Inter-RAT handover (E-UTRAN to UTRAN)

Computer Networks module - LTE assignment

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Assessment Feedback					
Aspect (& weighting)	Excellent	Very Good	Satisfactory	Needs some more work	Needs much more work
Content					
Critical Analysis					
Structure					
Referencing					
Presentation + Discussion					
Specific aspects of the assignment that the marker likes:		Specific aspects of the assignment that need more work:			
Tutor's Signature:		Date:		Grade	

List of Abbreviations

3GPP	Third Generation Partnership Project
CN	Core network
CSG	Closed subscriber group (of a home eNodeB)
E-UTRAN	Evolved UMTS terrestrial radio access network
EPS	Evolved packet system
GGSN	Gateway GPRS Support Node
GTP	GPRS tunnelling protocol
GTP-C	GPRS tunnelling protocol control part
GTP-U	GPRS tunnelling protocol user part
IMEI	International mobile equipment identity
LTE	Long term evolution
MME	Mobility management entity
NSAPI	Network Service Access Point Identifier
PDN	Packet data network
PDU	Protocol data unit
P-GW	Packet data network gateway
RAB	Radio access bearer
RNC	Radio network controller
SDU	Service data unit
SGSN	Serving GPRS Support Node
S-GW	Serving gateway
S-RNTI	Serving RNC Radio Network Temporary Identifier
TEID	Tunnel endpoint identifier
UE	User equipment
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS terrestrial radio access network

1 Introduction

The intra-RAT handover from E-UTRAN to UTRAN is composed of two phases, each of which involves (as well as the UE) either nodes from the LTE network and nodes from the UMTS netowork: the *preparation phase* and the *execution phase*. In particular, the LTE elements involved in the procedure are:

- eNodeB
- E-UTRAN network
- MME
- S-GW
- P-GW

while the UMTS elements are:

- RNC
- SGSN
- GGSN

It is assumed that both the LTE and the UMTS networks belong to the same operator. This means that the P-GW of the LTE network and the GGSN of the UMTS network are the same physical device, therefore, since in this paper the focus is on the LTE network, only the P-GW will be showed. Moreover, since the goal of this paper is to show only the intra-RAT handover procedure, some non-central aspects such as the relocation of the S-GW will not be considered and the related messages and parameters will be left out.

It is important to point out that before, during and after the handover the UE is in the state "LTE_ACTIVE" and user data is uploaded/downloaded (otherwise if the UE was in idle state it wouldn't be a handover but a simple cell reselection). In particular, as shown in figure 1, before the handover procedure both uplink and downlink user data is transmitted through:

- bearer(s) between UE and source eNodeB

- GTP[1] tunnel(s) between source eNodeB, S-GW and P-GW.

The figure 2 shows the elements involved in this handover procedure, how they are connected to each other and through which interfaces, figure 1 shows how data is transmitted before the start of the procedure.

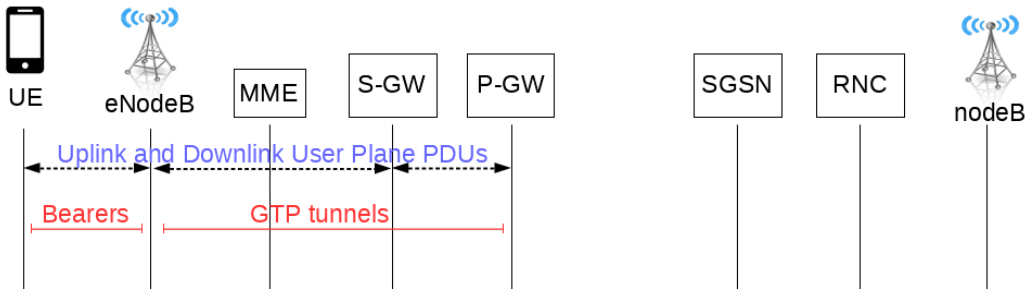


Figure 1: LTE and UMTS networks before the handover.

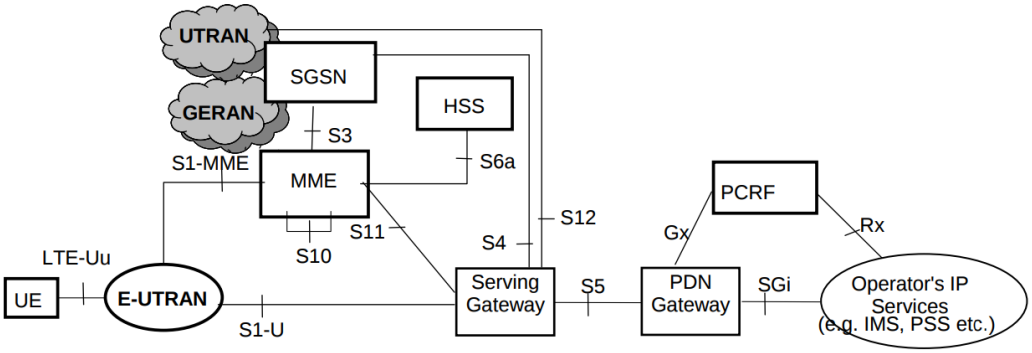


Figure 2: non-roaming architecture for 3GPP accesses.

[1]GPRS Tunneling protocol (GTP) is a IP/UDP based protocol used to encapsulate user data when passing through core network (GTP-U) or to carry bearer specific signalling traffic between various core network nodes (GTP-C).

