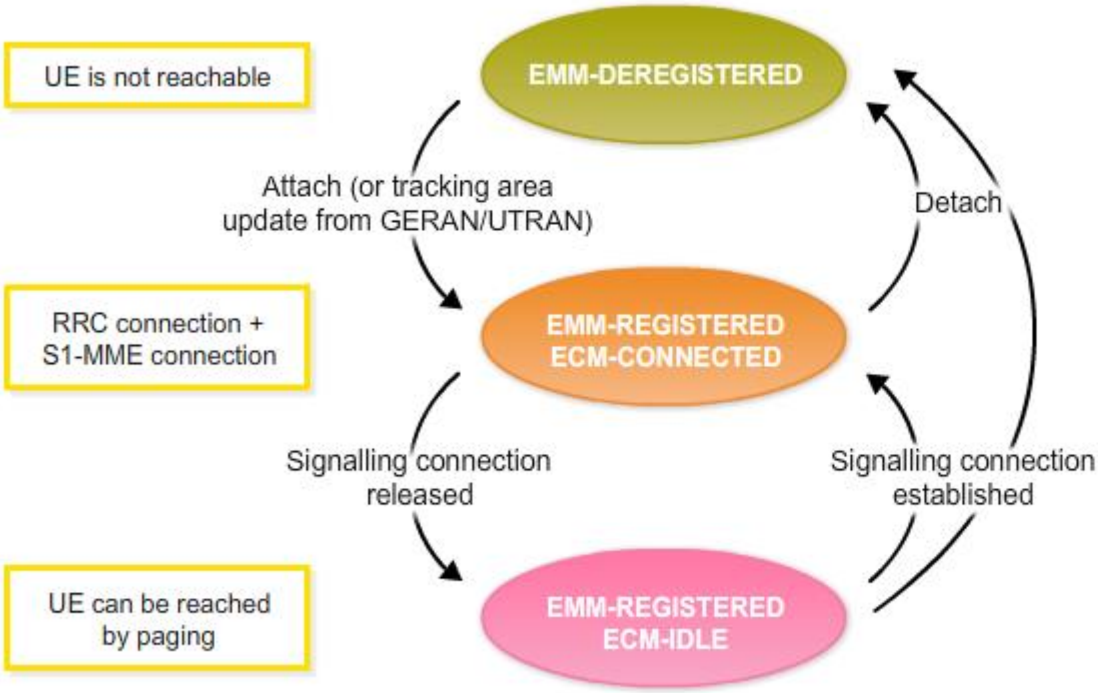
In the EMM-DEREGISTERED state, the MME holds no valid location information for the UE. The UE is not reachable, since its location is not known.

The UE enters the EMM-REGISTERED state either due to the LTE attach procedure or due to a tracking area update (TAU) from a 2G (GERAN) or 3G (UTRAN) network. In this state, the UE can be reached by paging.

The two EPS Connection Management (ECM) states, ECM-IDLE and ECM-CONNECTED, describe the signalling connectivity between the UE and Evolved Packet Core.

In the ECM-IDLE state, there exists no signalling connection between the UE and the MME.

In the ECM-CONNECTED state, there exists a signalling connection between the UE and the MME. The signalling connection is made up of two parts: an RRC connection between the UE and eNodeB, and an S1-MME connection between eNodeB and MME.



1.5 End-to-End Procedures and Technology

In this course, we will next examine various procedures required for managing the end-to-end LTE system.

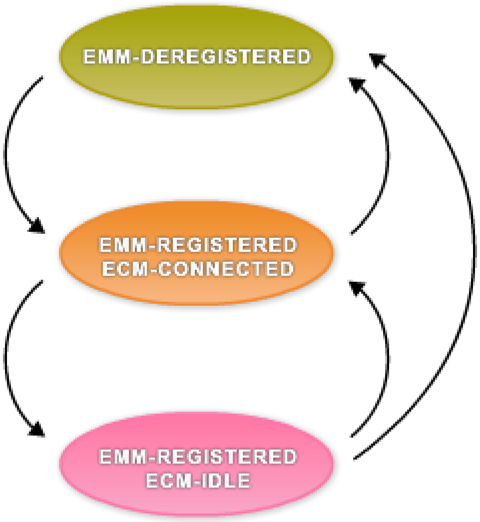
The procedures include mobility management procedures in the ECM-IDLE state, connection management procedures, and mobility management procedures in the ECM-CONNECTED state, also known as handovers. A small end-to-end example is provided at the end of the course.

In LTE End to End System Part 2, we will then turn our attention to various supporting technologies and solutions needed for achieving a complete functioning end-to-end system. Topics in the course include:

- Quality of Service (QoS) solutions, closely related to the EPS bearer concept
- Security solutions such as authentication and encryption of user and control data
- Charging solutions
- User plane transport options
- Interoperability between LTE and 2G/3G or 3GPP2 systems
- Radio network planning, frequency planning and licensing issues
- Network management
- Subscription data management

- Operator services.

LTE End to End System Part 1



LTE End to End System Part 2

- QoS solutions
- Security solutions
- Charging solutions
- User plane transport
- LTE - 2G/3G/CDMA2000 interoperability
- Radio network and frequency planning
- Licensing issues
- Network management
- Subscription data management
- Operator services

2 Mobility Management in ECM-IDLE State

2.1 Introduction

Mobility management (MM) functions are needed for keeping track of the current location of a UE.

The basic mobility management procedures in ECM-IDLE state are

• tracking area update, needed when the mobile terminal moves to a tracking area in which it is not registered

• paging, where the network indicates to the mobile terminal that it should enter the ECM-CONNECTED state.

These mobility management procedures will be described on the following pages. Note that mobility management procedures in the ECM-CONNECTED state - usually referred to as handovers - will be explained later in the course.

2.2 Tracking Area

If the network wishes to communicate with a UE that is in the ECM-IDLE state, it needs to have some information about where the UE is located. This is handled using the tracking area concept. Each cell belongs to a single tracking area (TA).

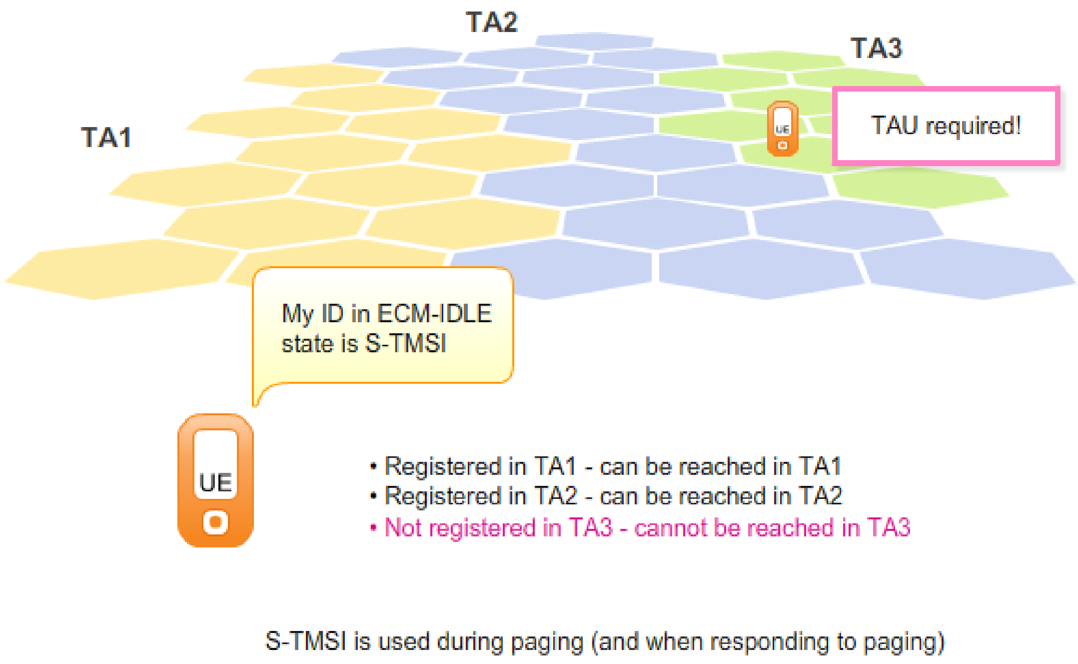
Note, however, that different cells in a certain eNodeB can belong to different tracking areas.

A UE in ECM-IDLE state can be reached in those cells that belong to the tracking area in which the UE is currently registered. The UE may be registered in multiple tracking areas.

The MME allocates the UE a Temporary Mobile Subscriber Identity (S-TMSI) which uniquely identifies the UE within a given tracking area. Thus, when a UE is in the ECM-IDLE state, the MME can request within one or more tracking areas that the UE with the required S-TMSI switch to the ECM-CONNECTED state. This MME request is done by paging.

When the UE moves to a tracking area in which it is not registered, a tracking area update (TAU) must be performed to ensure that it can be reached in the new tracking area.

Note that the UE may also perform tracking area updates on a periodical basis.



2.3 Paging

When a mobile terminal is in the ECM-IDLE state, it can only be reached through paging. The UE is paged in all cells of all tracking areas in which it is currently registered. Note that the UE may be registered in multiple tracking areas.

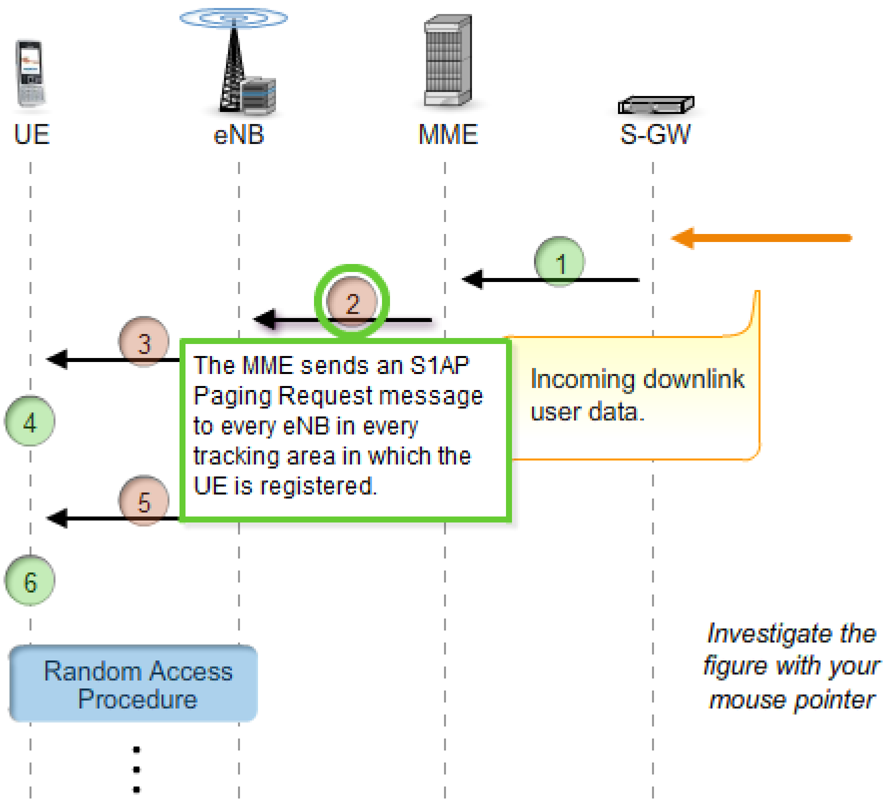
There are a number of reasons why the network needs to initiate contact. Most likely, downlink user data has arrived at the S-GW, in which case the S-GW requests the MME to page the UE to which the data should be sent.

The MME sends a paging message to every eNodeB in every tracking area in which the UE is registered.

The eNodeB then initiates a two-stage paging process. First, it indicates the paging group by broadcasting a paging indication message. UEs are allocated to paging groups based on the UE identifier (IMSI or S-TMSI). If a UE discovers that its group is being paged, only then the UE reads the full paging message.

When the UE detects that it is being paged, it initiates the transition from the ECM-IDLE to ECM-CONNECTED state. This always involves the random access procedure.

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



1. Downlink user data has arrived at the S-GW, and the MME is requested to page the UE. The S-GW will have received the identity and address of the serving MME during the initial attach procedure. This information is stored locally at the S-GW, and updated during MME relocation.

2. The MME sends an S1AP Paging Request message to every eNB in every tracking area in which the UE is registered.

3. The eNB broadcasts a paging indication message, which includes information about how the paging message can be read and what physical resources have been allocated for it. The paging indication is repeated until the UE responds or until the number of re-tries reaches a maximum.

4. The UE reads the paging indication message and notices that it belongs to the paging group indicated in the message.

5. The eNB broadcasts the paging message using the physical resources listed in the paging indication message.

6. Since the UE belongs to the paging group, it reads the full paging message. If the UE detects its own identifier (S-TMSI or IMSI) in the paging message, it knows that it is being paged and in this case starts to establish a signalling connection to the MME.

The random access procedure is necessary for establishing an RRC connection between UE and eNB. The signalling continues...

2.4 Tracking Area Update

When the UE moves to a tracking area in which it is not registered, it must perform a tracking area update (TAU) to ensure that it can be reached in the new tracking area. The UE discovers which tracking area it is in by listening to the broadcast channel.

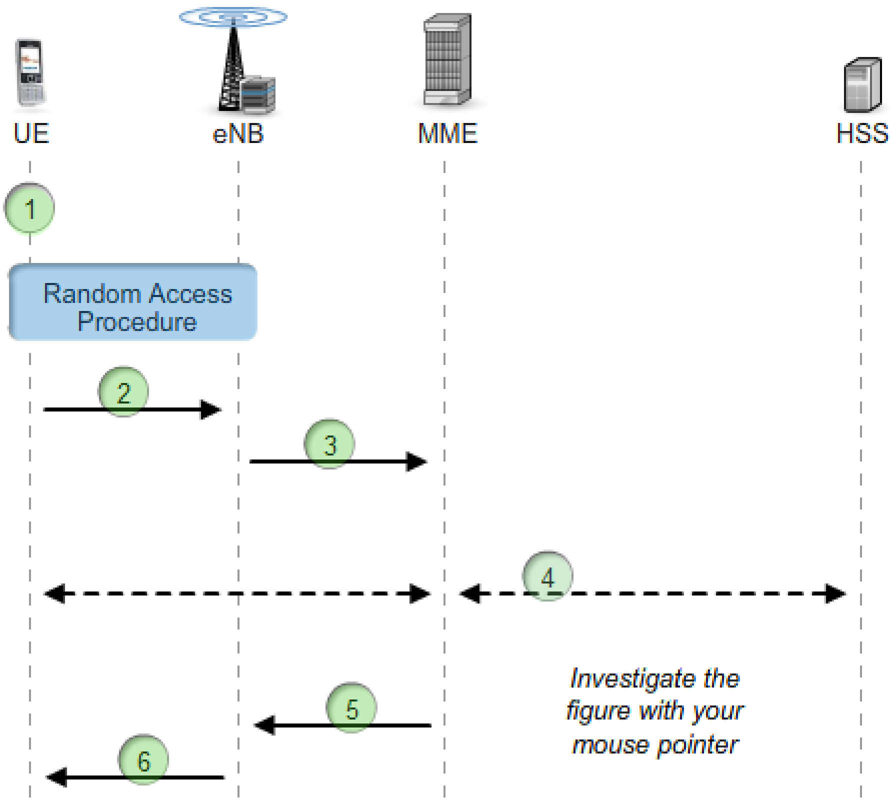
When a tracking area update is necessary, first an RRC connection between the UE and eNodeB must be established using the random access procedure.

Next, the UE sends a TAU Request message to the MME.

The MME may perform authentication, if necessary, and sends a TAU Accept message to the UE. The message includes, among others, a new list of tracking areas in which the UE is now registered.

In a more general case, the tracking area update includes a procedure called MME relocation, involving a “new MME” handling the new tracking area and the “old MME” which handled the previous tracking area. MME relocation includes signalling between the two MMEs, between the new MME and HSS for adding new information, and between the old MME and HSS for deleting old information. Actually, the Serving Gateway is also involved in the procedure, but this is not shown in the figure for the sake of simplicity.

Moving back to the less complex tracking area update case, you can see more details by moving your mouse pointer over the items in the procedure sequence chart.



1. The UE detects a change to a new tracking area (TA) by discovering that the current TA indicated on the broadcast channel is not in the list of TAs that the UE registered with the network.

The random access procedure is necessary for establishing an RRC signalling connection between UE and eNB.

2. The UE sends a TAU Request message to the eNB. The message includes (among others) the last visited TA, so that the MME can produce a good list of TAs to be sent to the UE. In other words, the MME can keep this TA in the new TA list, thus avoiding ”ping-pong”-like TAU behaviour.

3. The eNB forwards the TAU Request message to the MME.

4. The MME may perform authentication based on data obtained from the HSS.

5. If the MME accepts the tracking area update request, it sends a TAU Accept message to the UE. The message includes (among others) a new list of valid tracking areas for the UE.

2.5 LTE Inter-band and Inter-system Mobility

The LTE release RL10 introduces a number of system information blocks (SIBs) that are broadcast within the LTE network and are necessary for handling the following mobility scenarios:

An Inter-band mobility within the same system that is LTE.

Or an Inter-system mobility where the target cell belongs to another radio access technology.

Note that these mobility scenarios only apply to mobile terminals in ECM-IDLE state, not in ECM-CONNECTED state. In other words, the functionality concerned is cell re-selection, not a handover.

The LTE release RL50 introduces a quality-based inter-frequency band and inter-radio access technology system idle mode mobility cell re-selection or for short “RSRQ-based cell re-selection”.

Therefore, a number of additional quality parameters are supported by system information blocks 1, 3, 5 and 6.

SIB 1 provides the UE with the quality and evaluation information of the cell it is trying to access.

SIB 3 contains cell search and quality information for intra-frequency, inter-frequency and inter-RAT cell re-selection. It also contains the lowest allowed cell quality.

SIB 5 provides information about E-UTRAN frequencies and inter-frequency neighbouring cells needed during cell re-selection. Add to that, it contains cell re-selection quality parameters.

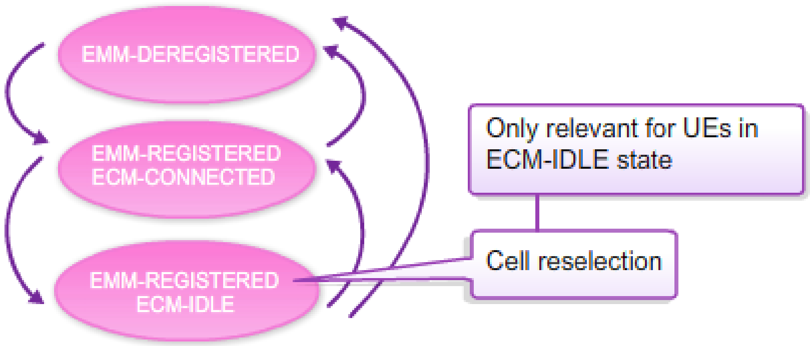
SIB 6 and SIB 7 provide similar information about WCDMA and GSM/EDGE frequencies and neighbouring cells. However, SIB6 contains cell re-selection quality thresholds.

SIB 8 provides the necessary information when the re-selected cell belongs to a 3GPP2 network.

Note that these mobility scenarios only apply to mobile terminals in ECM-IDLE state, not in ECM-CONNECTED state. In other words, the functionality concerned is cell re-selection, not a handover.

System information blocks (SIBs) needed for handling LTE inter-band or inter-system mobility

SIB 1: Provides the UE with the quality and evaluation information of the cell it is trying to access
SIB 3: Information on cell search and quality for intra-frequency, inter-frequency and inter-RAT cell re-selection
SIB 5: Information on other E-UTRAN frequencies and inter-frequency neighbouring cells as well as their signal quality
SIB 6: Information on UTRAN frequencies and neighbouring cells as well as their signal quality
SIB 7: Information on GERAN frequencies and neighbouring cells
SIB 8: Information on CDMA2000/1xRTT or eHRPD frequencies and neighbouring cells



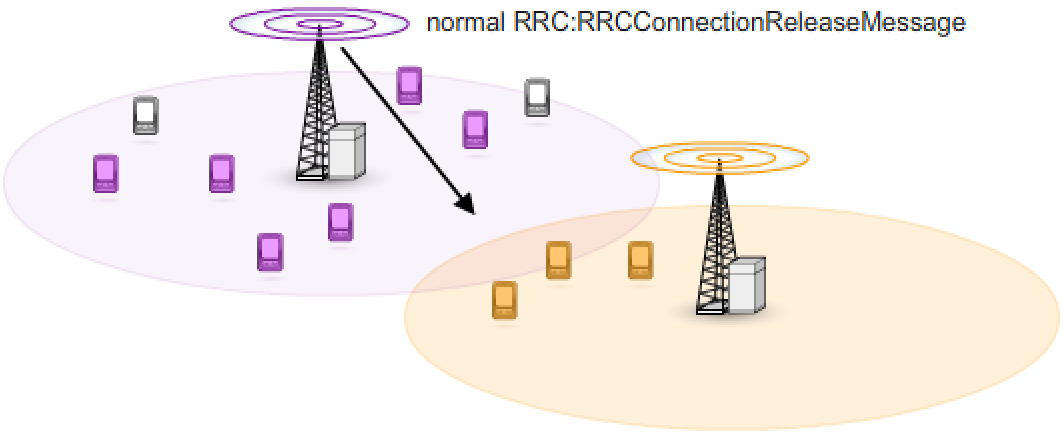
2.6 Idle mode load balancing

Idle mode load balancing is a new feature supported in NSN LTE release 50. It is a Radio Resource Management (RRM) functionality owned by the eNodeB. This feature helps to balance resource usage in multi-carrier or multi-band deployment.