2 Preparation phase

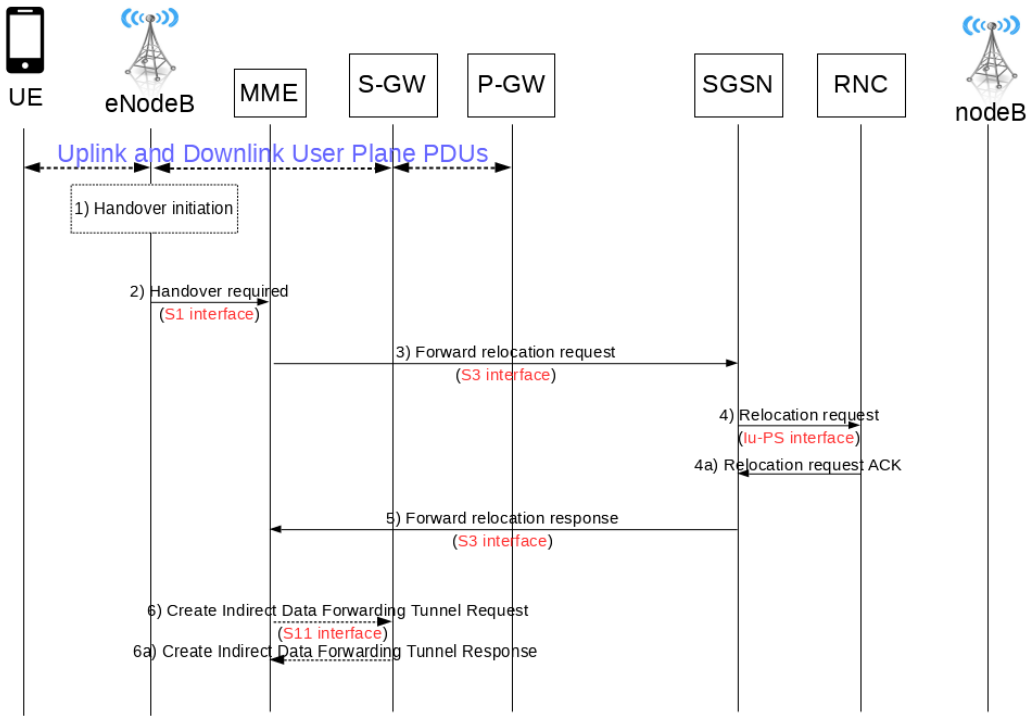


Figure 3: the flow of the messages and the nodes involved in the handover preparation phase

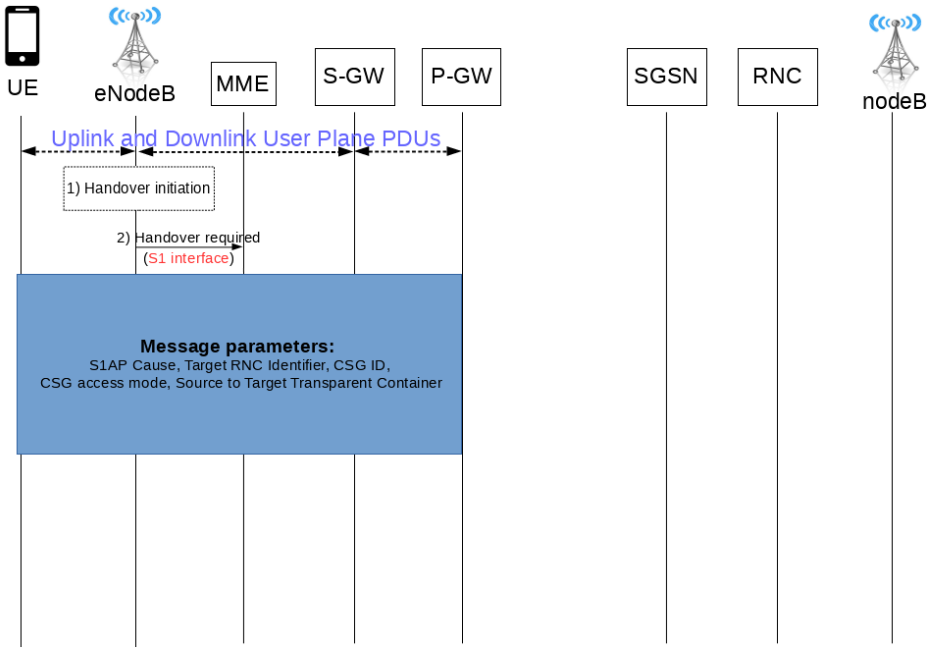
Step 1

The source eNodeB decides to initiate an Inter-RAT handover to the target access network.

Step 2

The source eNodeB sends a *Handover Required* message to the source MME, requesting the CN to establish resources in the target RNC and in the target SGSN. The message is sent through the S1 interface and it contains the following parameters:

- S1AP Cause: it specifies the reason of the message

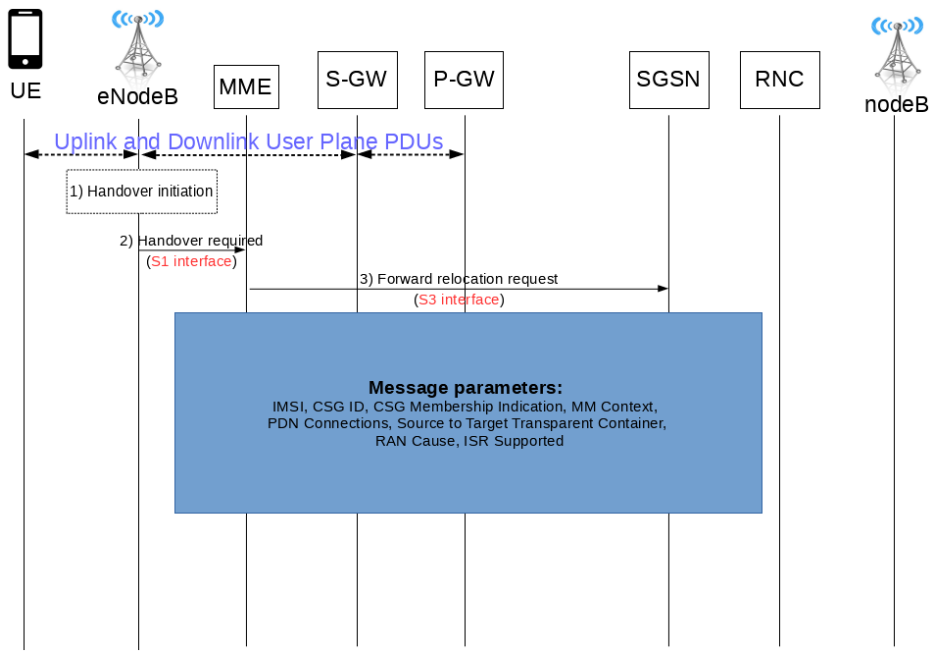


- Target RNC Identifier: it identifies the target RNC
- CSG access mode: included only if the target cell is a hybrid cell
- CSG ID: included only if the target cell is a CSG or hybrid cell, it identifies the cell
- Source to Target Transparent Container: it carries RRC parameters and Radio Bearer information necessary to set-up the radio bearers.

Step 3

The source MME determines from the "Target RNC Identifier" field that the type of handover is intra-RAT Handover to UTRAN Iu mode and, if the CSG ID is included in the message, it checks the UE's CSG subscribtion. If the UE isn't subscribed to the CSG, then the MME rejects the handover, unless the UE has emergency bearer services ongoing (in this case the handover to the target RNC is performed independent of the restrictions). If the handover isn't rejected then the MME selects the target SGSN and sends to it a *Forward Relocation Request* message through the S3 interface. Some of the parameters included in this message are:

- user IMSI



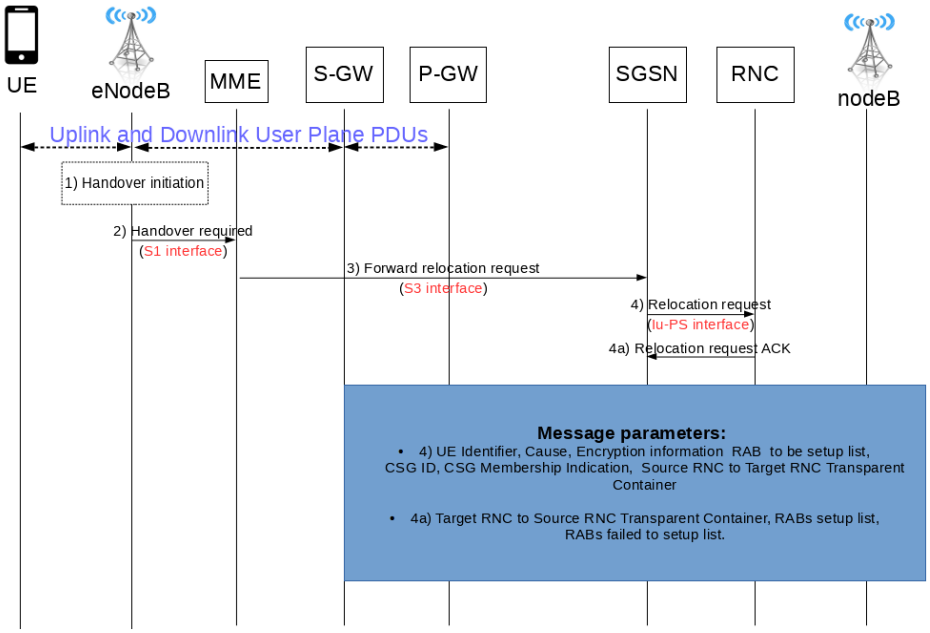
- ISR Supported: it indicates if the source MME and the source S-GW are able to activate ISR[2]
- PDN connections: it indicates the active PDN connections
- RAN cause: it's the S1AP cause received from the eNodeB
- CSG ID: included only if the target cell is a CSG cell or a hybrid cell
- CSG Membership Indication: it indicates if the UE is a CSG member. It's included only if the target cell is a hybrid cell or if it is a CSG cell and there is at least one emergency bearer service
- MM context: it includes information on the EPS Bearer[3] contexts
- Source to Target Transparent Container

If none of the UE's EPS Bearers is supported by the target SGSN, the source MME rejects the handover attempt and sends a Handover Preparation Failure message to the Source eNodeB (see chapter Handover Reject).

[2]ISR = "idle mode signalling reduction". When this mode is active the network can simultaneously register the UE in a routing area that is served by an SGSN and in one or more tracking areas that are served by an MME.

[3]EPS Bearers = Bearers between the UE and the P-GW

Step 4



The target SGSN establishes the EPS Bearer contexts indicated by the message received from the MME and deactivates the Bearer contexts which can't be estabilished.

After that, it requests the target RNC to establish the radio network resources (RABs) by sending the *Relocation Request* message through the Iu-PS interface. Some of the parameters included in this message are:

- Encryption information: it is sent in order to allow data transfer to continue in the new UTRAN target cell without requiring a new Authentication and Key Agreement (AKA) procedure
- RAB to be setup list: for each RAB to be set up it contains information such as the RAB ID (which contains the NSAPI value) and other RAB parameters
- CSG ID and CSG Membership Indication: included only when provided by the the source MME in the *Forward Relocation Request* message
- Source RNC to Target RNC Transparent Container: it includes the information received from the source eNodeB included in the Source to Target Transparent Container field of the *Handover required* message

If the target cell is a CSG cell, the target RNC verifies the CSG ID provided by the target SGSN and rejects the handover if it does not match the CSG ID for the target cell. If the CSG Membership Indication is "non member", the target RNC only accepts emergency bearers.

Step 4a

For each accepted bearer, the target RNC allocates radio and Iu user plane resources. After that, the target RNC sends back to the SGSN the *Relocation Request Acknowledge* messages, which contains a list of the setup bearers and a list of the failed to setup bearers, which will be deactivated by the SGSN.

After sending the ACK the RNC is prepared to receive downlink GTP PDUs[4] from the S-GW (or from the target SGSN if Direct Tunnel is not used) for the accepted bearers.