In an LTE network, idle mode users are not monitored continuously. Therefore, idle mode load balancing can be achieved by monitoring current active users' conditions and then adjusting cell re-selection priorities accordingly.

This cell re-selection adjustment can be made by forcing a percentage of users in the cell (usually cell-edge users) to select their strongest neighbour. Also, the users can transition to another carrier or band that has more resources available.

The functionality can be enabled / disabled per eNodeB by O&M setting.



Benefits:
balances resource usage in multi-carrier or multi-band deployment.

2.7 Exercise

In this exercise, the idea is to associate various statements with the correct mobility management procedure. Please go ahead.

Please click the correct tick boxes in the table below with your mouse pointer.
When you are ready, click "Submit".

	Paging	TAU
Downlink user data has arrived at the S-GW	✓	
Random access procedure is required as part of this procedure.	✓	✓
UE checks if it belongs to a certain "group".	✓	
The MME updates a certain "list" and sends this new list to the UE.		✓
MME relocation can also be part of this procedure		✓

3 Connection Management

3.1 Introduction

Now let us examine four connection management procedures in more detail: Random access, LTE attach, setting up a user data connection, and releasing the connection.

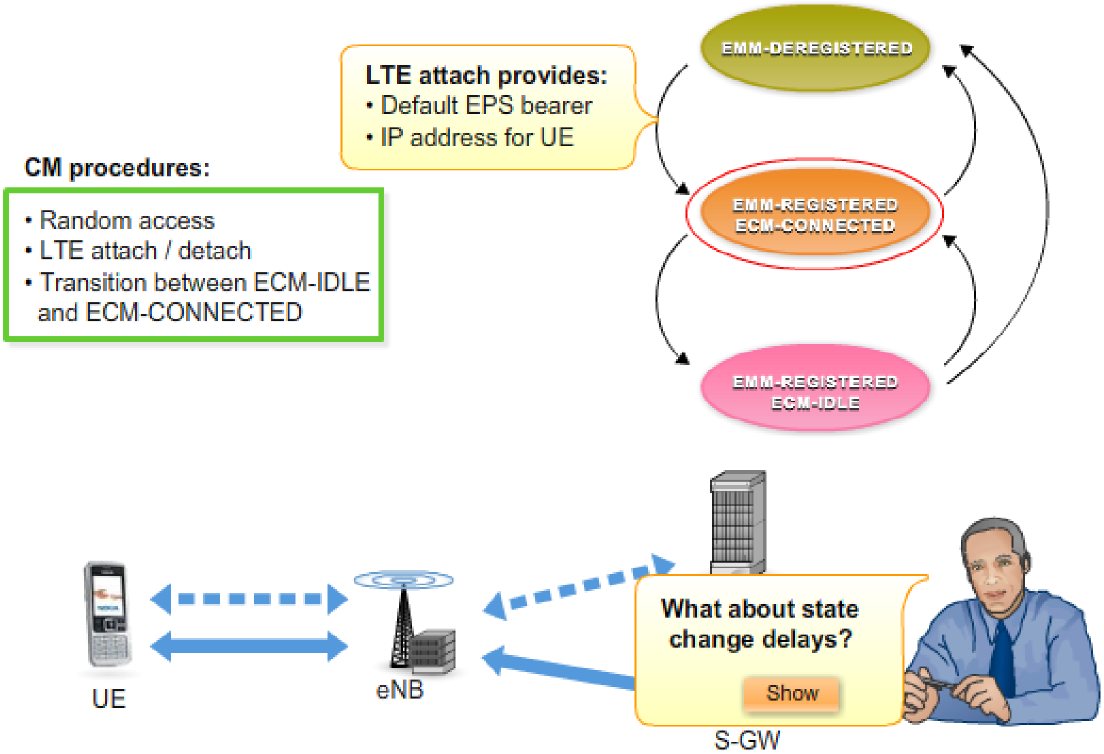
LTE attach means that a mobile device moves from the EMM-DEREGISTERED state to the EMM-REGISTERED and ECM-CONNECTED state. Note that during LTE attach a mobile terminal is always allocated a bearer - in other words the default EPS bearer - and an IP address.

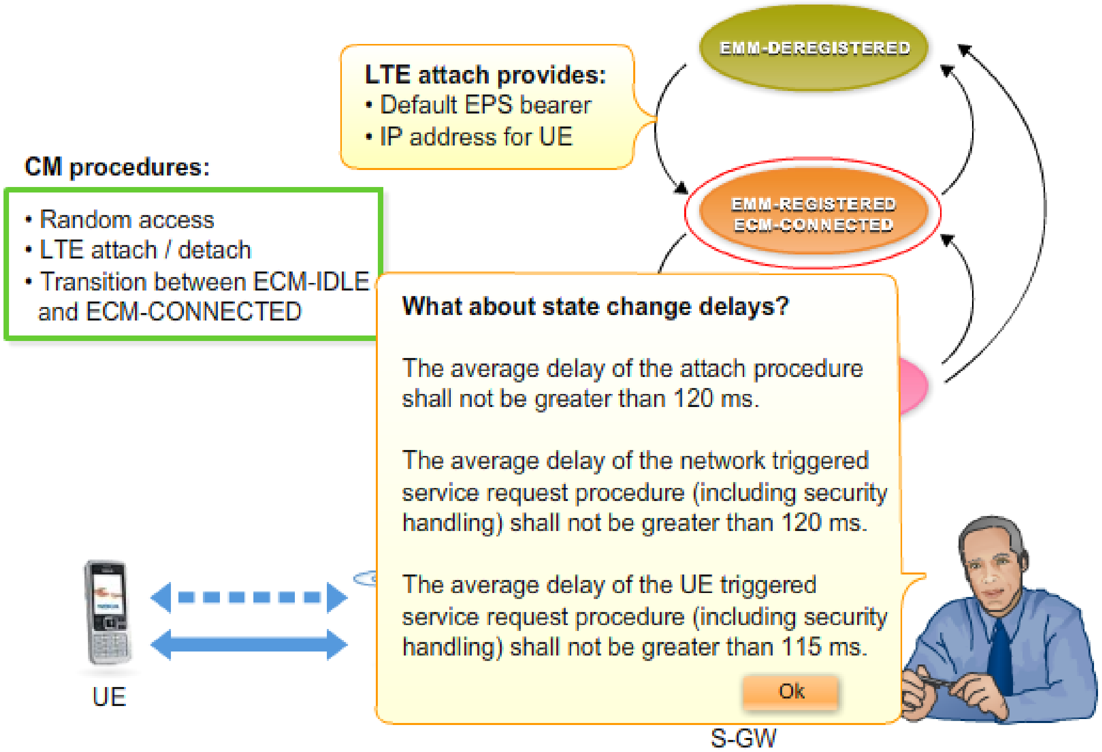
If there is no data traffic activity for some time, the connection management state is changed to ECM-IDLE. Now the location of the UE is known only at the tracking area level and the UE can only be reached through paging.

When a UE changes back from the ECM-IDLE to ECM-CONNECTED state, a Radio Resource Control (RRC) signalling connection is first established over the LTE air interface using a procedure called random access, and the MME establishes a signalling connection over the S1 interface. Next, the MME creates a user plane connection between the UE and Serving Gateway (S-GW). Now the transport of user data can take place.

In ECM-CONNECTED state, the location of the UE is known at the cell level and cell changes are controlled by handovers.

Finally, our tutor would like to introduce some performance requirements related to these state changes.


LTE attach provides:
• Default EPS bearer
• IP address for UE
CM procedures:
• Random access
• LTE attach / detach
• Transition between ECM-IDLE and ECM-CONNECTED
EMM-DEREGISTERED
EMM-REGISTERED ECM-CONNECTED
EMM-REGISTERED ECM-IDLE
What about state change delays?
Show
UE
eNB
S-GW


LTE attach provides:
• Default EPS bearer
• IP address for UE
CM procedures:
• Random access
• LTE attach / detach
• Transition between ECM-IDLE and ECM-CONNECTED
EMM-DEREGISTERED
EMM-REGISTERED ECM-CONNECTED
What about state change delays?
The average delay of the attach procedure shall not be greater than 120 ms.
The average delay of the network triggered service request procedure (including security handling) shall not be greater than 120 ms.
The average delay of the UE triggered service request procedure (including security handling) shall not be greater than 115 ms.
Ok
UE
S-GW

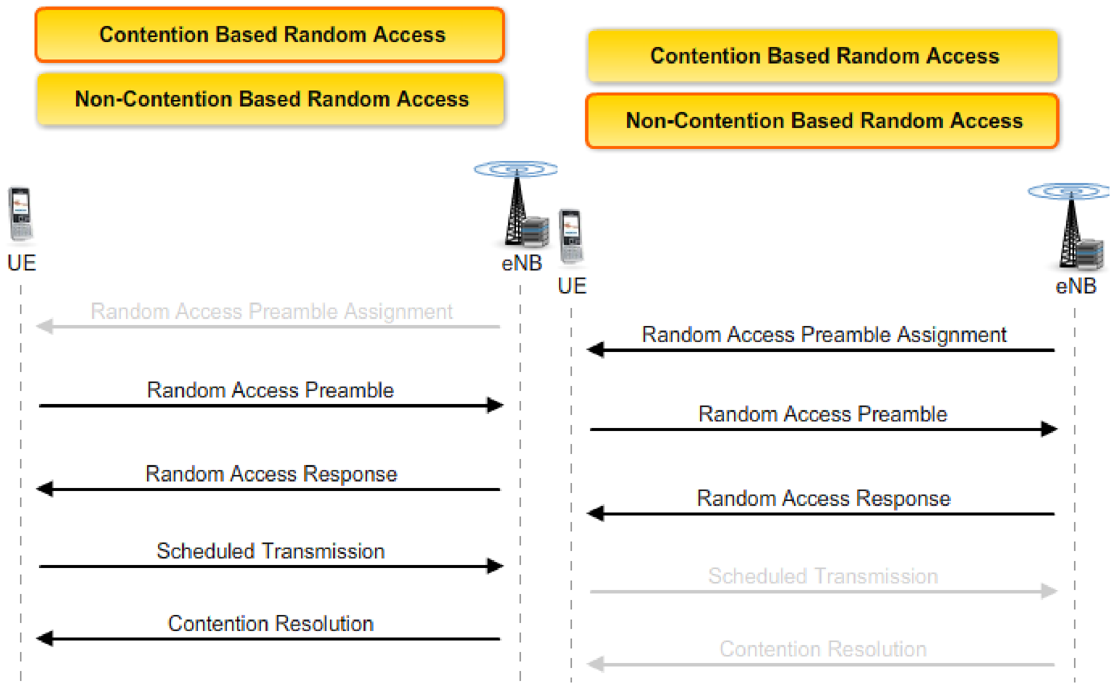
3.2 Random Access

Every time the UE wishes to initiate communication with the network, a procedure called random access has to be performed. Two random access procedures have been defined for LTE:

Contention based random access is used when the UE starts the LTE attach procedure, or when the UE is in ECM-IDLE state and wishes to contact the network. This is necessary for instance when there is user data to be sent in uplink or in downlink - which is indicated by paging the UE - or during a tracking area update.

Non-contention based random access is used in some special cases when the UE is in the ECM-CONNECTED state, for instance when there is data to be sent in the downlink but the UE is not synchronised to the network for some reason, or when the network commands the UE to perform a handover to another cell.

You can see more details by clicking the random access method buttons. Then move your mouse pointer over the text in the procedure sequence chart.



3.3 LTE Attach (1/2)

The LTE attach procedure is used when the UE is in the EMM-DEREGISTERED state and wishes to enter the EMM-REGISTERED state, in other words the UE wishes to register with the EPC network, for instance after power-on.

This animation - in two parts - outlines the main functionality of the attach procedure as specified by 3GPP. You can see more details by moving your mouse pointer over the items in the procedure sequence chart at the end of the animation.

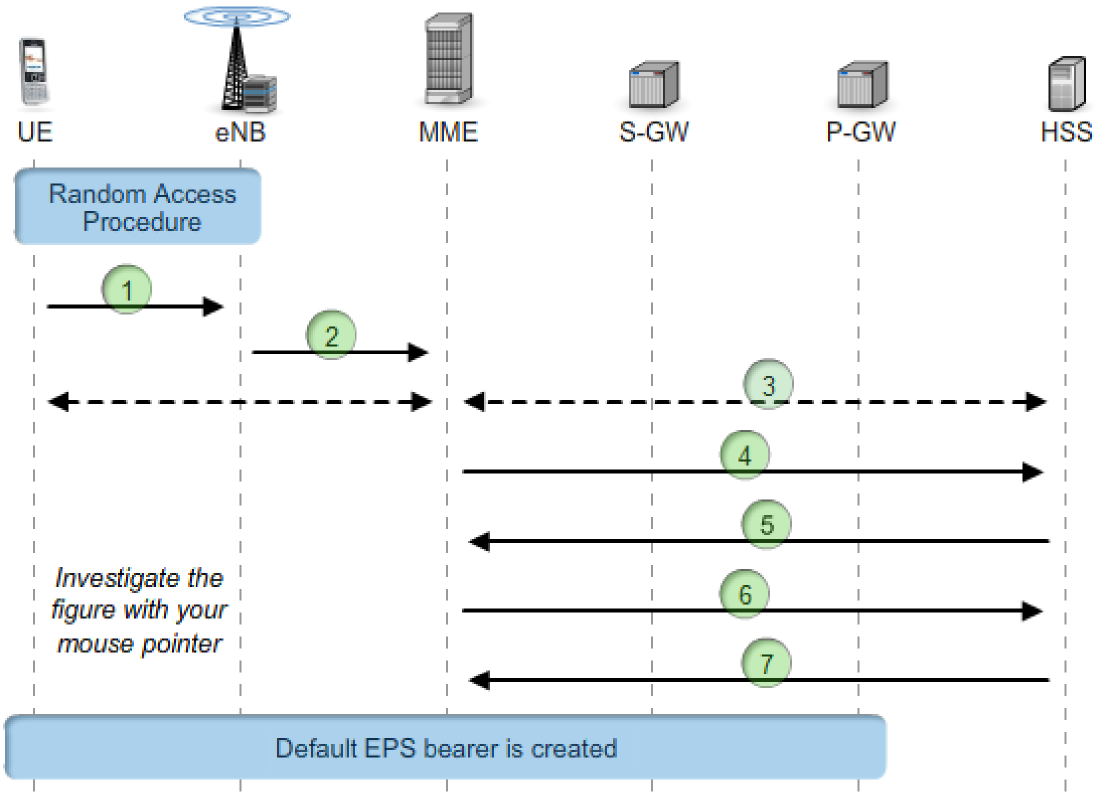
First, a procedure called random access is necessary. The purpose of this procedure is to establish a Radio Resource Control (RRC) signalling connection between the UE and eNodeB.

Using this RRC signalling connection, an Attach Request message is sent to the eNodeB. The message is then forwarded to the MME.

The MME may perform authentication at this stage, if required.

Next, the MME contacts the Home Subscriber Server (HSS), which sends the user's subscription data to the MME. The MME can now create a context for the UE.

In LTE, an integral part of the attach procedure is to establish the default EPS bearer. In effect, this means that the UE directly enters the ECM-CONNECTED state - at least temporarily. This is explained on the next page.



The random access procedure is necessary for establishing an RRC signalling connection between UE and eNB.

1. A Non Access Stratum (NAS) Attach Request message is sent to the eNB encapsulated in an RRC message.

2. The eNB chooses an MME to serve the UE and forwards the NAS Attach Request message to the MME encapsulated in an S1AP Initial UE Message.

3. If there is no context for the UE anywhere in the network then authentication must be performed. The authentication is based on data obtained from the HSS.

4. If authentication was successful, the MME informs the HSS that it is now serving the UE by sending a Location Update message.

6. The HSS sends the user's subscription data to the MME. The MME acknowledges this action.

7. The HSS acknowledges the Update Location message received from the MME in step 4.

In LTE, an integral part of the attach procedure is to establish the default EPS bearer.

3.4 LTE Attach (2/2)

Establishing the default EPS bearer includes the following steps:

• The user plane connection between the PDN Gateway (P-GW), Serving Gateway (S-GW), and eNodeB is established

• The UE is allocated an IP address

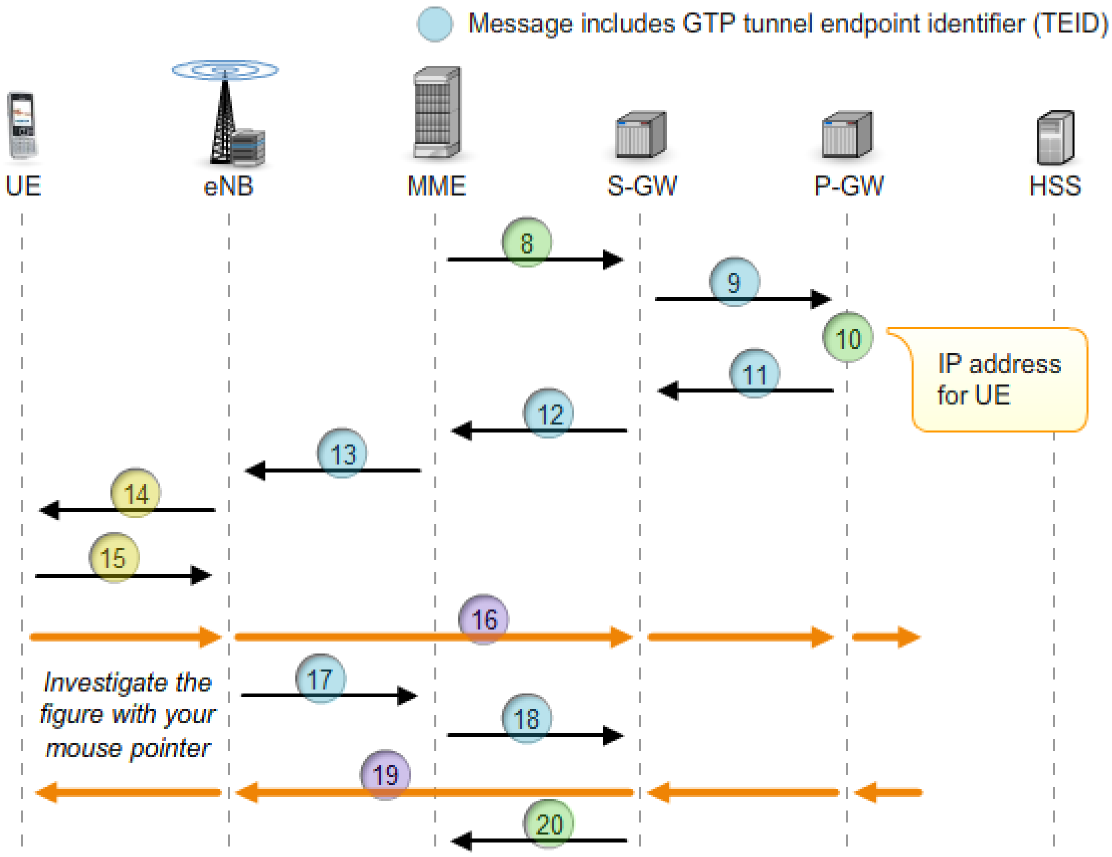
• The radio bearers are established

• Uplink user data (if available) can be sent starting from this point

• Downlink user data (if available) can be sent starting from this point.

Note that GPRS Tunnelling Protocol (GTP) tunnels must be set up in both directions for the default bearer in the user plane between the eNodeB and P-GW, and for the control plane signalling between the S-GW and P-GW. When setting up GTP tunnels, tunnel endpoint identifier (TEID) information must be sent to the relevant nodes. Messages carrying TEID information are indicated with blue circles in the figure.

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



8. The MME selects a Serving Gateway (S-GW) and requests it to set up the default bearer. Included in the message is the MME identifier and address, used later for paging purposes (see the paging animation).

9. The S-GW requests the P-GW to set up the default bearer in the user plane over the S5/S8 interface. This message includes the tunnel endpoint identifiers (TEIDs) of the downlink GTP tunnel endpoints in the S-GW for the user plane and control plane GTP tunnels.

10. The P-GW assigns the UE an IP address.

11. The P-GW responds to the S-GW with the TEIDs of the uplink GTP tunnel endpoints (for the user plane and control plane GTP tunnels) in the P-GW.

12. The S-GW responds to the MME with the TEID of the uplink GTP tunnel endpoint in the S-GW for the user plane default bearer.

13. The MME forwards the S-GW TEID (received in message 12) to the eNB and instructs the eNB to set up the radio bearers towards the UE. The message includes the NAS Attach Accept message to be sent to the UE.

14. The eNB forwards the NAS Attach Accept message to the UE and starts setting up the radio bearers over the air interface.