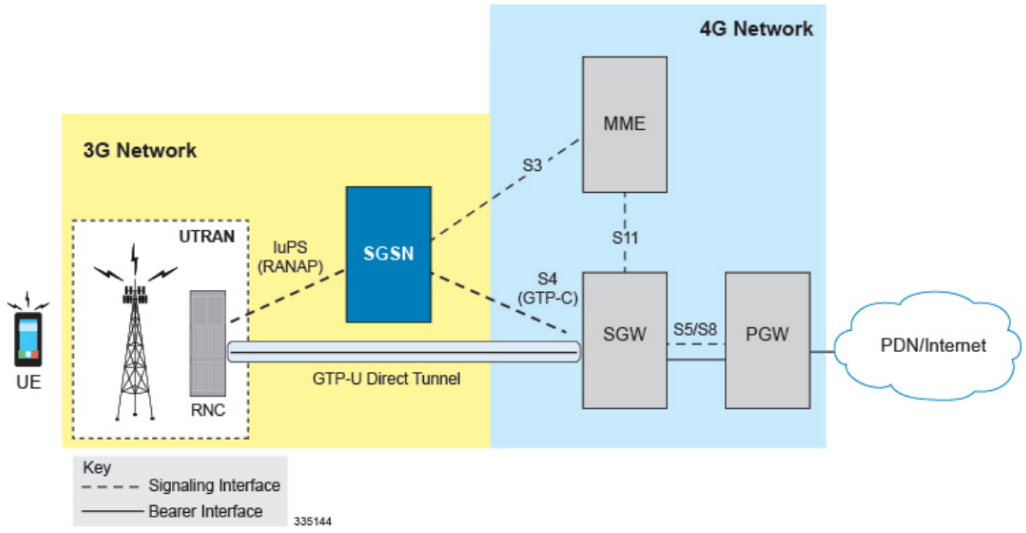
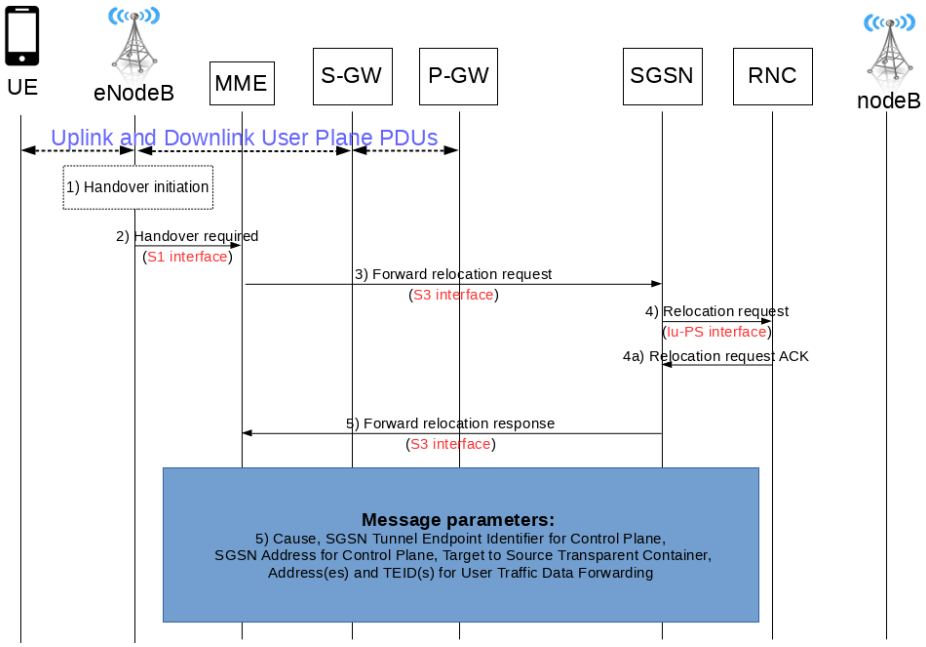


Figure 4: Direct tunnelling in a LTE network [1]

Step 5

The target SGSN sends the *Forward Relocation Response* message to the source MME through the S3 interface. Some of the parameters contained in

[4]Packets received by a protocol layer are called SDU while packets output of a layer are called PDU.

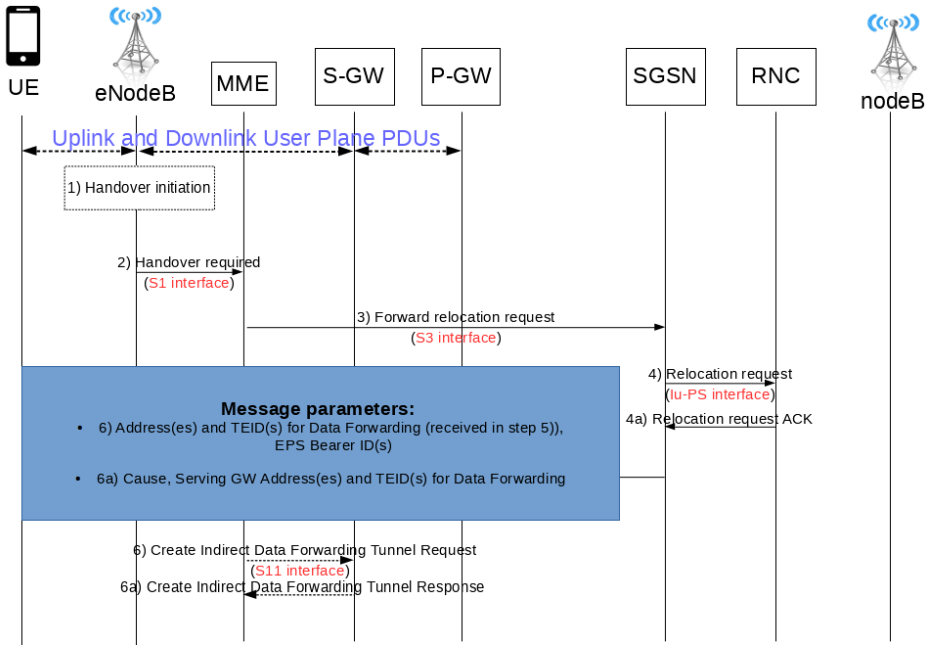


the message are:

- Target to Source Transparent Container: it contains the value of the Target RNC to Source RNC Transparent Container received from the target RNC
- Address(es) and TEID(s) for User Traffic Data Forwarding: this field define the destination tunnelling endpoint for user data forwarding. If Direct Tunnel is used then it contains the addresses and GTP-U tunnel endpoint parameters to the Target RNC, otherwise it contains the DL GTP-U tunnel endpoint parameters to the Target SGSN.
- SGSN Tunnel Endpoint Identifier for Control Plane
- SGSN Address for Control Plane

Step 6

If "Indirect Forwarding" applies, the Source MME sends the message *Create Indirect Data Forwarding Tunnel Request* to the S-GW used for indirect forwarding. The parameters contained in the message are the list of "Address(es) and TEID(s) for Data Forwarding" received in step 5 and the EPS Bearer ID(s).

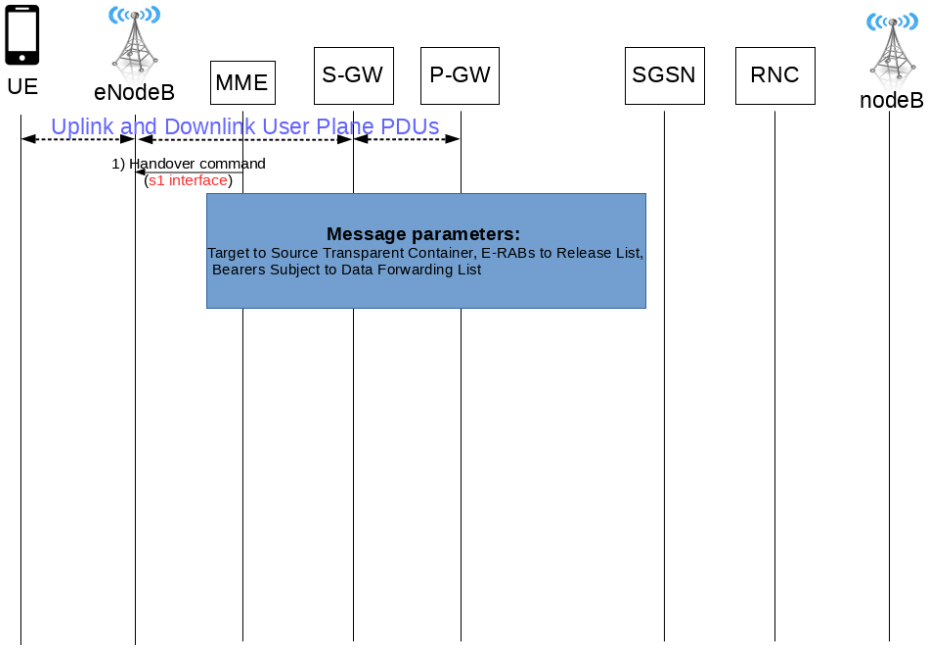


Step 6a

The S-GW replies sending message *Create Indirect Data Forwarding Tunnel Response*, which contains the S-GW Address(es) and the TEID(s) for data forwarding. Note that the Indirect Forwarding may be performed via a S-GW which is different from the S-GW used as the anchor point for the UE. If the S-GW doesn't support data forwarding, the message contains only an appropriate cause.

3 Execution phase

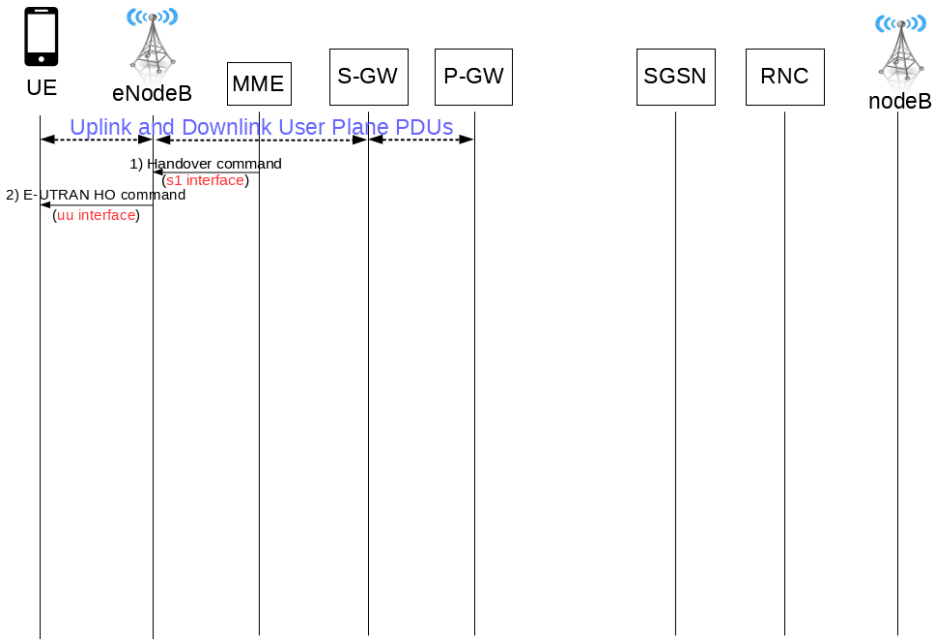
Step 1



The source MME completes the preparation phase by sending to the source eNodeB the *Handover command* message through the interface S1. The message contains the following parameters:

- Target to Source Transparent Container
- E-RABs to Release List
- Bearers Subject to Data Forwarding List: if "Direct Forwarding" applies it is the list of "Address(es) and TEID(s) for user traffic data forwarding" received from the target SGSN during step 5 of the preparation phase (addresses and GTP-U tunnel endpoint parameters to the Target RNC or to the target SGSN if direct tunnel is used), otherwise if "Indirect Forwarding" applies it contains the parameters received in step 6a (S-GW addresses)

Step 2



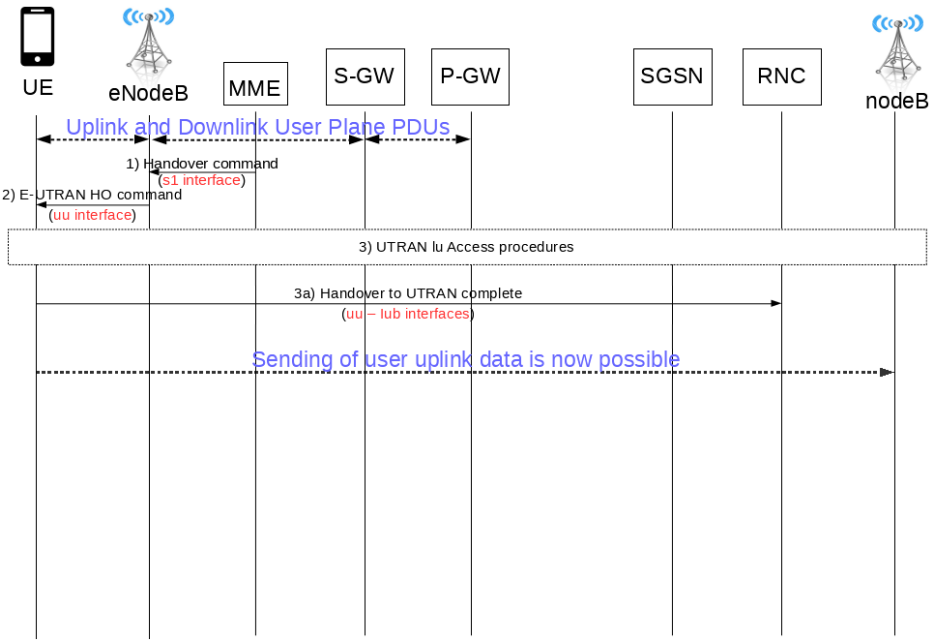
The source eNodeB initiates data forwarding for bearers specified in the "Bearers Subject to Data Forwarding List" of the message received from the MME.