15. A confirmation is sent back to the eNB when the radio bearers have been set up. Also included is the NAS Attach Confirm message.

16. Since the eNB has obtained the S-GW TEID information (in message 13), it can send the uplink user data (received from the UE) to the S-GW.

17. The eNB sends a confirmation to the MME that the radio and S1 bearers have been set up and the UE is now capable of transmitting uplink user data. The eNB also includes the TEID of the downlink GTP tunnel endpoint in the eNB, and forwards the NAS Attach Confirm message (received in message 15) to the MME.

18. The MME forwards the eNB TEID (received in message 17) to the S-GW.

19. After receiving the eNB TEID information, the S-GW can now send downlink user data to the eNB. However, it is unlikely that there is any downlink user data at this point, since the UE has only just attached to the network.

20. Finally, the S-GW sends an acknowledgement to the MME.

3.5 UE-initiated Communication

The ECM-IDLE to ECM-CONNECTED state transition procedure involves the UE, eNodeB, MME and S-GW, and is required when there is user data to be sent to/from the UE while the UE is in the ECM-IDLE state.

If the UE has uplink data to be sent, the procedure is initiated by the UE as shown in the figure - hence the name UE-initiated communication.

The procedure includes the following steps:

• An RRC connection between the UE and eNodeB is established

• The UE sends a Service Request message to the MME, partly using the RRC connection

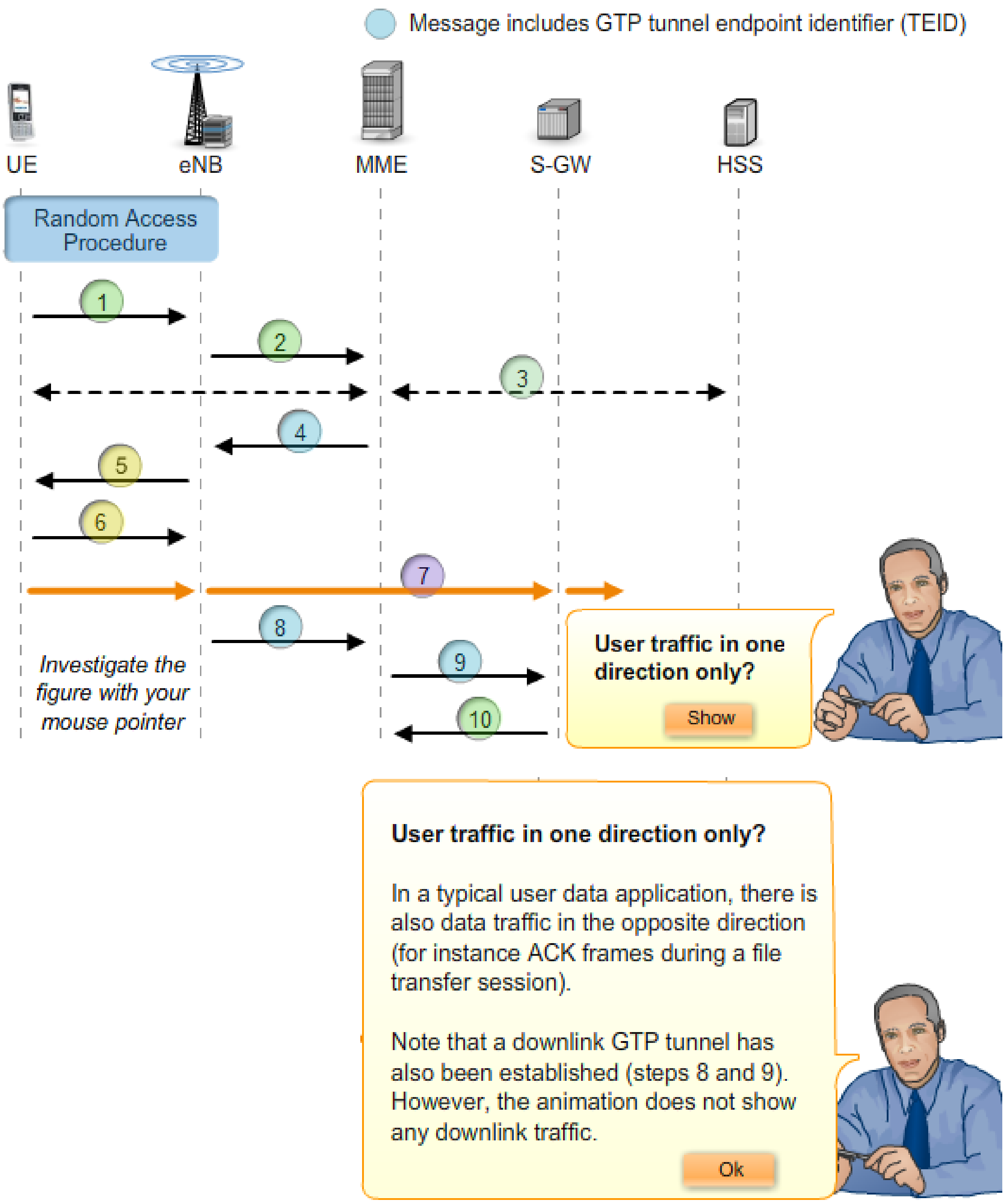
• The MME may perform authentication, if necessary

• The S1 bearers are established

• The radio bearers are established

• The user data is sent in the uplink.

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



The random access procedure is necessary for establishing an RRC signalling connection between UE and eNB.

1. A Non Access Stratum (NAS) Service Request message is sent to the eNB encapsulated in an RRC message.

2. The NAS Service Request message is forwarded to the MME encapsulated in an S1AP Initial UE Message.

3. The MME may perform authentication based on data obtained from the HSS.

4. The MME sends an S1AP Initial Context Setup Request message to the eNB. This message includes (among others) the tunnel endpoint identifier (TEID) for the uplink

GTP tunnel endpoint in the S-GW. The MME obtained this information when the default EPS bearer was established during the LTE attach procedure.

6. Signalling needed for setting up the radio bearers over the air interface.

7. After receiving the S-GW TEID information, the eNB can send the uplink user data received from the UE to the S-GW.

8. The eNB sends an S1AP Initial Context Setup Complete message to the MME. This message includes the eNB TEID for the downlink GTP tunnel.

9. The MME forwards the eNB TEID information to the S-GW.

10. Finally, the S-GW sends an acknowledgement to the MME.

3.6 Network-initiated Communication

In order for the network to trigger the ECM-IDLE to ECM-CONNECTED state transition, the UE must be paged.

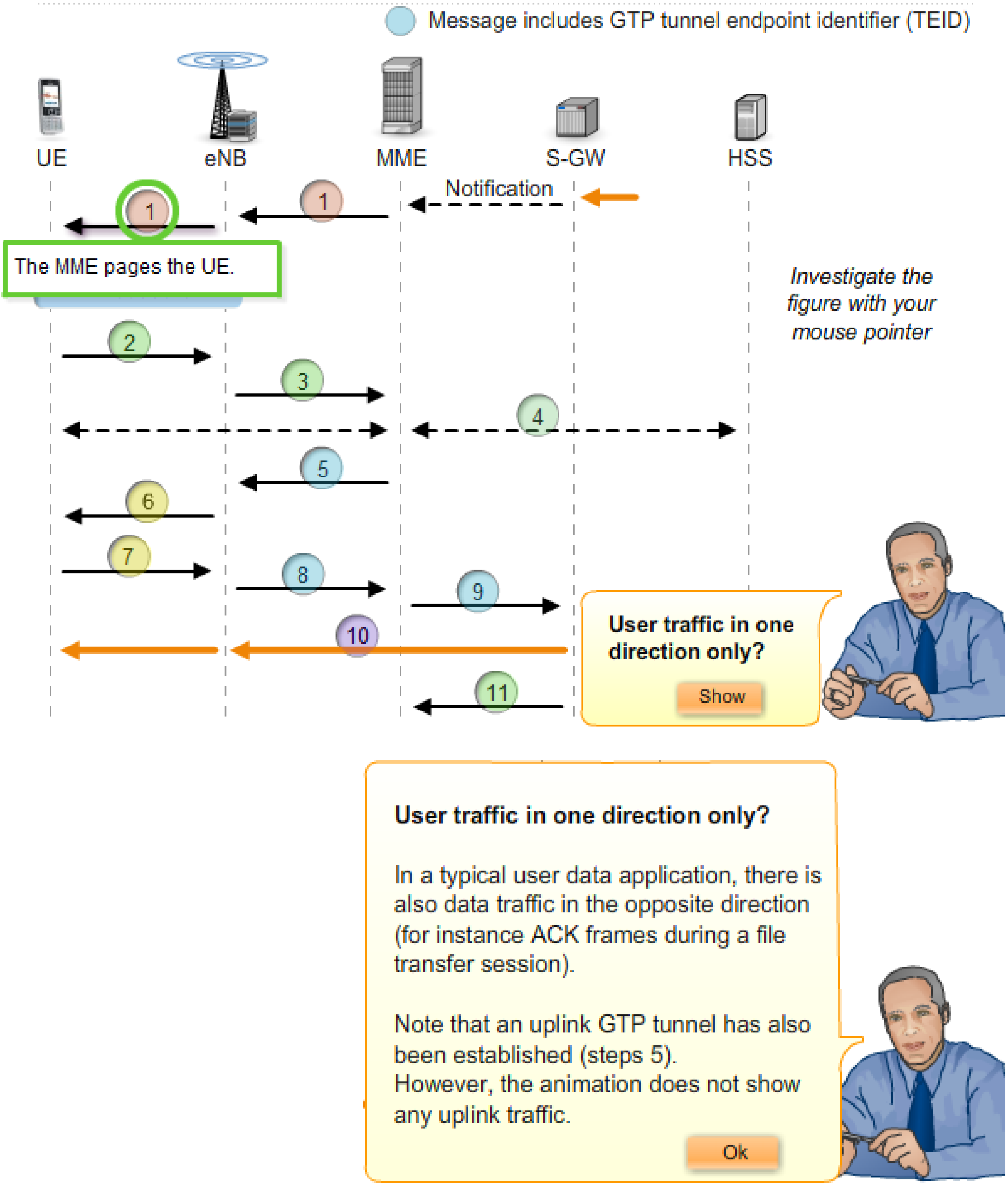
The main reason for network-initiated communication is the arrival of downlink user data at the Serving Gateway.

When the UE responds to the paging request, the signalling procedure is similar to that employed in UE-initiated communication, but with the following differences:

• The UE will probably not have any uplink data to send

• However, the network has downlink data to be sent to the UE

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



The random access procedure is necessary for establishing an RRC signalling connection between UE and eNB.

1. The MME pages the UE.

2. A Non Access Stratum (NAS) Service Request message is sent to the eNB encapsulated in an RRC message.

3. The NAS Service Request message is forwarded to the MME encapsulated in an S1AP Initial UE Message.

4. The MME may perform authentication based on data obtained from the HSS.

5. The MME sends an S1AP Initial Context Setup Request message to the eNB. This message includes (among others) the tunnel endpoint identifier (TEID) for the uplink GTP tunnel endpoint in the S-GW.

7. Signalling needed for setting up the radio bearers over the air interface.

8. The eNB sends an S1AP Initial Context Setup Complete message to the MME. This message includes the eNB TEID for the downlink GTP tunnel.

9. The MME forwards the eNB TEID information to the S-GW.

10. After receiving the eNB TEID information, the S-GW can send the downlink user data via the eNB to the UE.

11. Finally, the S-GW sends an acknowledgement to the MME.

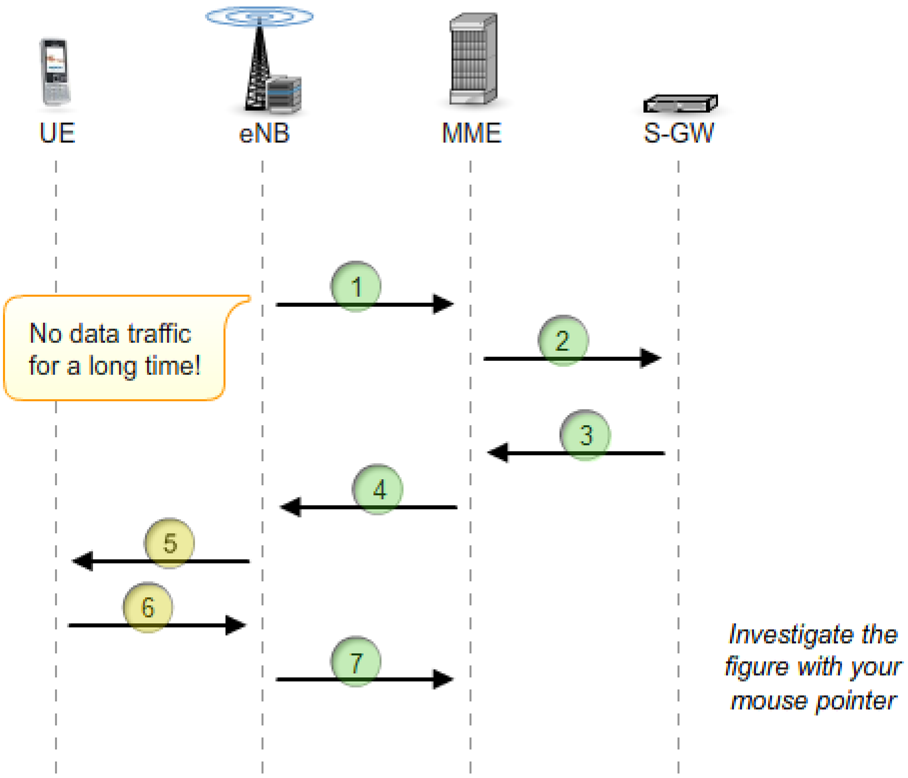
3.7 Connection Release

The release of a connection, in other words moving from the ECM-CONNECTED to ECM-IDLE state, may occur for several reasons, for instance user inactivity.

In this case the eNodeB requests the MME to release the signalling and user plane connections associated with this UE.

Naturally, the eNodeB also makes sure that the radio bearers are released.

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



1. The eNB decides that the UE should move to the ECM-IDLE state and sends a UE Context Release Request message to the MME.

2. The MME sends an S1AP Update Bearer Request message to the S-GW, informing the S-GW that the UE will now move to the ECM-IDLE state.

3. The S-GW releases the eNB related information such as the tunnel endpoint identifiers (TEID) of the downlink GTP tunnel endpoints in the eNB. The S-GW acknowledges the release to the MME. Any downlink data for the UE that arrives at the S-GW after this point will have to be buffered. The UE can only be reached through paging.

4. The MME sends an S1AP UE Context Release Command message to the eNB.

6. Signalling needed for releasing the radio bearers over the air interface.

7. The eNB releases the S-GW related information such as the tunnel endpoint identifiers (TEID) of the uplink GTP tunnel endpoints in the S-GW. The eNB acknowledges the release by sending an S1AP UE Context Release Complete message to the MME.

3.8 UE Identifiers used in LTE

Let us next look at some important UE identifiers used in LTE.

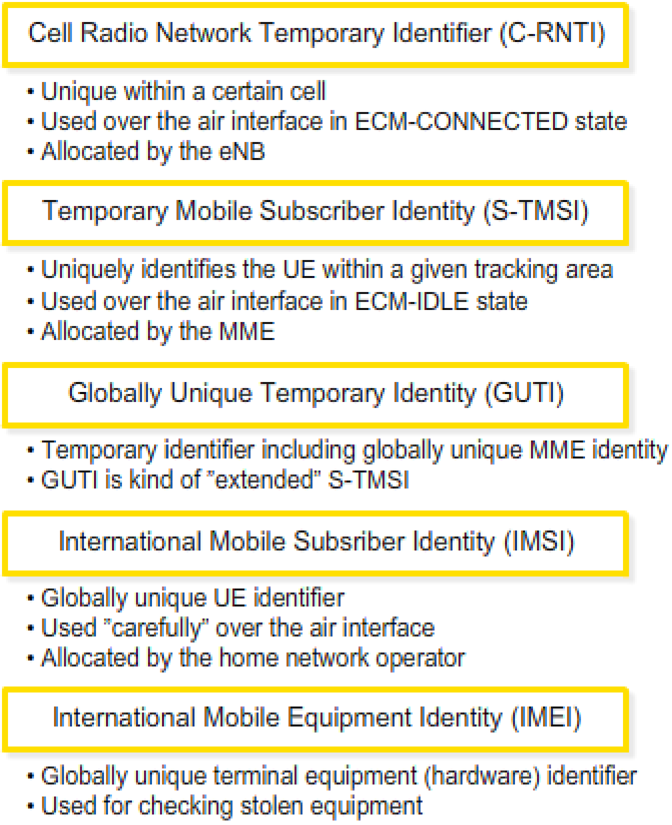
The Cell Radio Network Temporary Identifier (C-RNTI) is used over the LTE air interface. It uniquely identifies the UE within a certain cell. The C-RNTI only exists when the UE is in the ECM-CONNECTED state.

The Temporary Mobile Subscriber Identity (S-TMSI) uniquely identifies the UE within a certain tracking area. This identifier is primarily used when the UE is in the ECM-IDLE state.

The Globally Unique Temporary Identity (GUTI) can be considered an extended version of the S-TMSI, since it uniquely identifies both the UE within a certain tracking area and the MME handling the UE.

The International Mobile Subscriber Identity (IMSI) uniquely identifies the UE anywhere in the world. Since it is so revealing, it is not transmitted unencrypted over the air interface if not absolutely necessary. The S-TMSI is used instead in this case.

Finally, the International Mobile Equipment Identity (IMEI) uniquely identifies the teminal equipment hardware. This number can be used by the network to stop a stolen phone from accessing the network.



3.9 DRX in RRC Connected Mode

In LTE release RL30, the Flexi Multiradio BTS supports discontinuous reception (DRX) in the RRC connected mode. As a result, mobile terminals supporting this functionality can decrease their power consumption and the battery life is extended.

DRX means that the mobile terminal enters power-saving mode and no longer monitors the Physical Downlink Control Channel (PDCCH). Since the PDCCH handles both uplink and downlink scheduling, DRX impacts both the uplink and downlink performance of the radio link.

The DRX functionality can be switched on or off and is controlled by operator-configurable parameters on a per-QoS-class basis:

The DRX cycle specifies the periodic repetition of the On Duration followed by a possible period of inactivity. The cycle provides a trade-off between setup delay and UE battery power consumption.

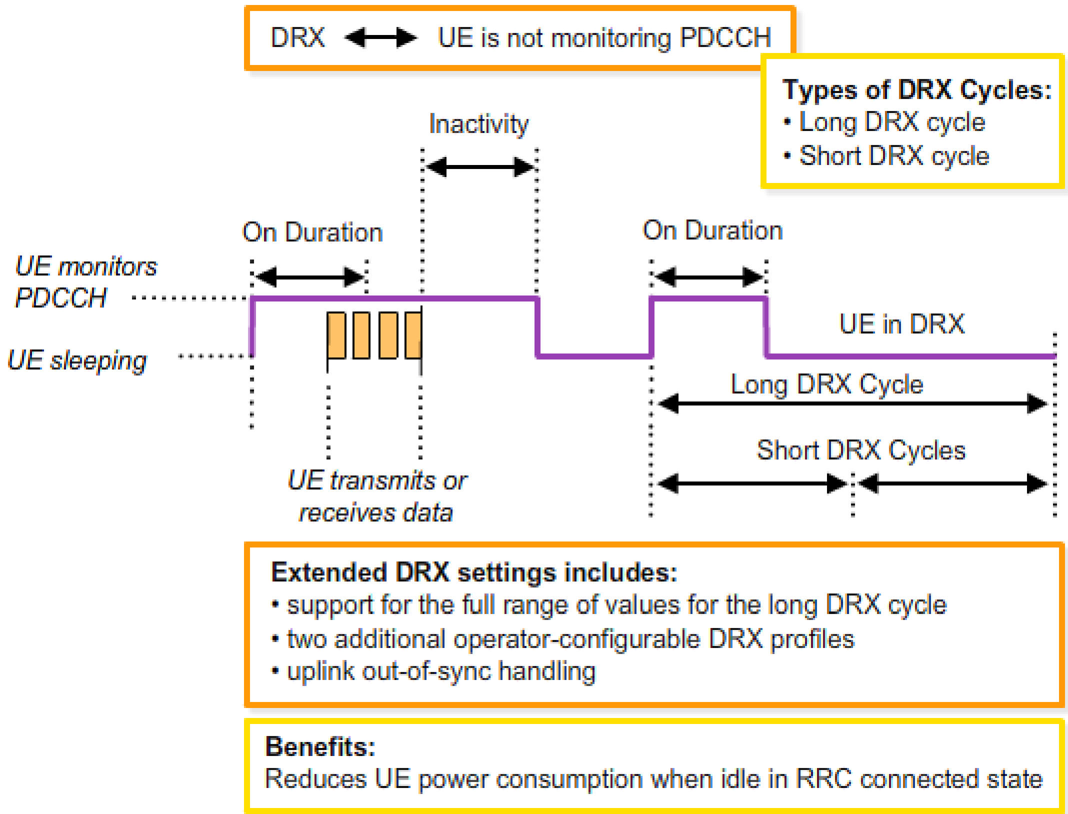
The On Duration specifies the number of consecutive transmission time intervals (TTIs) during which the UE monitors the PDCCH for possible allocations.