After that, the eNodeB sends the E-UTRAN command *HO* to the UE for telling it to handover to the target access network. This message includes a transparent container which contains the radio parameters that the RNC has set-up during the preparation phase. The message is sent through the DCCH logical channel, which maps to the DL-SCH transport channel, which maps to PDSCH physical channel [3].

After the reception of the HO command the UE has to associate its bearer IDs to the respective RABs according to the relation with the NSAPIs[5] and has to suspend the uplink transmission of user data.

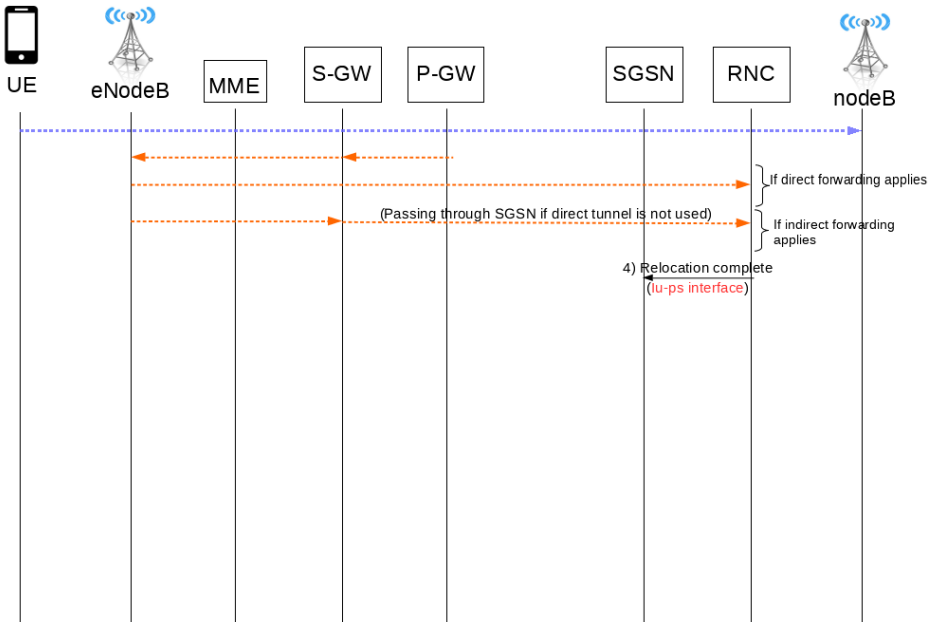
[5]NSAPI is used to identify PDP contexts in the SGSN. A PDP context is a data structure which contains subscriber's session information such as its IMSI and its IP address

Step 3



The UE executes the handover to the target UTRAN according to the prameters contained in the message received in step 2. At this point it can resume the user data transfer only for those NSAPIs which have been associated to a RAB, namely the NSAPIs for which there are radio resources allocated in the target RNC.

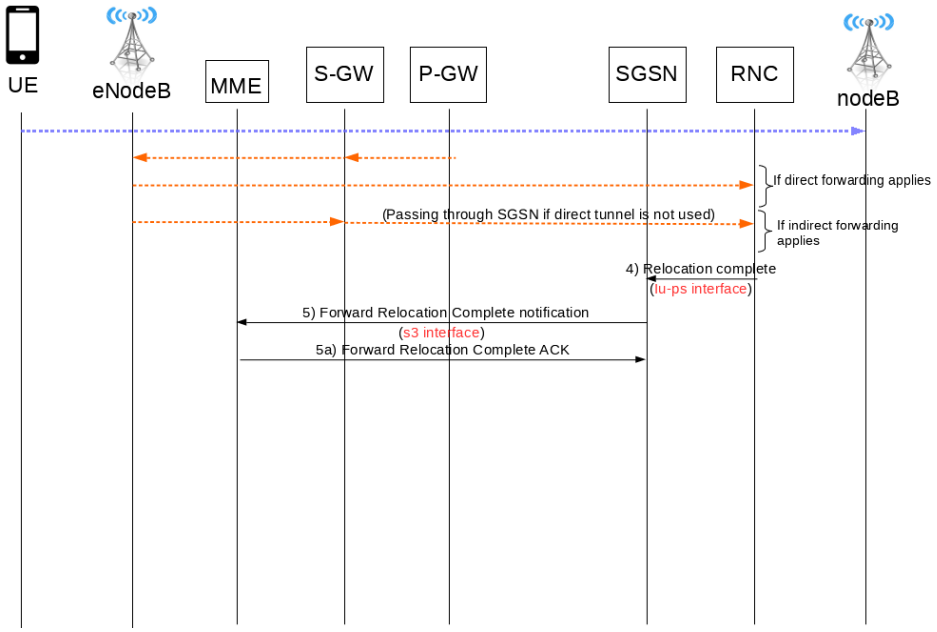
Step 4



After the RNC-ID and the S-RNTI[6] are exchanged with the UE, the target RNC sends the *Relocation Complete* message to the target SGSN, indicating therefore the completion of the relocation from the source E-UTRAN to the target RNC. After receiving this message, the SGSN is ready for receiving data from the target RNC.