When the UE has been transmitting or receiving data, the Inactivity timer specifies a certain delay before the UE enters power-saving mode. This timer is especially beneficial in the case of bursty traffic.

Additionally, the extended settings for DRX includes:

- support for the full range of values for the long DRX cycle
- two additional operator-configurable DRX profiles, and
- uplink out-of-sync handling

In RL50, a short DRX cycle is introduced. This smart DRX addition allows for a more flexible configuration of the DRX Inactivity Timer for long DRX cycles (≥ 160ms). Therefore, improved power savings can be promised to users.



3.10 RRC Connection Re-establishment

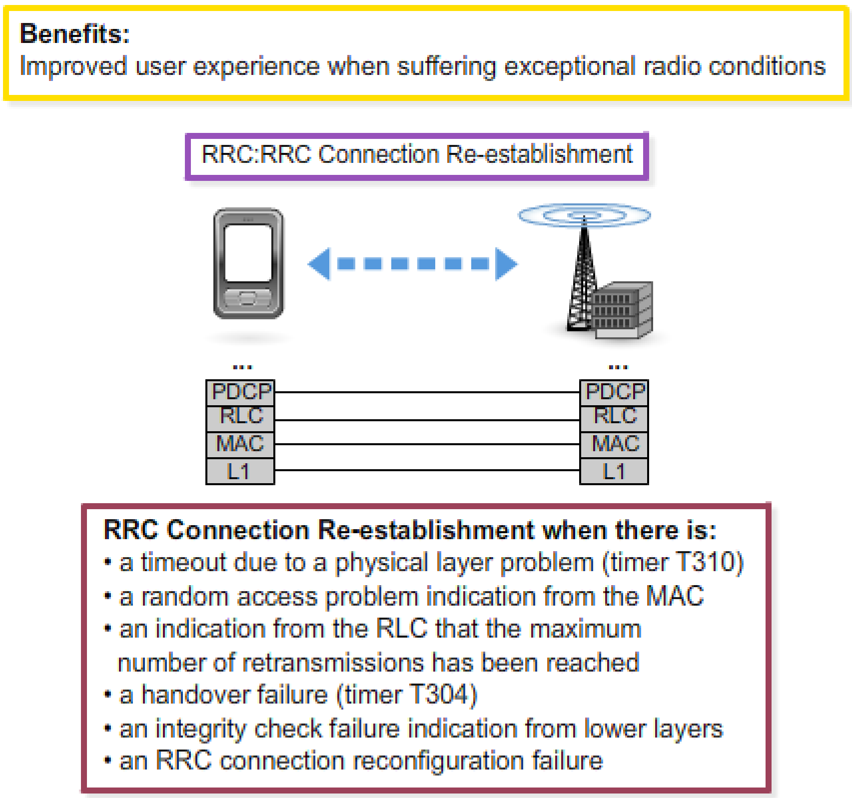
In LTE release RL30, RRC Connection Re-establishment is used when a temporary radio link failure happens, or during a handover if there is a physical link failure.

The benefit of this feature is that it reduces the recovery delay experienced resulting from this kind of temporary event.

The procedure is initiated by the terminal in RRC connected state in case of radio link failure detection due to:

- a timeout due to a physical layer problem, or
- a random access problem indication from MAC, or
- an indication from the RLC that the maximum number of retransmissions has been reached, or
- a handover failure, or
- an integrity check failure indication from lower layers, or
- an RRC connection reconfiguration failure

To initiate this procedure, the UE sends an "RRC Connection Re-establishment Request" message to the eNode B. The eNode B will respond positively if it still has a valid record for the UE.



3.11 S1 Overload Handling

From LTE release RL40 onwards the Flexi Multiradio BTS supports S1 overload handling.

The MME can indicate to the Flexi Multiradio BTS an overload situation by sending the following S1AP messages:

- Overload Start
- Overload Stop.

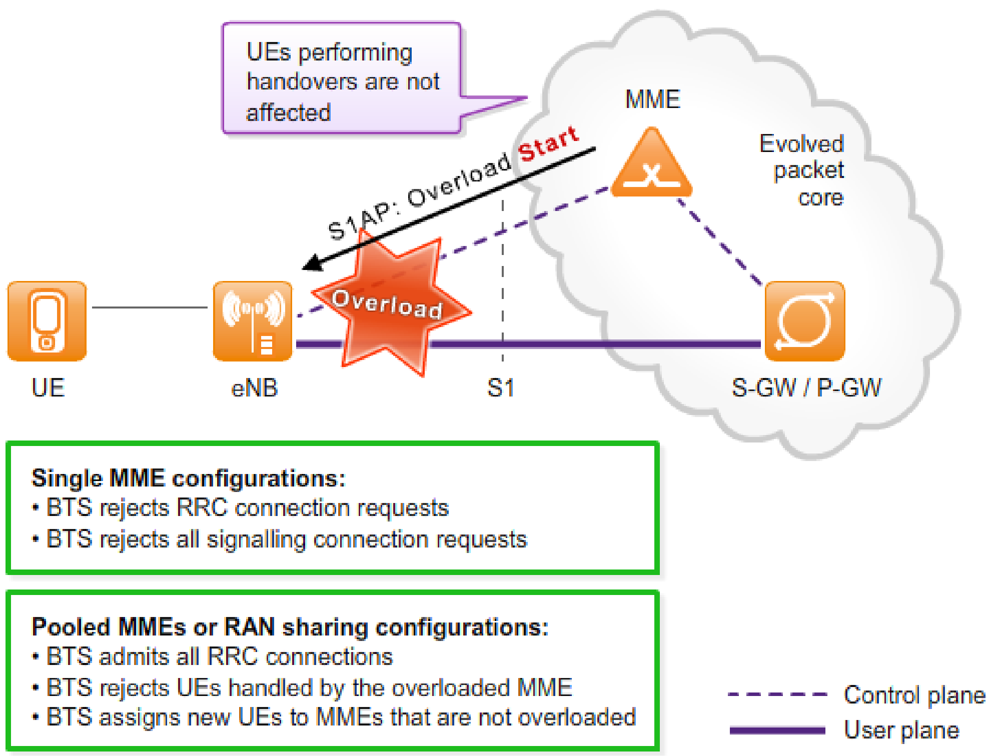
The Flexi Multiradio BTS performs the following actions during the overload period depending on the MME configuration:

In the case of single MME configurations, the BTS

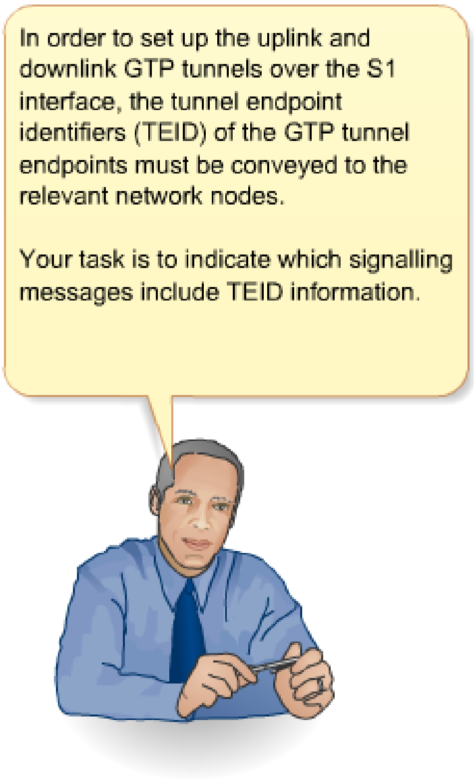
- rejects all RRC connection requests except emergency RRC connections
- rejects all signalling connection requests.
- In the case of MMEs in a pool or RAN sharing configurations (if enabled), the BTS
- admits all RRC connections in order to identify the target MME
- rejects UEs handled by the overloaded MME except those making emergency calls
- assigns new UEs to MMEs that are not overloaded.

UEs performing handovers within the MME area are not affected by the overload handling.

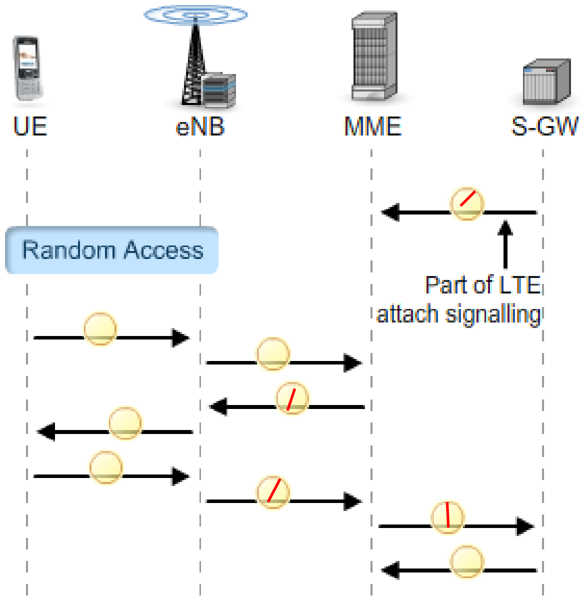
The overload handling functionality can be enabled or disabled via O&M means.



3.12 Exercise



In the figure below, four signalling messages include TEID information. Click these messages with your mouse pointer and click "Submit" when ready.



4 Mobility Management in ECM-CONNECTED State

4.1 Introduction

Up to now, we have been examining connection management and mobility management procedures in the ECM-IDLE state. Now let us turn to mobility management procedures in the ECM-CONNECTED state, which are also called handovers.

The following types of handover will be explained in this course:

Intra cell handovers take place within the serving cell. This handover is used to refresh security keys and re-synchronize the mobile terminal to the eNodeB. Moreover, it is used to activate/deactivate TTI bundling for the UE.

Intra-LTE intra-eNodeB handovers take place between cells within a certain eNodeB.

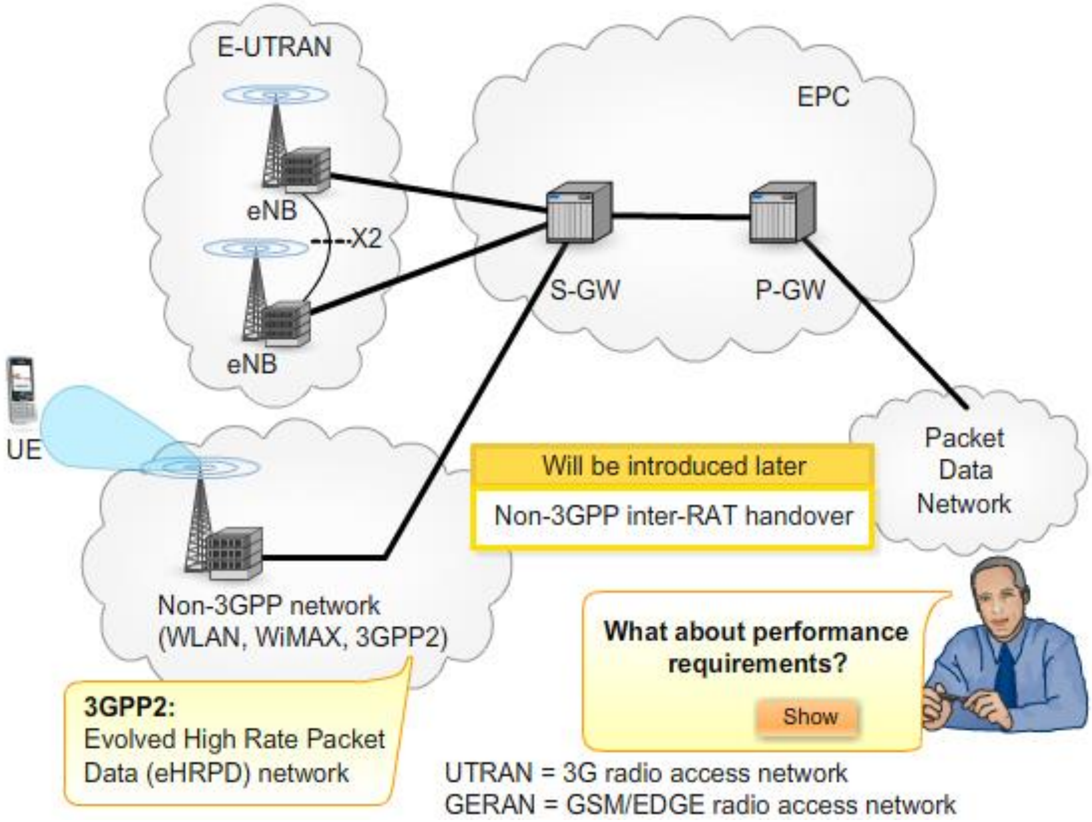
Intra-LTE inter-eNodeB handovers take place between different eNodeBs, for instance by utilising the X2 interface as shown in this course.

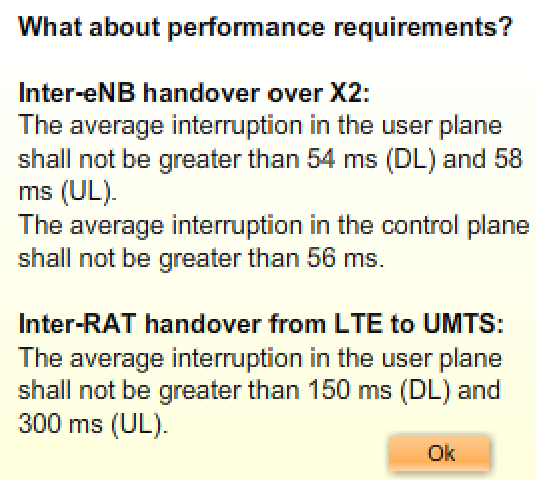
LTE TDD FDD Handovers take place between different operating modes in LTE networks, for instance from TDD LTE network to FDD network or vice-versa.

3GPP inter radio access technology (inter-RAT) handovers take place between the Evolved UTRAN and a non-LTE 3GPP access network (for instance UTRAN or GERAN). This course shows an E-UTRAN to UTRAN handover.

A non-3GPP inter-RAT handover takes place between the Evolved UTRAN and a non-3GPP access network, for instance WLAN, WiMAX or 3GPP2 access network. This course shows a handover from an LTE network to a 3GPP2 evolved High Rate Packet Data (eHRPD) network.

Finally, our tutor would like to introduce some performance requirements related to handovers.





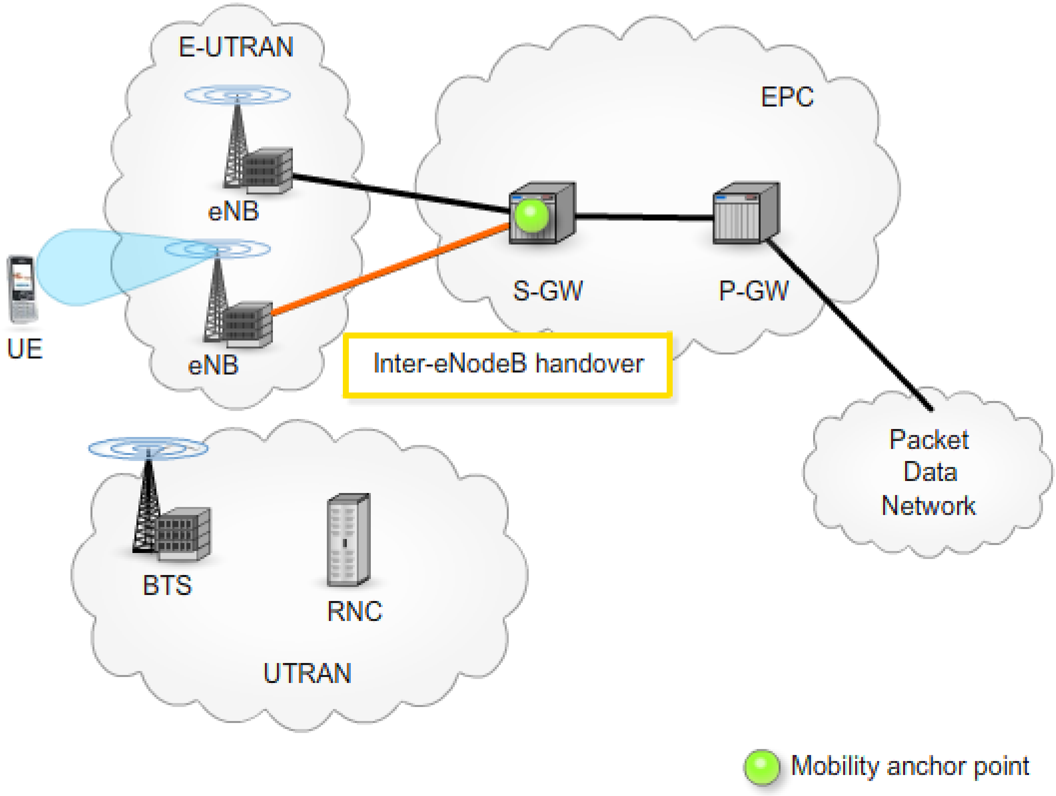
4.2 Mobility Anchor Point

During mobility, the user plane data path continuity to the packet data network is maintained using a concept called mobility anchoring.

The path from the UE to the mobility anchor point may change during the handover. However, the path from the anchor point to the peer entity in the packet data network does not change.

During an intra-eNodeB handover, the eNodeB serves as the anchor point.

During an inter-eNodeB handover, the anchor point is located in the Serving Gateway.



4.3 Intra-eNodeB Handover

Intra-eNodeB handovers take place between different cells within the same eNodeB. The handover procedure is shown in the figure.

Since the UE is in the ECM-CONNECTED state, user data can be sent both in uplink and downlink before the handover.

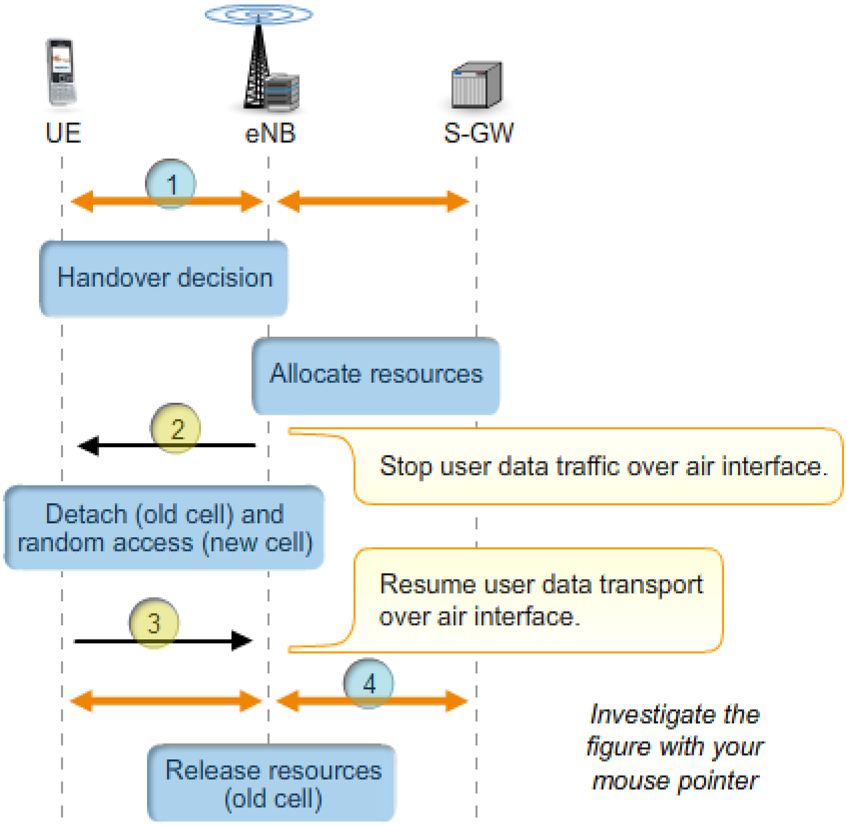
The handover decision in the eNodeB is based on a measurement report sent by the UE as well as radio resource management (RRM) information.

In the case of a handover decision, the eNodeB allocates the resources for the target cell. From this point on, downlink user data is buffered in the eNodeB and uplink user data in the UE until the handover has been completed.

The UE detaches from the source cell and synchronises with the target cell using the non-contention based random access procedure.

After successful handover, the user data transport over the air interface can be resumed.

You can see more details by moving your mouse pointer over the items in the procedure sequence chart.



1. The UE is in the ECM-CONNECTED state so that user data can be sent both in uplink and downlink.
• The eNB makes the decision to handover the UE to another cell within the same eNB based on measurement and RRM information.
• The radio bearers in the target cell are configured. The UE is allocated a new C-RNTI for identification in the new (target) cell. From this point on, downlink user data is buffered in the eNB and uplink user data in the UE until the handover has been completed.

2. The eNB sends an RRC Handover Command message towards the UE with the necessary information (e.g. new C-RNTI) to allow the UE to connect to the target cell.
• The UE immediately detaches from the source cell and synchronises with the target cell using the non-contention based random access procedure.

3. After successful handover, the UE sends the RRC Handover Confirm message to the eNB.

4. The eNB can begin sending downlink user data towards the UE, and the UE can begin sending uplink user data to the eNB.