[6]In UMTS the S-RNTI is the UE identifier which is allocated by the RNC and it's unique within that RNC

Step 5

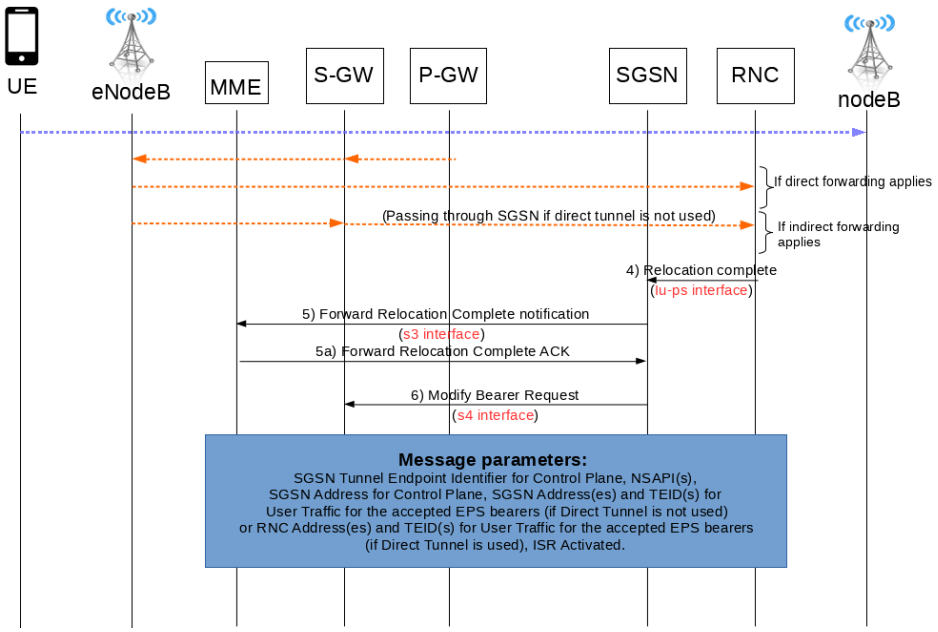


The target SGSN informs the source MME that the UE has arrived to the target side (UMTS network) by sending the Forward Relocation Complete Notification message.

When the MME receives the message it starts a timer and it releases all the bearers that were not included in the Forward Relocation Request message sent in step 3 of the preparation phase by sending a Delete Bearer Command to the S-GW.

When the timer expires, if ISR Activated was not indicated in the message received from the SGSN and Indirect Forwarding is used (and therefore the SGSN allocated S-GW resources for it), the MME releases all the bearer resources of the UE by sending Delete Indirect Data Forwarding Tunnel Request message to the S-GW used for indirect forwarding (see step 9).

Step 6

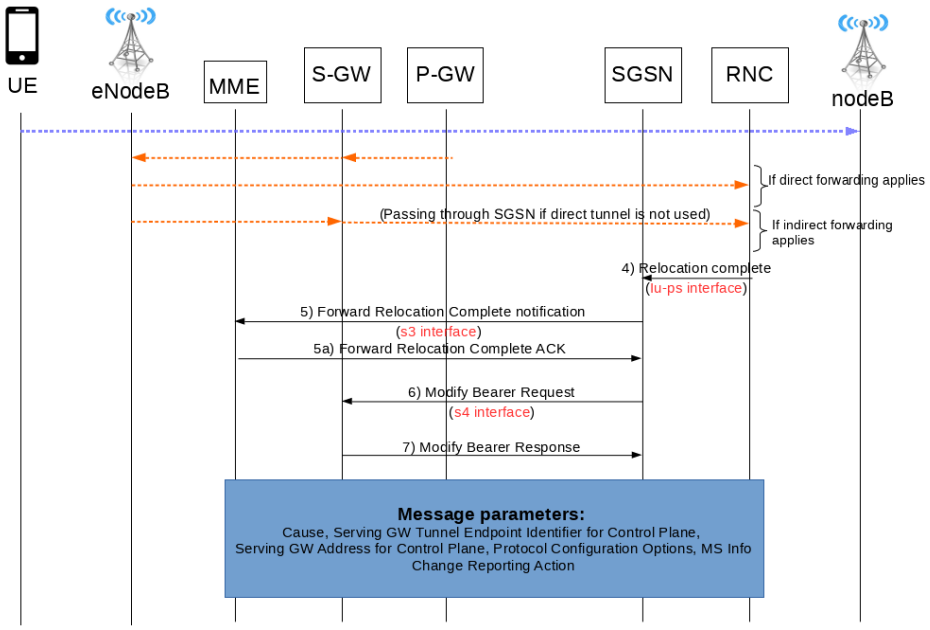


The SGSN informs the S-GW that now the SGSN is responsible for all the EPS Bearer contexts that the UE has established by sending to it a Modify Bearer request per each PDN connection. The message contains the following parameters:

- SGSN address and Tunnel Endpoint Identifier for Control Plane
- NSAPI(s)
- SGSN Address(es) and TEID(s) for User Traffic for the accepted EPS bearers (if Direct Tunnel is not used)
- RNC Address(es) and TEID(s) for User Traffic for the accepted EPS bearers (if Direct Tunnel is used)
- RAT type
- ISR Activated
- User location information (only if the SGSN supports location information change reporting)

??? The SGSN releases the non-accepted EPS Bearer contexts by triggering the Bearer Context deactivation procedure. If the Serving GW receives a DL packet for a non-accepted bearer, the Serving GW drops the DL packet and does not send a Downlink Data Notification to the SGSN. ???

Step 7



The S-GW sends to the SGSN the Modify Bearer Response message for acknowledging the user plane switch to the target SGSN.

After this step the user data path is finally established and it's shown in figure 5.

Step 8

When the UE recognises that its current Routing Area is not registered with the network, or when the UE's TIN indicates "GUTI", the UE initiates a Routing Area Update procedure with the SGSN. This procedure is the UMTS equivalent of the Tracking Area Update procedure in LTE and it's described in reference [2].