5. The eNB releases the UE's resources in the source cell.

4.4 Intra-LTE Inter-eNodeB Handover 1/3

Let us next see how an inter-eNodeB handover is performed. The animation is in three steps.

It is assumed that the X2 interface exists between the source and target eNodeB. If this interface does not exist, the handover must be performed over the S1 interface instead, which means more complex signalling.

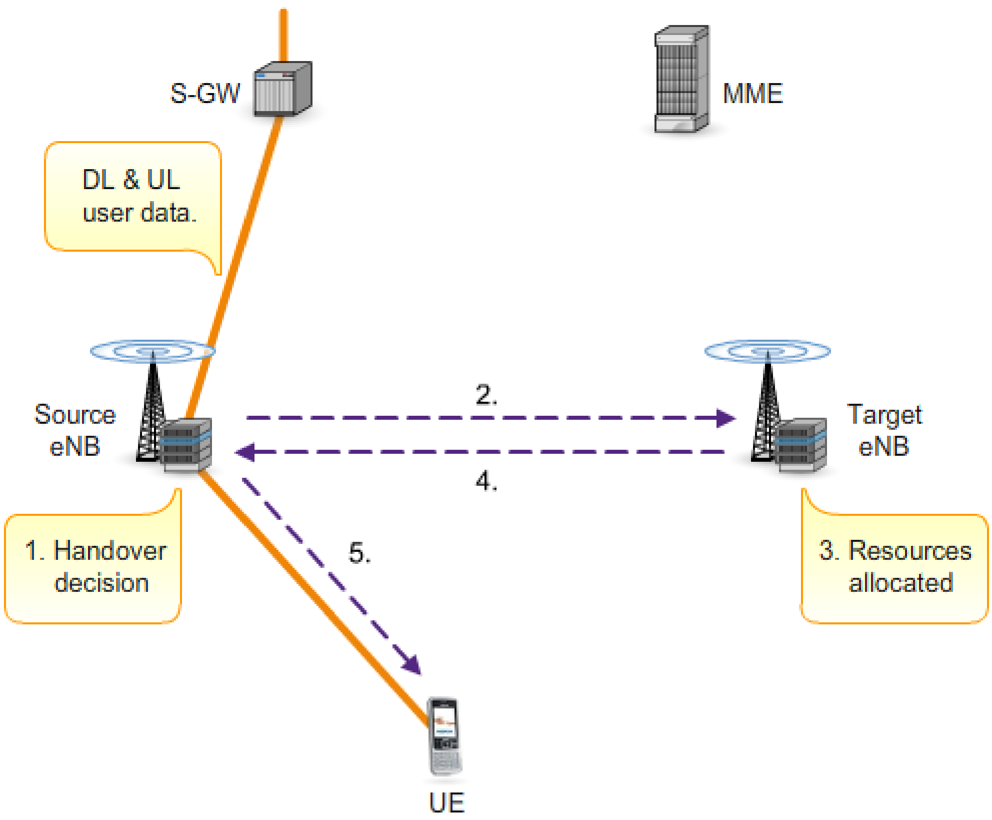
To begin with, the downlink and uplink user data is carried via the source eNodeB.

Based on UE measurement and RRM information, the source eNodeB decides that a handover to the target eNodeB is necessary.

The source eNodeB sends a Handover Request message over the X2 interface to the target eNodeB. The message contains necessary information to prepare the handover at the target side.

The target eNodeB allocates resources for the target cell. The UE is allocated a new C-RNTI for identification in the target cell.

The target eNodeB sends a Handover Request Acknowledge message to the source eNodeB, which in turn sends an RRC Handover Command message over the air interface to the UE, including necessary information (such as the new C-RNTI) so that the UE can perform the handover.



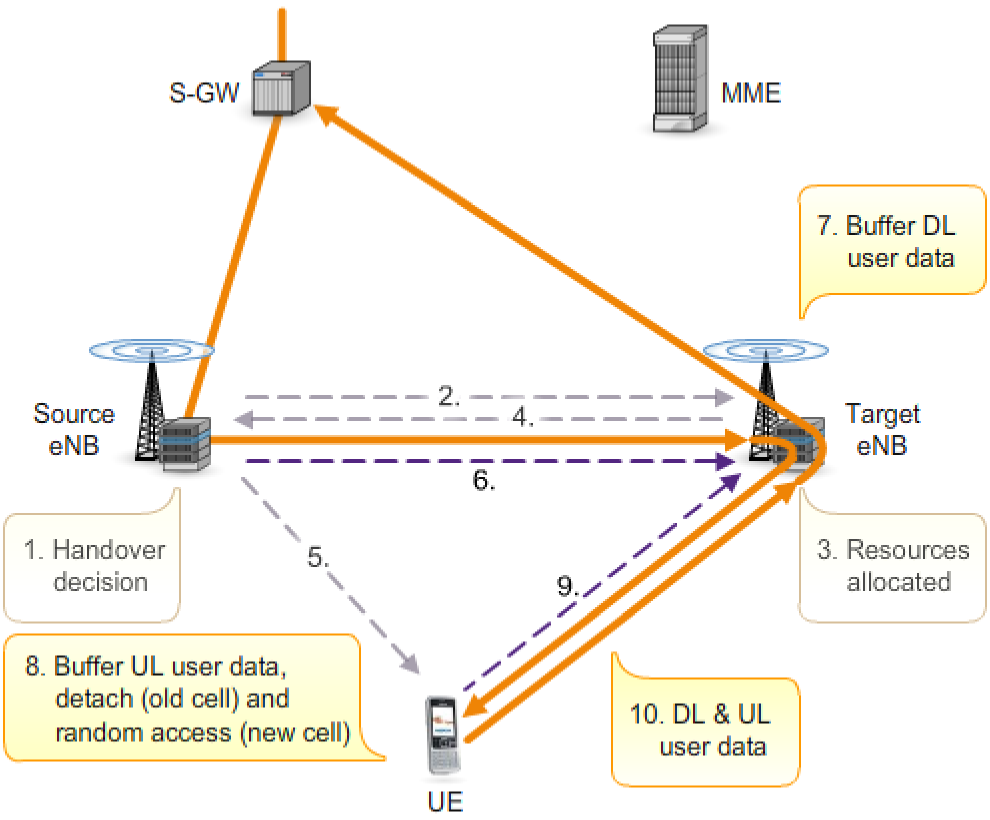
4.5 Intra-LTE Inter-eNodeB Handover 2/3

The source eNodeB sends Packet Data Convergence Protocol (PDCP) sequence number (SN) information to the target eNodeB in an SN Status Transfer message. This information is necessary to avoid missing or duplicating PDCP packets when the uplink and downlink user data paths are switched from the source eNodeB to the target eNodeB. Also, the source eNodeB now forwards the received downlink user data packets to the target eNodeB instead of sending them to the UE. The downlink user data packets are buffered in the target eNodeB until the handover is completed.

As soon as the Handover Command message is received (step 5), the UE buffers the uplink user data until the handover has been completed, detaches from the source cell, and synchronises with the target cell using the non-contention based random access procedure.

Next, the UE sends a Handover Confirm message to the target eNodeB to indicate that the handover procedure is completed as far as the UE is concerned.

Now the UE can start sending the buffered uplink user data and the target eNodeB can forward the downlink user data to the UE. The uplink user data is sent via the target eNodeB directly to the Serving Gateway. This is possible, since the uplink tunnel endpoint identifier (TEID) in the S-GW was conveyed to the target eNodeB already in step 2.



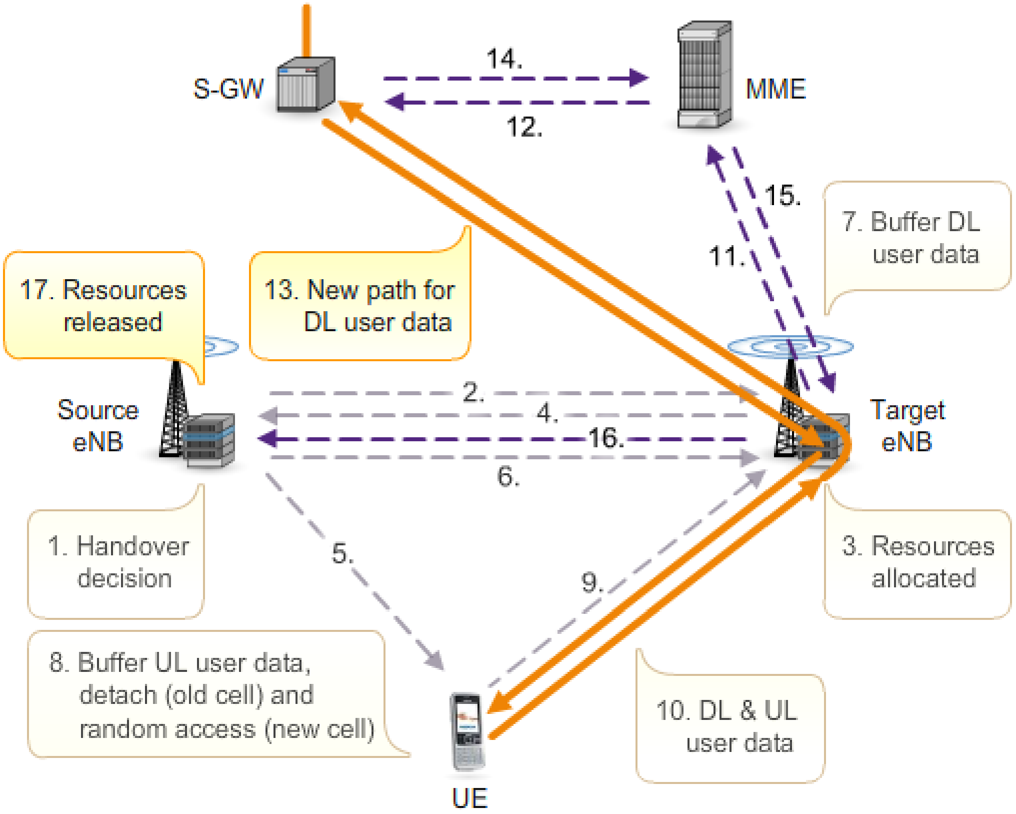
4.6 Intra-LTE Inter-eNodeB Handover 3/3

Next, the target eNodeB sends its downlink tunnel endpoint identifier (TEID) to the MME, which forwards it to the Serving Gateway.

Now the S-GW can send the downlink user data directly to the target eNodeB.

Before the S-GW can release any user plane resources towards the source eNodeB, it sends one or more ”end marker” packets to the source eNodeB as an indication that the downlink data path has been switched. It should be noted that these packets do not contain any user data, and are transparently forwarded by the source eNodeB to the target eNodeB to help it decide when the last forwarded packet was received.

After receiving an acknowledgement message the target eNodeB informs the source eNodeB about the success of the handover. As a final step, the source eNodeB releases all air interface and control plane resources associated with the UE context. Now the handover is completed.



4.7 Mobility Robustness

In LTE release RL30, the feature Mobility Robustness is a self-organizing network (SON) feature. It aims to improve the system performance by optimizing the radio network handover configuration for intra-LTE handovers. This is to reduce too early or too late handovers.

Reducing such events reduces the number of dropped calls due to radio link failures, as well as reducing signaling.

The feature optimizes the handover-related thresholds such as:

- handover offsets, and
- time-to-trigger

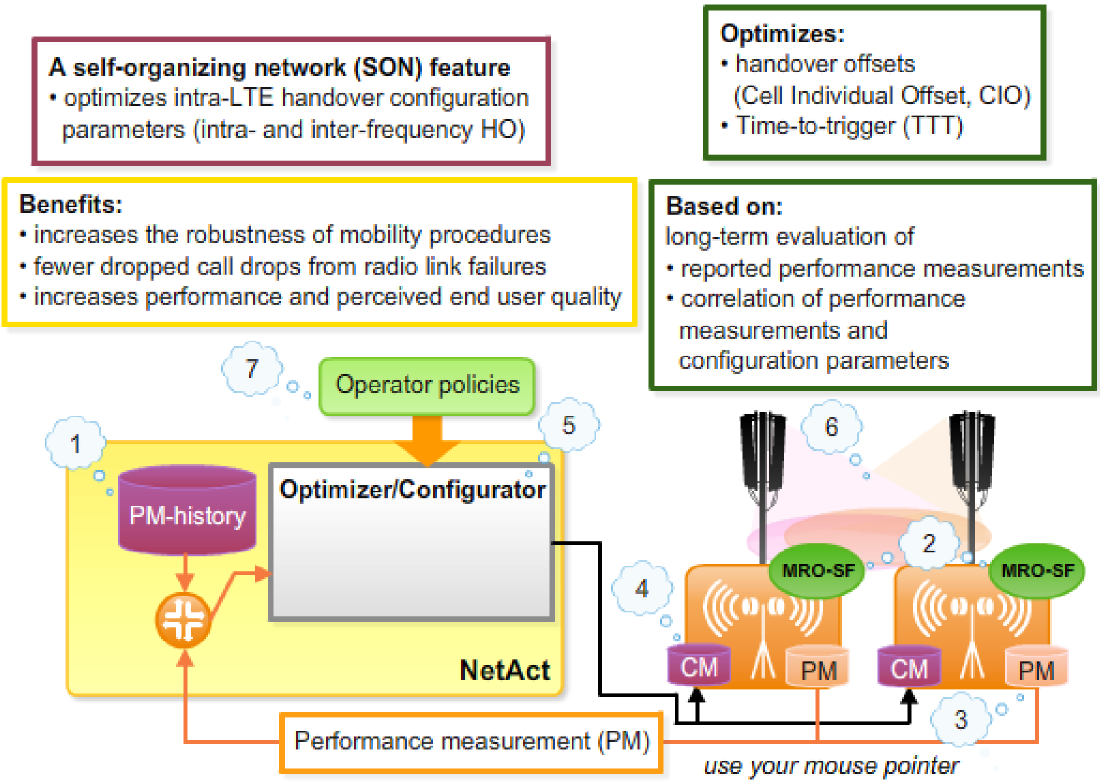
These are based on the long-term evaluation of

- reported performance measurements, and
- correlation of those measurements and configuration parameters

In addition to optimizing mobility-related parameters, the feature indicates unresolvable incidents in the centralized SON framework and triggers further actions to solve the problem or to notify the operator.

The key part of the feature is NetAct, which collects measurements from Flexi BTSs and analyzes them by several algorithms and then suggests new handover parameters. Earlier, the handover parameters were fine-tuned manually by analyzing key performance indicators and drive-tests.

This feature has to be considered as a first step of a fully implemented Mobility Robustness. It does not yet cover all the 3GPP-defined use cases.



1. It is essential to have enough feedback from performance measurements history. Therefore, the MRO-algorithm will not operate if there is not enough performance information available.

2. MRO-SF = Mobility Robustness Optimization Support Function

3. PM = performance measurements database

4. CM = configuration management database

5. The basis for evaluating sub-optimal HO performance will be the KPIs, either existing or new ones, collected by the Flexi Multiradio BTS and reported to NetAct. NetAct will elaborate the reported KPIs, also comparing and correlating reports from different BTSs, via appropriate algorithms and, possibly, propose new settings for parameters at a specific Flexi Multiradio BTS.

The feature is of semi-static nature: It applies a limited sequence of adjustment steps on the time scale of days-to-weeks. Consequently, it does not react to short-term or suddenly-occurring HO problems.

The algorithm follows an iterative approach, meaning that once new values for CIO and/or TTT have been applied, the network is monitored again, and another iteration is applied if necessary.

6. The biggest gains of MRO are expected in the case of scenarios with specific local propagation effects, e.g. urban infrastructure deployments and specific arrangements of UE movements and cell coverage such as

highway movement on cell edge.

7. The operator is able to specify a set of policies (thresholds). If a threshold is exceeded, the system will start the optimization process. (s*ee optimizer/configurator*)

When the MRO proposes optimized parameter values, the operator can manually confirm the new values or let the system automatically configure the new values.

4.8 Support of High-Speed Users

From LTE release RL40 onwards the Flexi Multiradio BTS is able to handle UE speeds of up to 350 km/h in open space and up to 300 km/h in tunnels.

This facilitates LTE deployment along motorways and railway tracks.

From a technical viewpoint, the Flexi Multiradio BTS supports “high speed mode”, which means it supports a restricted set of cyclic shifts used in the generation of Random Access Channel (RACH) preambles. Thus, it is recommended to apply dedicated mobility settings in cells handling high speed UEs, such as cells near motorways or railways.

High speed mode is operator configurable on a per-cell basis.

Note that this feature cannot be enabled together with the RL40 feature “IRC for 2 RX Paths”.

4.9 SPID selective mobility profiles

SPID or Subscriber Profile ID is a profile for subscriber that is uniquely identifiable and it is usually associated with an MSISDN.

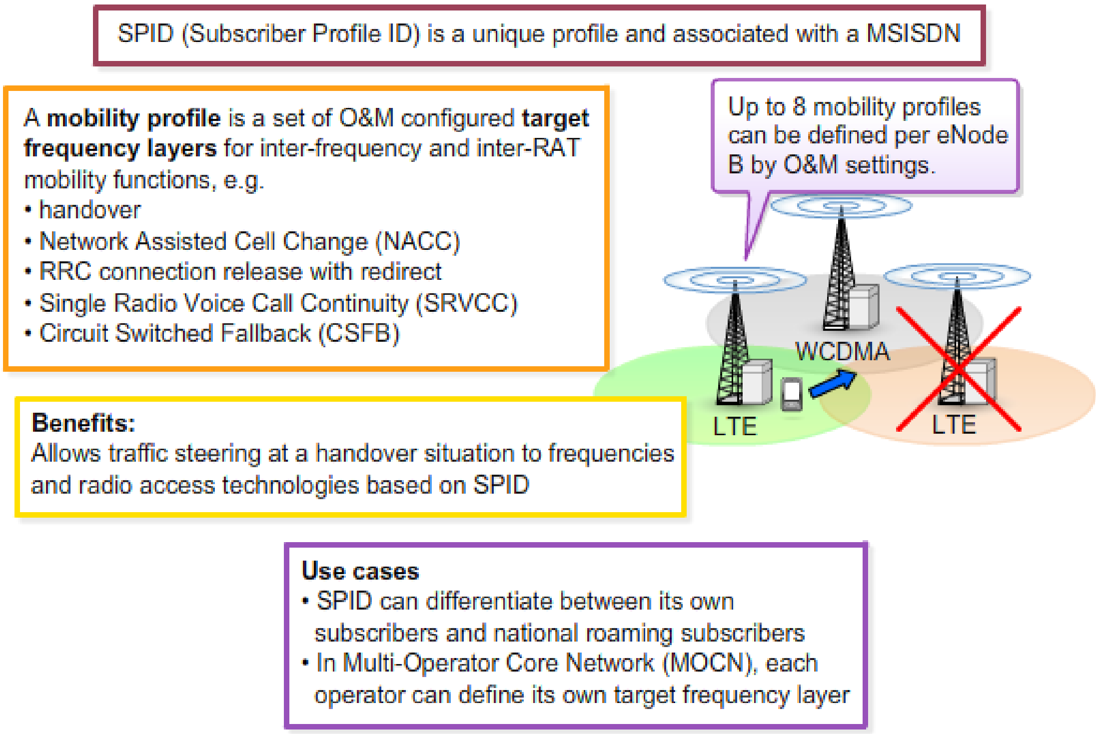
The feature SPID Selective Mobility Profiles then allows the operator to link these subscriber profiles to mobility profiles of the eNode B. A mobility profile is a set of target frequency layers for handovers.

Simply put, the operator knows the probable direction or pattern that the subscriber is traveling and can then optimize the selected frequency layer or radio access technology at a handover situation.

To be more precise, at a handover situation, the eNode B will only use the neighbor cells that are listed in the mobility profile which is linked to the SPID.

A typical use case is national roaming, where the SPID provided by the MME is used to identify one's own subscribers and national roaming subscribers. Another use case would be a Multi-Operator Core Network where each operator can define its own target frequency layer.

A default mobility profile is used when no SPID is received or the SPID is unknown.



4.10 Intra-LTE Handover via S1 Interface

LTE release RL20 introduces the possibility of performing inter-eNodeB handovers via the S1 interface instead of via the X2 interface as previously supported.