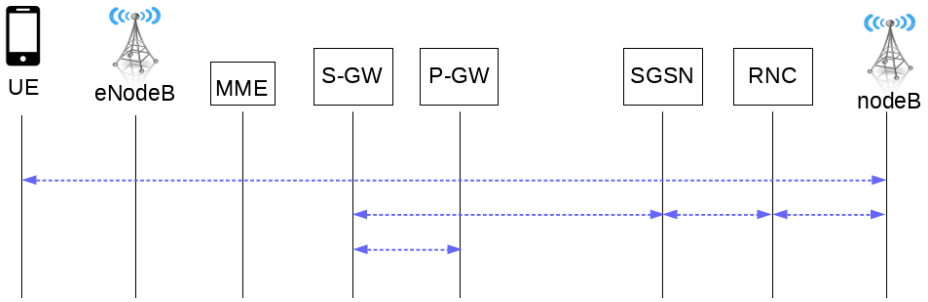
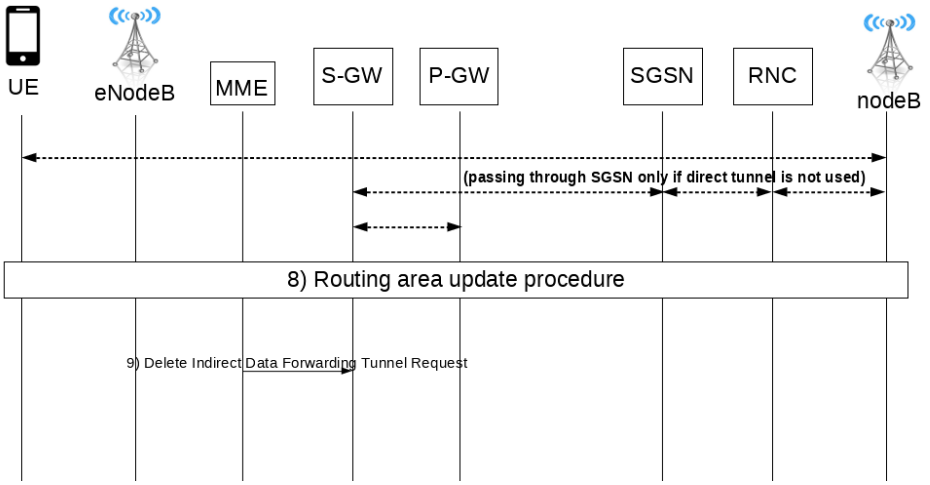


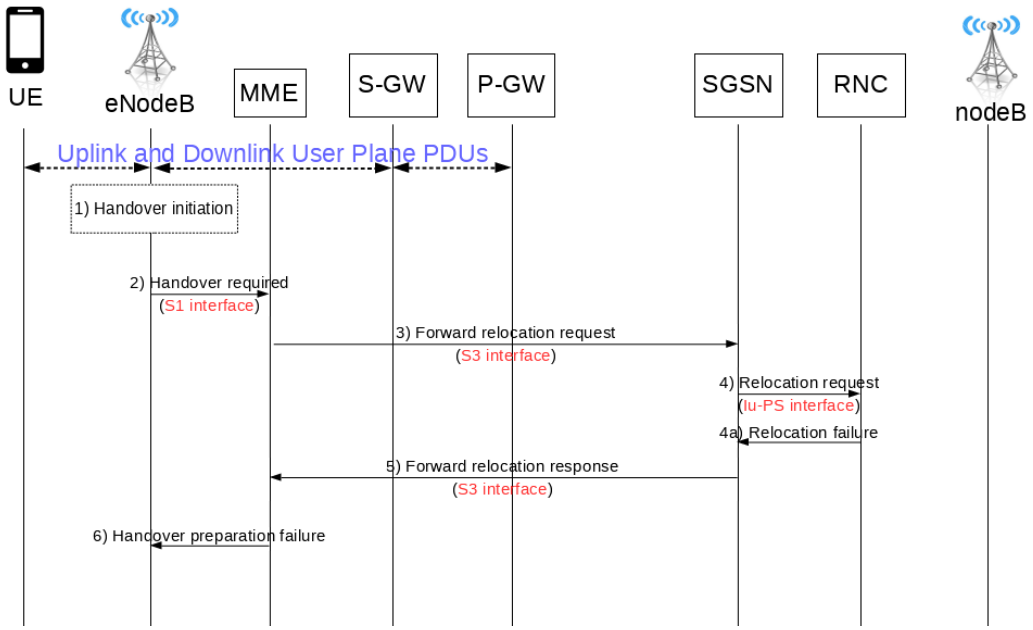
Figure 5: The user data path after the step 7. In this case it is assumed that direct tunnel is not used, therefore the link between the RNC and the S-GW passes through the SGSN. If direct tunnel is instad used then the data go straight from the RNC to the S-GW.

Step 9

If indirect forwarding was used then when the timer started by the MME at step 5 expires the MME sends a Delete Indirect Data Forwarding Tunnel Request message to the S-GW for releasing the temporary resources used for indirect forwarding.



4 Handover reject



The Target RNC may reject the Handover if none of the RABs specified in the Relocation Request message could be established. In this case no UE context is established in the SGSN/RNC and no resources are allocated, the UE therefore remains in the Source eNodeB/MME.

Step 1

Step 1 to 4 are identical to the ones shown in the first chapter (Execution phase).

Step 4a

The RNC fails to allocate any resources for any of the requested RABs, therefore it sends to the SGSN a Relocation Failure message. When the SGSN receives the Relocation Failure message it clears any reserved resources for this UE.

Step 5

The SGSN sends the Forward Relocation Response message to the Source MME, specifying the handover reject as parameter in the message (cause field).

Step 6

When the MME receives the Forward Relocation Response message it sends a Handover Preparation Failure message to the Source eNodeB.

References

[1] Cisco. (2017). *P-GW Administration Guide, StarOS Release 20 - Direct Tunnel for 4G (LTE) Networks [Cisco ASR 5000 Series]*. [online] Available at: https://www.cisco.com/c/en/us/td/docs/wireless/asr_5000/20/P-GW/b_20_PGW_Admin/b_20_PGW_Admin_chapter_011111.html [Accessed 5 May 2018].

[2] 3GPP TS 23.401 (September 2011) *General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Access*, Release 10, sections 5.3.3.3, 5.3.3.6.

[3] Poole, I. (n.d.). *LTE Physical, Logical and Transport Channels :: Radio-Electronics.Com*. [online] Radio-electronics.com. Available at: http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/physical-logical-transport-channels.php [Accessed 16 May 2018].