In LTE release RL20, the Flexi Multiradio BTS supports the following S1-based intra-LTE handover scenarios:

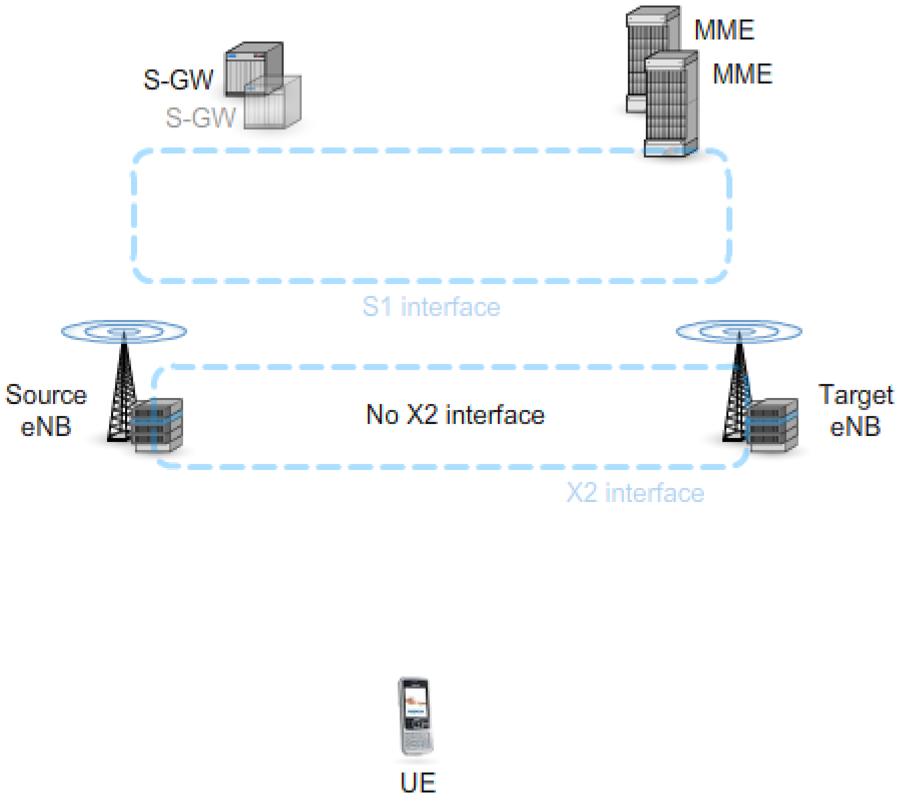
- Inter-eNodeB, intra-MME and intra-S-GW
- Inter-eNodeB, inter-MME and intra-S-GW
- Inter-eNodeB, inter-MME and inter-S-GW.

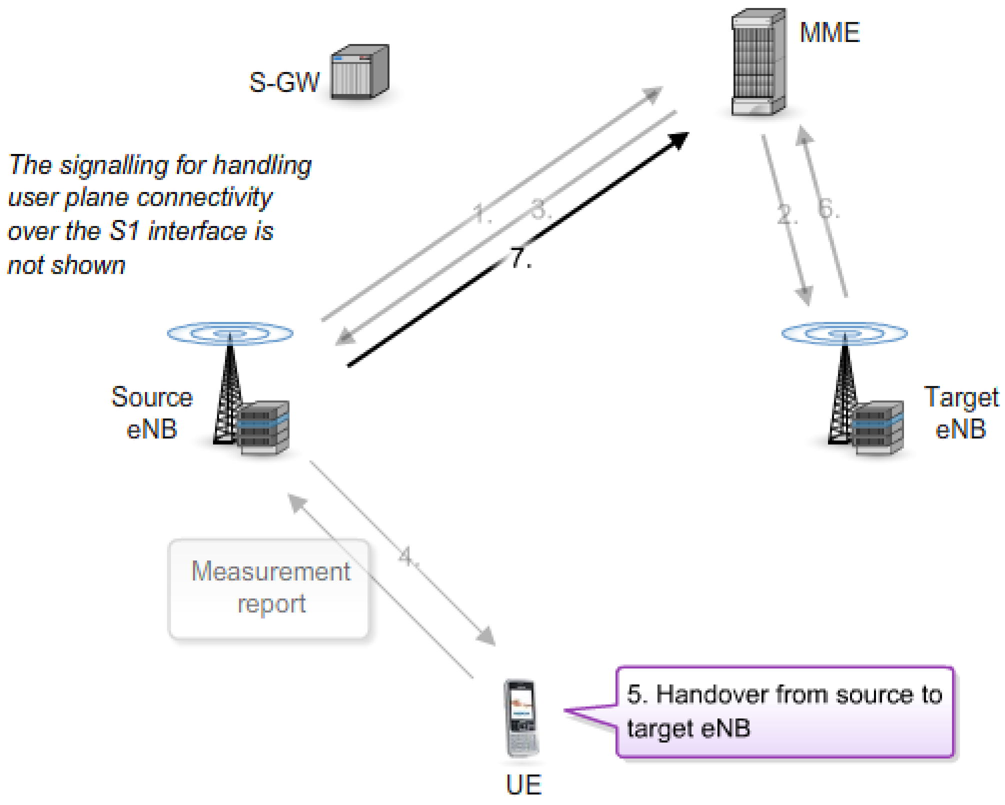
The handover is triggered either via LTE intra-frequency measurements or via LTE inter-frequency measurements if this feature is enabled.

The source eNodeB initiates the handover after receiving a measurement report form the UE by sending a Handover Required message to the MME. The MME prepares the resources at the target eNodeB by sending a Handover Request message.

The handover execution is initiated by the MME with the Handover Command message to the source eNodeB. The source eNodeB then sends an RRC Connection Reconfiguration message to the UE. This message forces the UE to the new cell. In the case of a successful handover the target eNodeB sends a Handover Notify message to the MME.

Finally, the resources in the source eNodeB are released after reception of the UE Context Release message from the MME.





4.11 Inter-Frequency Handover

Inter-frequency handovers are also supported in LTE release RL20.

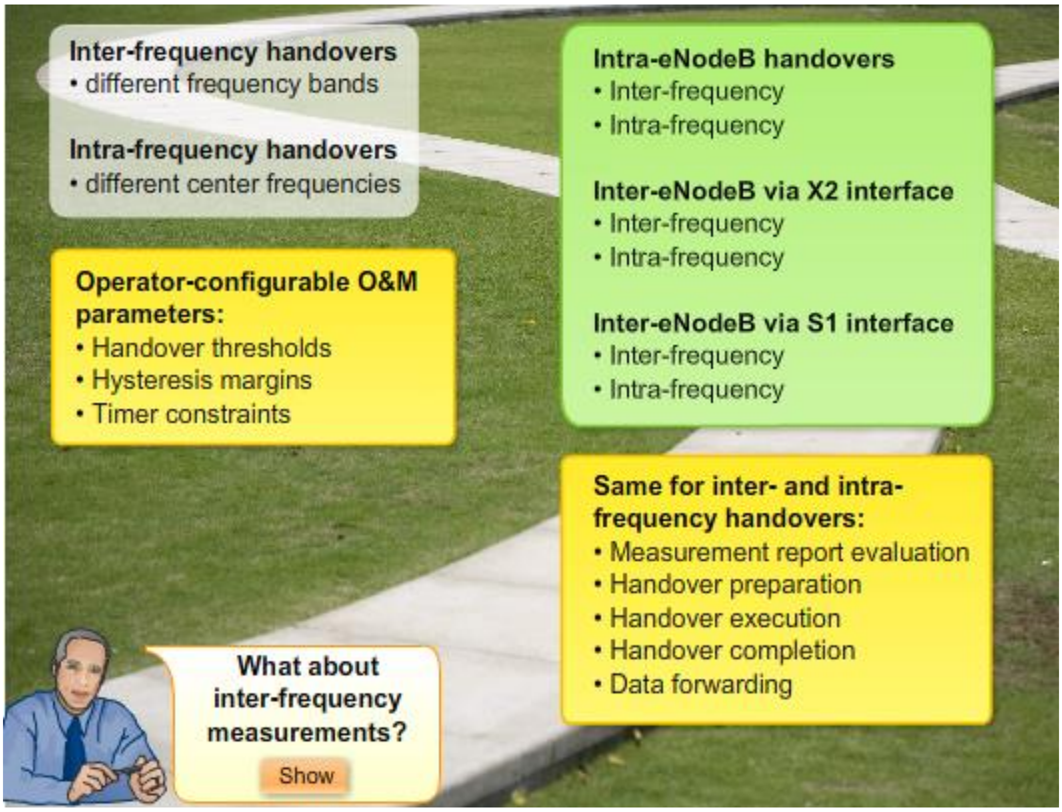
Inter-frequency handovers allow service continuity for LTE deployments in different frequency bands as well as for LTE deployments within a single frequency band but with different center frequencies.

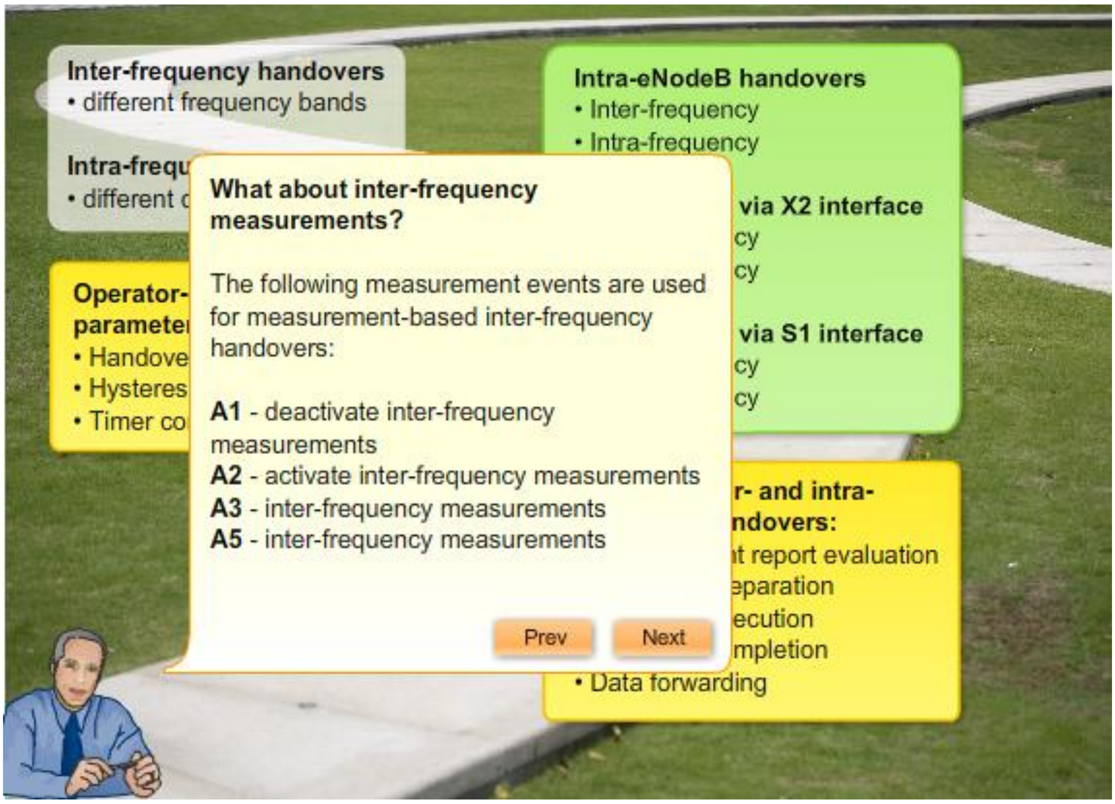
The following inter-frequency handover scenarios are supported by the Flexi Multiradio BTS:

- Intra-eNodeB handovers
- Inter-eNodeB handovers via X2 interface
- Inter-eNodeB handovers via S1 interface.

The evaluation of measurement reports, the handover preparation, execution and completion, and the data forwarding are all identical to the corresponding intra-frequency handover functionality.

The handover thresholds, hysteresis margins and timer constraints as related to inter-frequency handovers are O&M parameters that can be configured by the operator.


Inter-frequency handovers
• different frequency bands
Intra-frequency handovers
• different center frequencies
Operator-configurable O&M parameters:
• Handover thresholds
• Hysteresis margins
• Timer constraints
Intra-eNodeB handovers
• Inter-frequency
• Intra-frequency
Inter-eNodeB via X2 interface
• Inter-frequency
• Intra-frequency
Inter-eNodeB via S1 interface
• Inter-frequency
• Intra-frequency
Same for inter- and intra-frequency handovers:
• Measurement report evaluation
• Handover preparation
• Handover execution
• Handover completion
• Data forwarding
What about inter-frequency measurements?
Show


What about inter-frequency measurements?
The following measurement events are used for measurement-based inter-frequency handovers:
A1 - deactivate inter-frequency measurements
A2 - activate inter-frequency measurements
A3 - inter-frequency measurements
A5 - inter-frequency measurements
Prev
Next

4.12 RRC Connection Release with Redirect

Starting from LTE release RL10, mobile terminals can be redirected to other frequency layers in the case of poor radio conditions.

In previous releases, The Flexi Multiradio BTS triggers the process ”RRC connection release with redirect” based on downlink reference signal received power (RSRP) measurements in the source cell only.

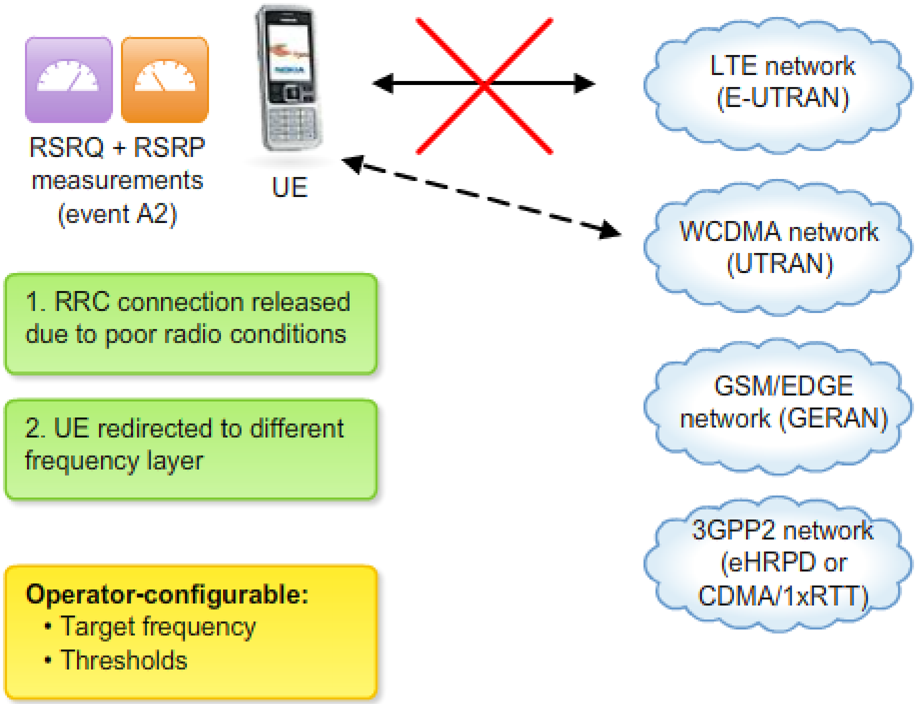
Consequently, In LTE release 50, Reference Signal Received Quality (RSRQ) is used in addition to reference signal received power (RSRP) to trigger ”RRC connection release with redirect”.

The use of both RSRP and RSRQ measurements allows more efficient severe inter-cell interference scenarios handling.

The target frequency and various thresholds for this event are operator-configurable. The target radio network can be Evolved UTRAN, UTRAN, GERAN, eHRPD or CDMA/1xRTT.

The UE capabilities are considered when choosing the redirect target.

The redirect functionality can be enabled or disabled by means of O&M.



4.13 3GPP Inter-RAT Handover 1/2

The following example illustrates a 3GPP inter radio access technology (inter-RAT) handover. The animation in two parts outlines the basic operation during an LTE to 3G (that is, E-UTRAN to UTRAN) handover.

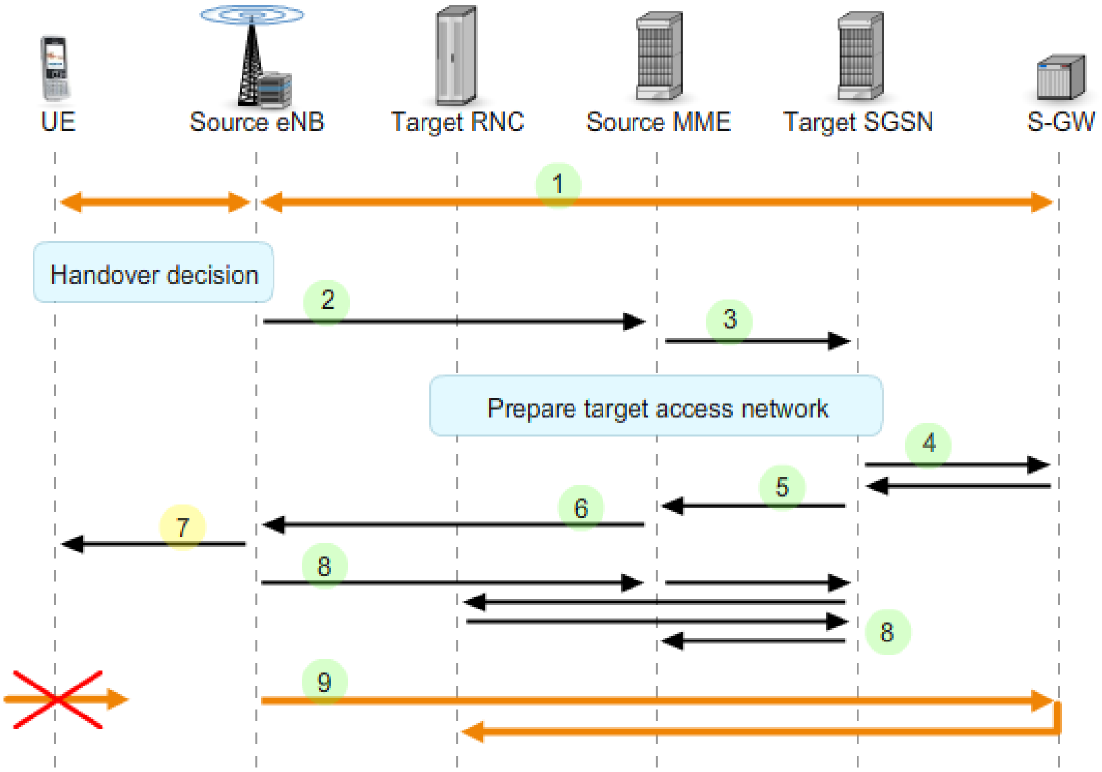
To begin with, the downlink and uplink user data is carried via the source eNodeB.

Based on UE measurement and RRM information, the source eNodeB decides that a handover to the target access network is necessary and sends to the MME a message containing necessary information to prepare the handover at the target side. The MME sends the information to the SGSN which in turn prepares the target access network for the handover.

Next, the SGSN provides relevant information to the Serving Gateway, so that it can forward downlink user data to the target RNC. Also, the SGSN sends necessary information to the UE so that the UE can perform the handover.

The eNodeB at this point sends so-called "Serving Radio Network Subsystem (SRNS) Context" information to be stored in the target SGSN and RNC.

The downlink user data received at the eNodeB is forwarded via the Serving Gateway to the target RNC. Obviously, since the UE is performing a handover it will not send any uplink user data at this
point.



4.14 3GPP Inter-RAT Handover 2/2

The UE detaches from the source cell and synchronises with the target cell using the WCDMA-based random access procedure.

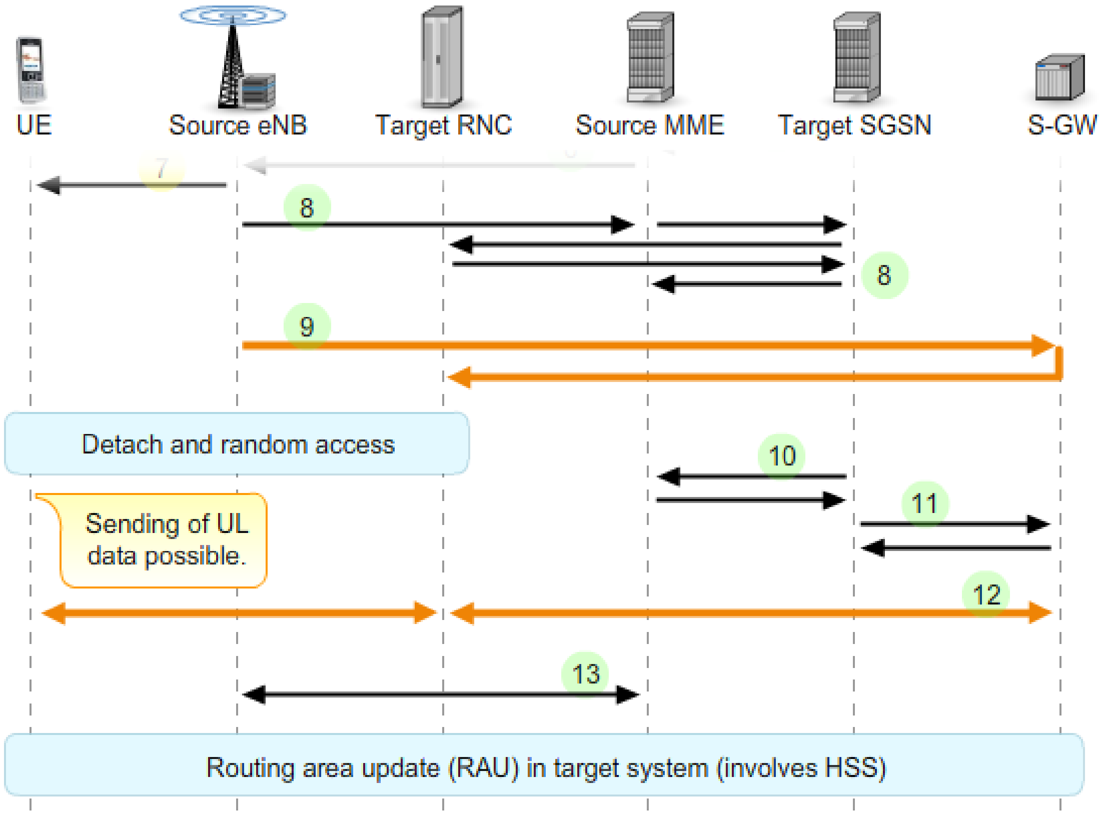
Now the UE can send uplink user data via the target RNC to the Serving Gateway.

At this stage the target SGSN informs the source MME that the UE has successfully moved to the target access network.

The target SGSN completes the handover procedure by informing the Serving Gateway that the downlink user data can be sent directly to the target RNC instead of being sent back and forth via the source eNodeB. Now, both the downlink and uplink user data is carried via the target RNC.

Finally, the MME releases the resources in the source access network.

Note that also the Home Subscriber Server (HSS) must be informed about the handover. This means that a routing area update must be performed after the handover.



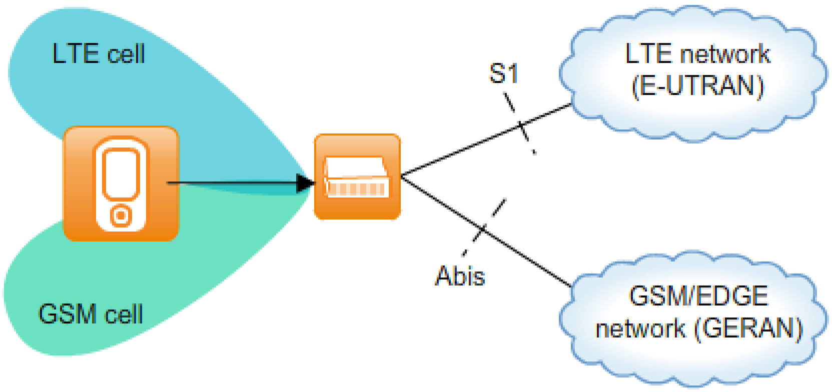
4.15 Networked Assisted Cell Change to GSM

The LTE-to-GSM Network Assisted Cell Change (NACC) functionality of the Flexi Multiradio BTS, supported in LTE release RL30, provides improved service continuity for data services when changing from an LTE cell to a GSM cell.

Network Assisted Cell Change is only applicable for mobile devices that support both LTE and GSM in their respective frequency bands. The UE capabilities are signalled to the eNodeB using the feature group indicator.

Let our tutor explain the NACC operation in more detail.

Benefits:
Short service interruption time for data services when changing from LTE to GSM.



Some words about NACC operation...

NACC is based on the following inter radio access technology (IRAT) measurement events:

A1 - deactivate IRAT measurements
A2 - activate IRAT measurements
B2 - IRAT measurements

The measurement events **A2** and **A1** are used to start and stop IRAT measurements and can be configured by the operator.

The eNodeB will trigger IRAT measurements only for NACC-capable UEs. The UE capabilities (e.g., support of measurement gap and support of frequency bands) are also taken into account when setting up the IRAT measurement configuration.

The target cells for the IRAT measurements can be configured by the operator. Blacklisting of target cells is supported.

Measurement settings such as source cell thresholds (RSRP – Reference Signal Received Power), target cell thresholds (RSSI – Received Signal Strength Indicator), hysteresis, time-to-trigger and speed-dependent scaling can be configured by the operator.

4.16 GSM Redirect with System Information

Starting from LTE release RL40, the Flexi Multiradio BTS supports additional system information to be provided together with the “RRC Connection Release” message during redirection from LTE to GSM. This enhances the following procedures:

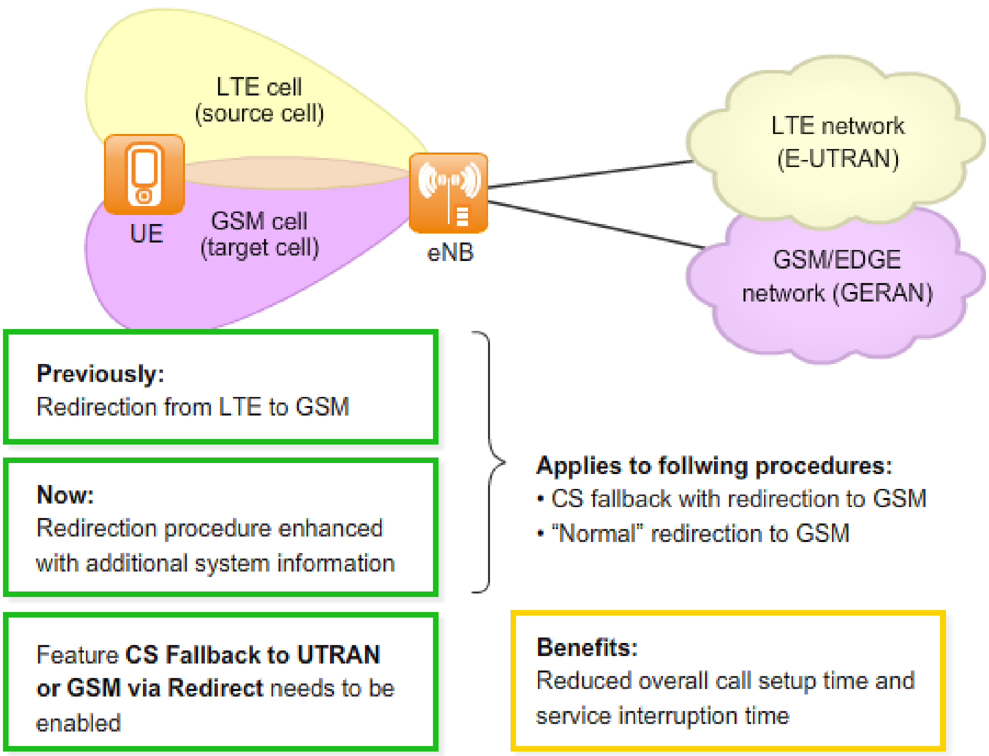
- CS fallback with redirection to GSM

- “Normal” redirection to GSM.

As a result, the call setup time and the service interruption time are reduced, when compared with redirection to GSM without this additional system information.

System information for up to 16 cells can be configured – and the functionality can be enabled or disabled – via O&M means.

This feature requires the RL20 feature “CS Fallback to UTRAN or GSM via Redirect” to be enabled.



4.17 LTE to CDMA2000 Handover

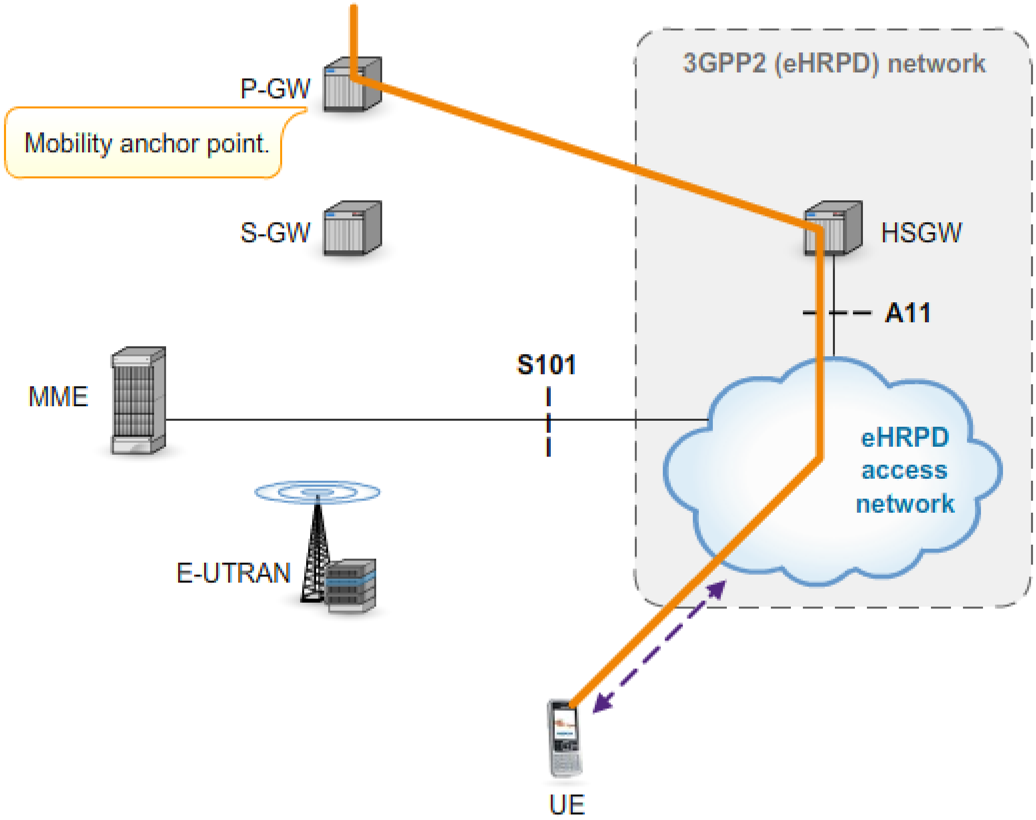
Seamless handover will be supported between LTE and CDMA2000 - to be more specific between an LTE network and a 3GPP2 evolved High Rate Packet Data (eHRPD) network - and general acceptance has been reached that a closely coupled architecture is needed to fulfill the stringent latency requirements.

In the case of an LTE to eHRPD handover, before the actual handover the UE performs pre-registration with the target eHRPD access network using the S101 interface between the MME and eHRPD access network. Pre-registration is performed in order to speed up the actual handover phase. A basic task of pre-registration is to set up a data forwarding path over the S103 interface between the LTE Serving Gateway and the HRPD Serving Gateway (HSGW).

Using this path, the downlink user data is forwarded to the eHRPD access network during the handover as shown in the figure.

After completing the handover - again signalled over the S101 interface - the user data is routed directly between the P-GW and the HSGW, and transport resources in the Evolved Packet Core are released.

Note that the PDN Gateway acts as the mobility anchor point during the handover.



4.18 LTE TDD – FDD Handover

A handover is supported between the FDD and the TDD eNodeBs. This feature allows the operator to offer service continuity to its subscriber during FDD/TDD transitions. Hence, LTE TDD/FDD handover enables complete global roaming.

The following FDD/TDD handover scenarios are supported by Flexi Multiradio BTS:

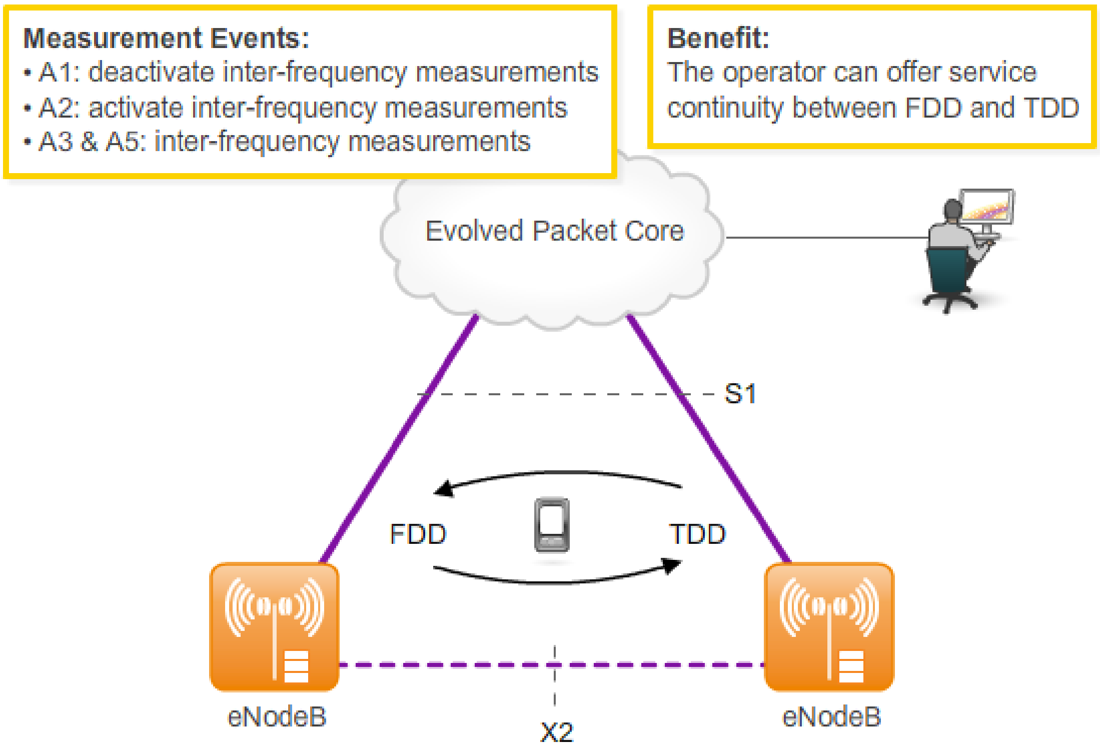
- Inter-eNodeB, inter-frequency band via an X2 interface.
- Inter-eNodeB, inter-frequency band via an S1 interface (if enabled).

The handover can be carried out in any direction, FDD to TDD or TDD to FDD. Both these handover directions are supported in release 50.

There are four measurement events used for inter-frequency handover: A1, A2, A3 and A5.

The O&M parameters related to inter-frequency handover such as handover threshold, hysteresis margins and timer constrains can be configured by the operator.

Finally, the operator can disable the functionality for each eNodeB by O&M settings.



4.19 Intra Cell Handover

The intra cell handover feature allows a handover to the serving cell. This feature is important because LTE does not support synchronized call processing procedures between the UE and the radio access network.

Therefore, intra cell handover is performed in LTE whenever reconfigurations must be applied synchronously on both the UE and network sides. For example, intra cell handover is applied to perform security key change or to activate/deactivate TTI bundling for the UE.

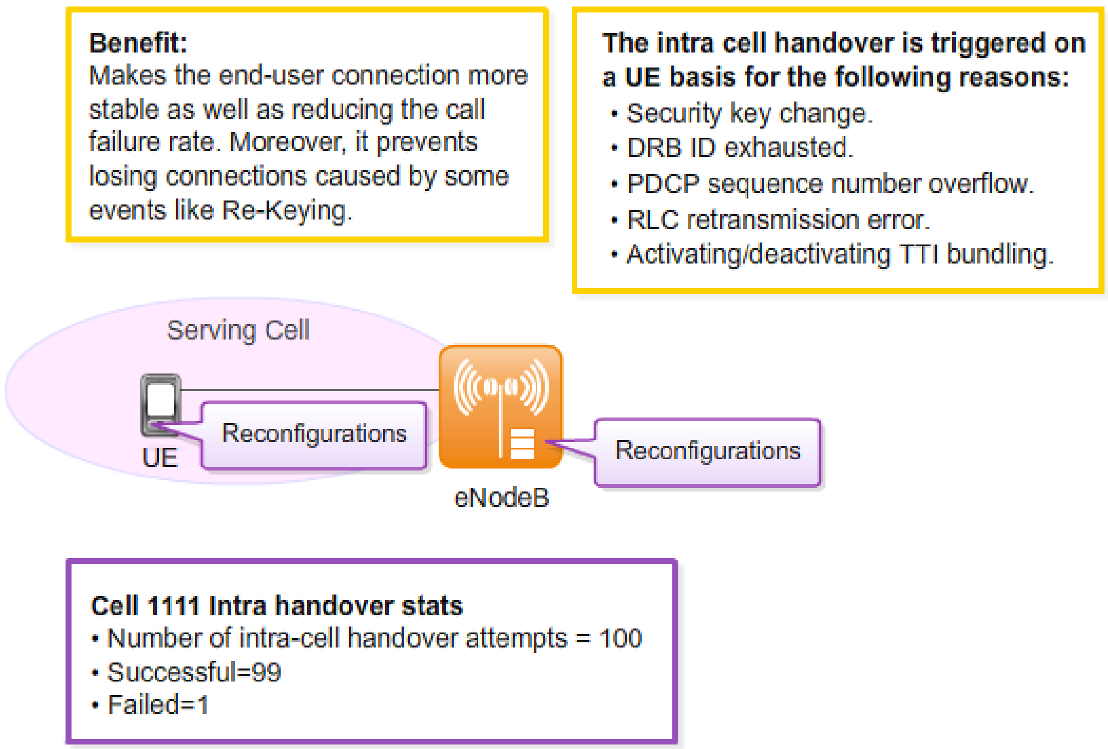
Typically, the intra cell handover is used for the following reasons:

- Security key change
- Data Radio Bearers Identification (DRB ID) exhausted
- Packet Data Convergence Protocol (PDCP) sequence number overflow
- Radio Link Control (RLC) retransmission error
- Activating or deactivating TTI bundling.

This feature makes the end-user connection more stable, as well as reducing the call failure rate. Moreover, it prevents losing connections caused by some events like Re-Keying.

Finally, for performance management monitoring purposes, the following counters are supported for each cell:

- The number of intra cell handover attempts.
- The number of successful intra cell handovers.
- The number of failed intra cell handovers.



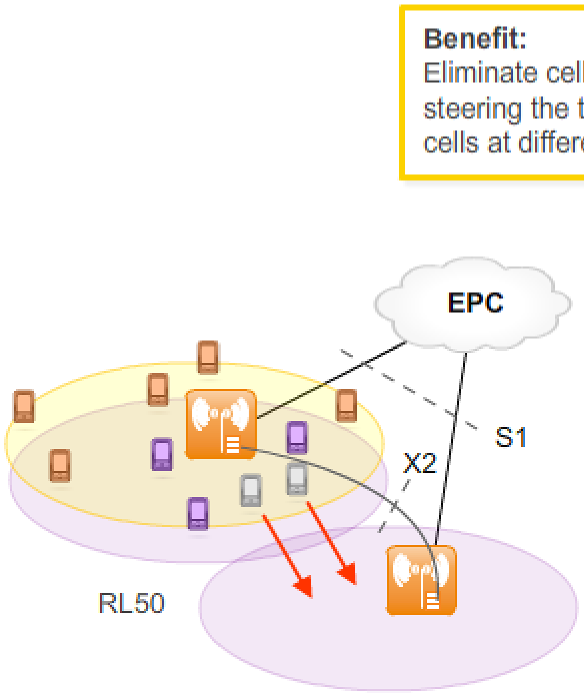
4.20 Inter-eNodeB Inter-Frequency Load Balancing 1

The “Inter-eNodeB Inter-Frequency load balancing” feature introduced in release 50 is an extension to the NSN LTE release 40 feature “Intra-eNodeB Inter-Frequency Load Balancing”.

The function of this feature is to eliminate cell overloading by distributing a percentage of the traffic into less loaded cells at different frequency layers. Hence, the frequency layers become load balanced.

The Inter-eNodeB Inter-Frequency Load Balancing feature makes the flexi multiradio BTS able to support a load-based inter-frequency handover between different eNodeBs by using the X2 interface or the S1 interface.

UEs entering connected state are the possible targets for Inter Frequency Load Balancing (IFLB). UEs that are already connected are NOT offloaded to neighboring cells via an IFLB handover.



4.21 Inter-eNodeB Inter-Frequency Load Balancing 2

The procedure of Inter-eNodeB Inter-Frequency Load Balancing is formed in four main stages:

Stage 1 is called "Load Supervision and Exchange":

- Once this feature is enabled, the eNodeB will continuously monitor Downlink Guaranteed Bit Rate, Downlink non-Guaranteed Bit Rate and PDCCH load for each of its own cells.

- Then, these load measurements are processed to calculate the relative load and the estimated available capacity. Depending on the filtered load measurements, eNodeB decides whether the cell enters or exits the active inter-frequency load balancing (iF-LB) state.

- If any cell in an eNodeB has a load greater than the High-Load threshold, then it enters into the Active iFLB state. On the other hand, if any cell in an eNodeB has a load less than the target-Load threshold, then it exits the Active iFLB state.

Stage 2 is called the "Candidate UE Selection for measurement solicitation":

- For each UE that enters the connected state, the iFLBBearCheckTimer is started.

- As soon as the iFLBBearCheckTimer expires, the eNodeB runs several checks to know whether the UE selection conditions are met.

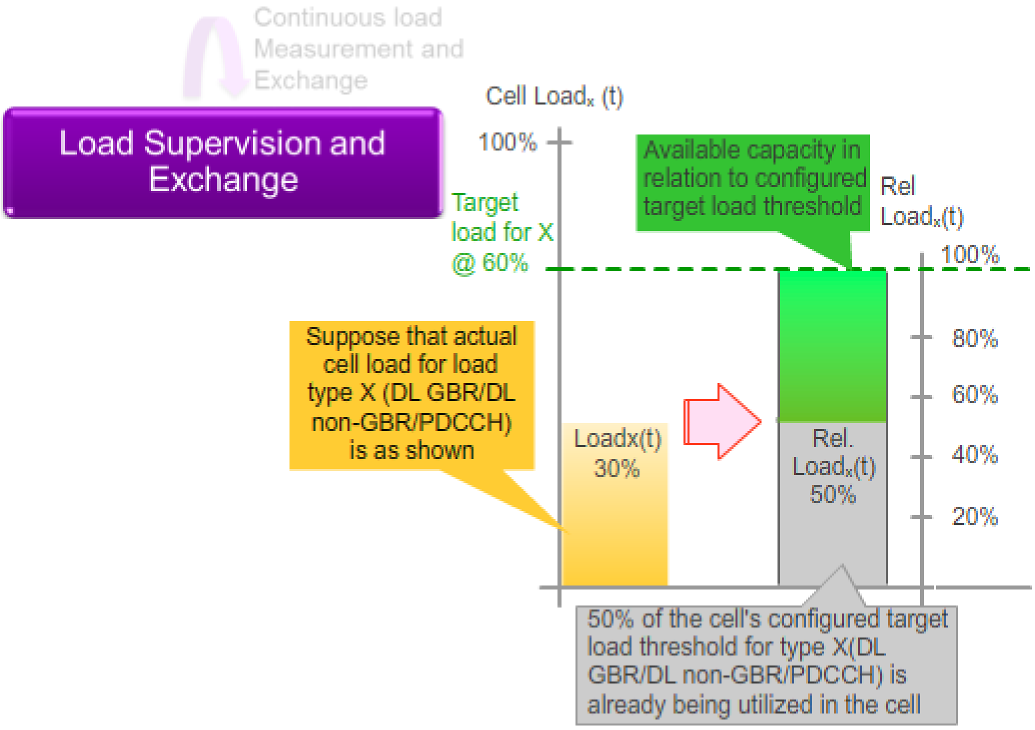
Stage 3 is called “Measurement Solicitation”:

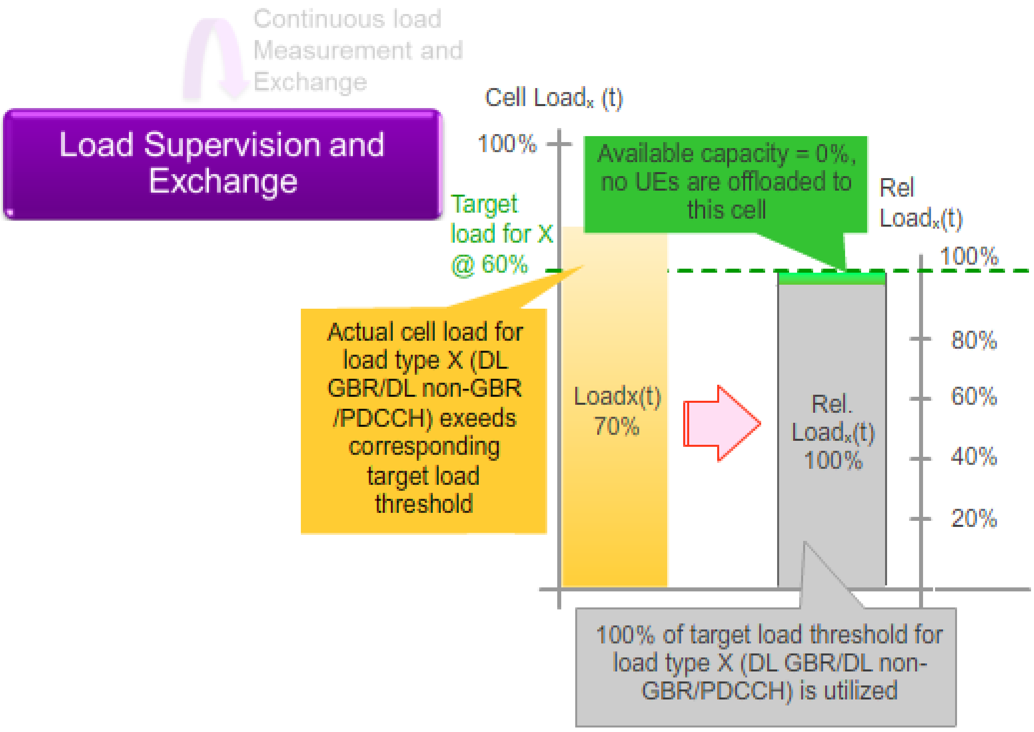
- If all conditions are met, the A4 configuration is activated. However, if all conditions are not met, the UE under consideration is removed from possible candidates for offloading.

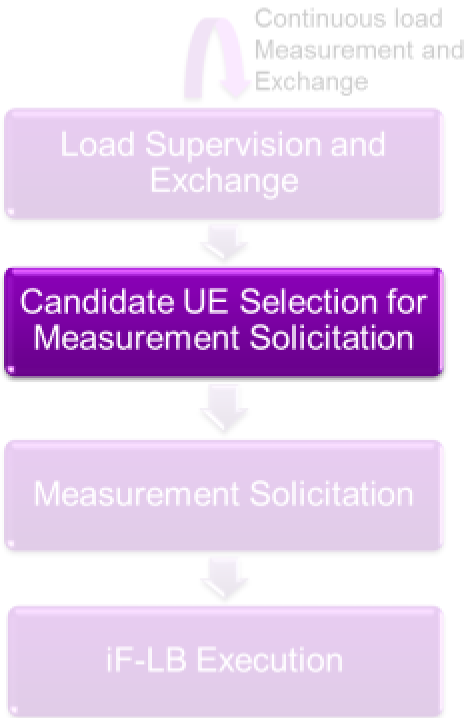
Stage 4 is called “iF-LB Execution”:

- Once the A4 reports are received, the target cell list (TCL) is processed to eliminate unsuitable cells. Cells with a low signal level, high load, blacklisted or belonging to another radio access technology are removed from the TCL.
- The TCL is organized so that the best cells are listed first. Meanwhile, cells with an unknown CAC (Composite Available Capacity) are appended to the end of the known CAC cells.
- Since the topmost cell in the sorted TCL is the best cell; it is always chosen as the target cell for handover.
- Then, a handover request is initiated by the source cell to cause “reduce load in serving cell”. Then, the admission control in the target cell will examine its capacity and will determine whether it should accept or reject the load based handover.
- Hence, the target cell can reply with a handover preparation failure due to no radio resource available or accept the HO request with partial admission of bearers due to load reasons.

Finally, the UE follows normal handover execution and completion procedures for Intra-eNodeB handover via X2 or S1.

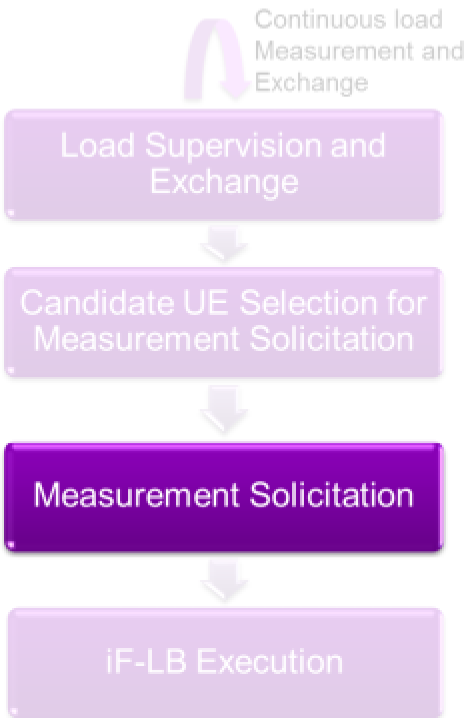

Continuous load Measurement and Exchange
Load Supervision and Exchange
Cell Load$_x$ (t)
100%
Target load for X @ 60%
Available capacity in relation to configured target load threshold
Rel Load$_x$(t)
100%
80%
60%
40%
20%
Suppose that actual cell load for load type X (DL GBR/DL non-GBR/PDCCH) is as shown
Loadx(t) 30%
Rel. Load$_x$(t) 50%
50% of the cell's configured target load threshold for type X(DL GBR/DL non-GBR/PDCCH) is already being utilized in the cell

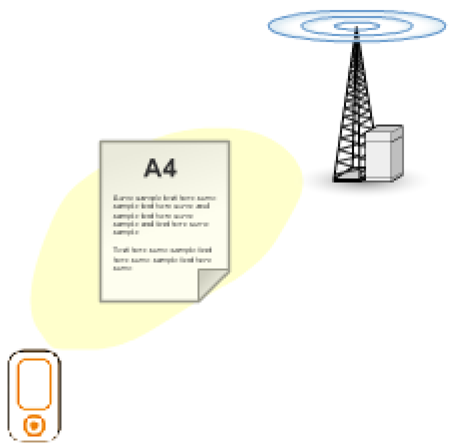

Continuous load Measurement and Exchange
Load Supervision and Exchange
Cell Load$_x$ (t)
100%
Target load for X @ 60%
Available capacity = 0%, no UEs are offloaded to this cell
Rel Load$_x$(t)
100%
80%
60%
40%
20%
Actual cell load for load type X (DL GBR/DL non-GBR /PDCCH) exeeds corresponding target load threshold
Loadx(t) 70%
Rel. Load$_x$(t) 100%
100% of target load threshold for load type X (DL GBR/DL non-GBR/PDCCH) is utilized

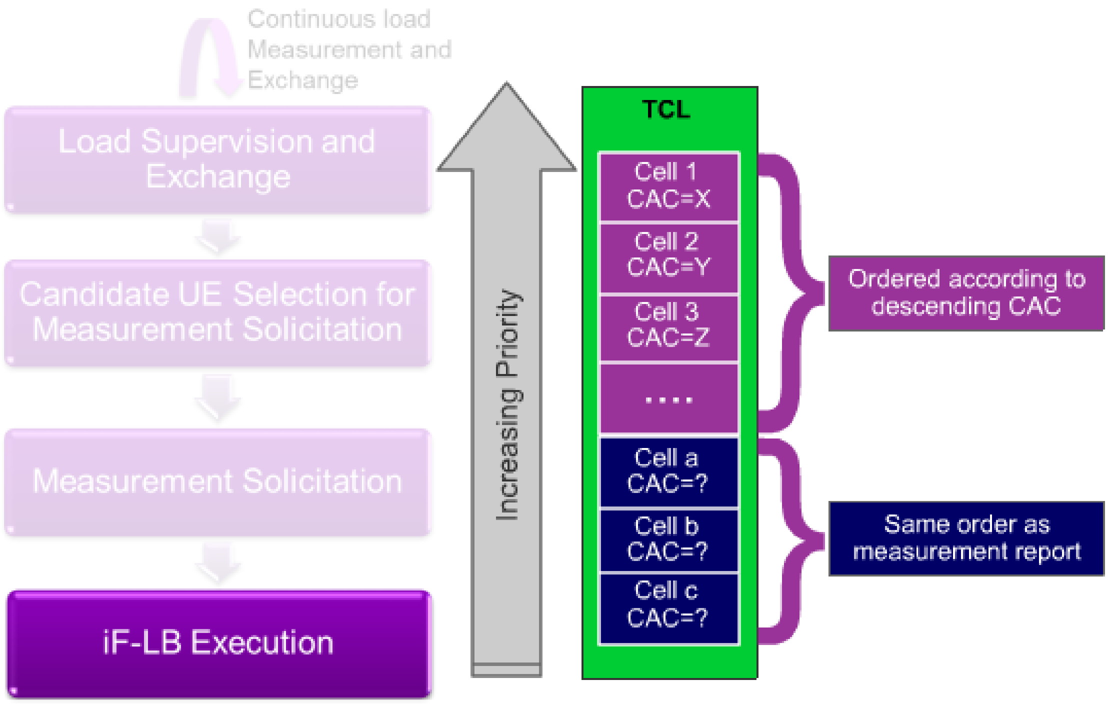


UE selection conditions are:

1. Serving cell is in Active iF-LB state
2. UE has no QCI1 bearer (optional)
3. Frequencies configured in LNHOIF are supported by the UE
4. A4 measurements and reporting supported by UE
5. No ongoing inter-frequency or inter-RAT measurements for the UE
6. If carrier aggregation is supported, UE has no SCC configured (FDD RL50 only as CA not supported in RL35TD)







4.22 Exercise

In this exercise, the idea is to associate various statements with the correct type of handover. Please go ahead.

	Intra-eNB handover	Inter-eNB handover	Inter-RAT handover
X2 interface is relevant here	☐	☐	☐
Random access procedure is involved	☐	☐	☐
Non-LTE access technology is involved	☐	☐	☐
Mobility anchor point is in S-GW	☐	☐	☐
Mobility anchor point is in eNB	☐	☐	☐

5 End-to-End Example

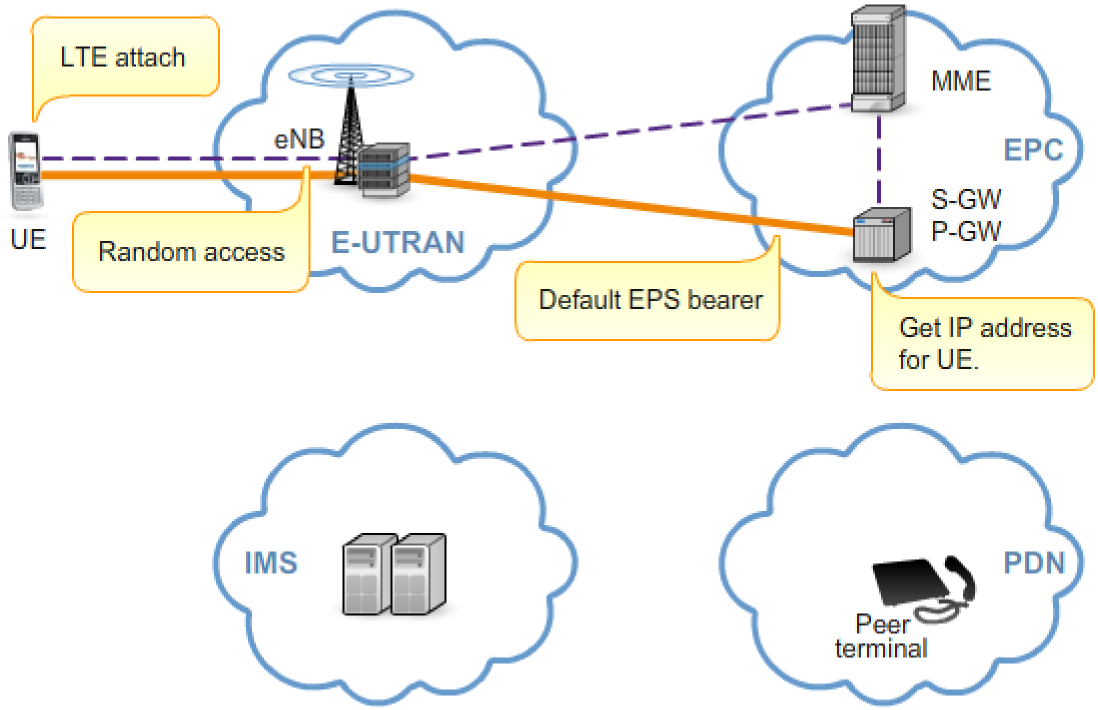
Now let us summarise the procedures taking place when a user switches on his/her mobile terminal, connects to the LTE network, and starts using Voice over IP (VoIP) for communicating with another user.

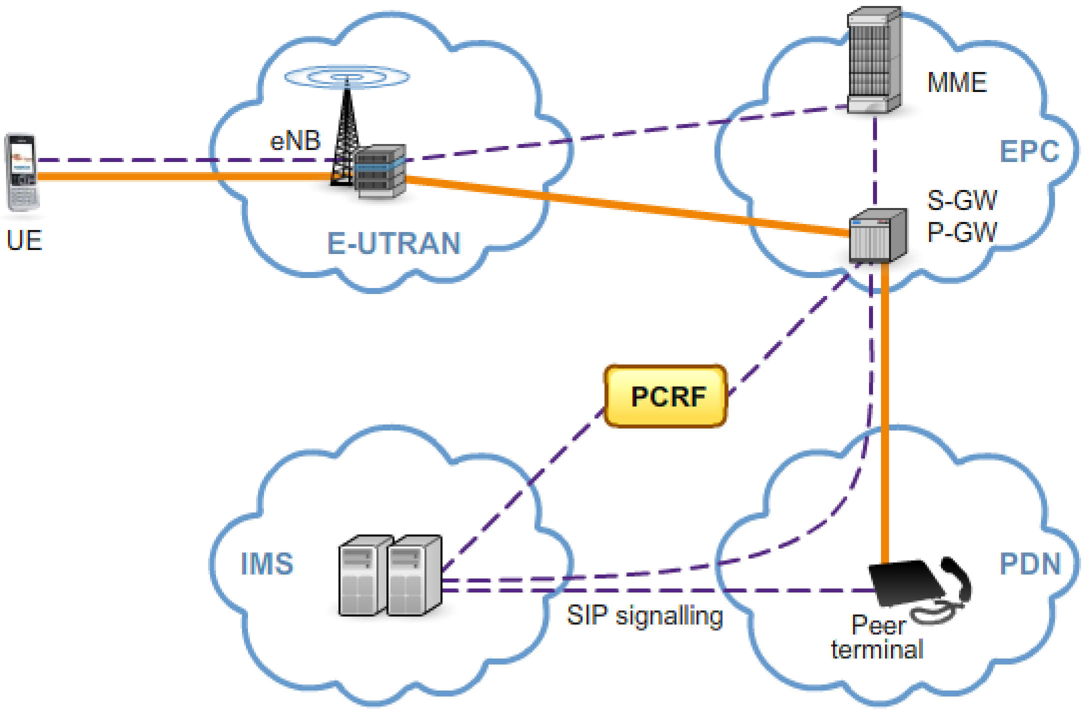
When the UE is switched on, this means in technical terms the “LTE attach” procedure. Like in any mobile technology, the first step is to perform random access in order to set up a signalling connection over the radio interface.

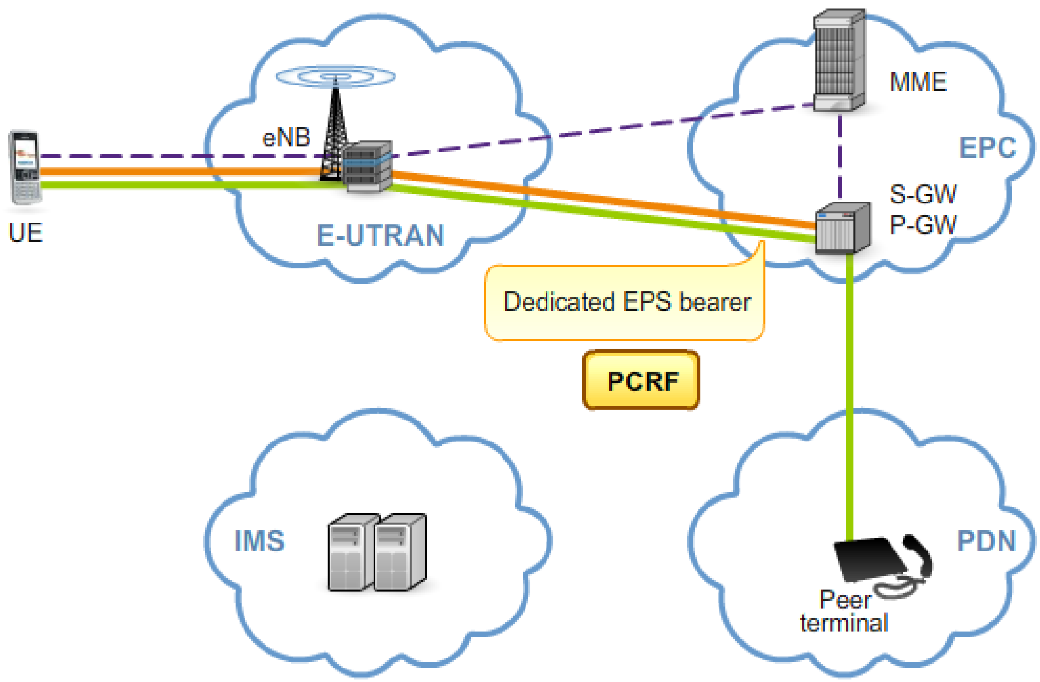
Unlike in WCDMA/HSPA, the attach procedure by default includes setting up a user plane connection to the Evolved Packet Core - the default EPS bearer connection. Also, an IP address is allocated to the UE.

The VoIP connection is then set up using Session Initiation Protocol (SIP) signalling. The SIP signalling messages are carried transparently through the Evolved Packet System. The IP Multimedia Subsystem (IMS) may also interact with the PDN Gateway via a Policy and Charging Rules Function (PCRF) node as will be explained in part two of this course.

If the network is not QoS-aware, the VoIP traffic is carried within the EPS over the default EPS bearer. In a QoS-aware network, however, a separate dedicated EPS bearer could be established for the “high priority” VoIP traffic. When setting up a dedicated EPS bearer, the signalling is quite similar to the signalling used when setting up the default EPS bearer. The main task of the signalling in both cases is to convey tunnel endpoint identifier (TEID) information to the network elements terminating the GTP tunnel in the user plane.




MME
EPC
eNB
S-GW
P-GW
UE
E-UTRAN
PCRF
IMS
PDN
SIP signalling
Peer
terminal


MME
EPC
eNB
S-GW
P-GW
UE
E-UTRAN
Dedicated EPS bearer
PCRF
IMS
PDN
Peer
terminal