Interoperable UE Handovers in LTE

By: V. Srinivasa Rao, Senior Architect & Rambabu Gajula, Lead Engineer

Overview

With the fast-changing mobile landscape and convergence in all aspects of telecommunications, "seamless handover" is important for any technology to succeed. Operators and consumers both benefit from seamless handover in terms of cost effectiveness, enhanced features, location independence and ease of use, not only within a Long Term Evolution (LTE) network but also between networks including UMTS, GSM and CDMA.

In this paper we briefly touch upon the procedures executed by the user equipment (UE) and the various network elements to provide the handover services requested by the UE. We cover Intra-LTE and LTE to/from UMTS handovers.

CONTENTS

Objectives of Handover Procedures

1. It is important that QoS is maintained, not just before and after a handover, but during the handover as well.

2. Handover shall not drain the UE battery power.

3. Service continuity shall be maintained (i.e., minimal handover latency).

4. Seamless handoff to 3G / 2G / CDMA technology.

There are two ways a handoff can be decided:

• Network Evaluated: the network makes the handover decision

• Mobile Evaluated: the UE makes the handoff decision and informs the network about it. In this instance, the final decision will be made by the network based upon the Radio Resource Management.

In 3G and LTE networks, a hybrid approach is used to decide on the handover. In this case, the UE will assist in the handoff decision by measuring the neighboring cells and reporting the measurements to the network, which in turn decides upon the handoff timing and the target cell/node. The parameters to measure and the thresholds for reporting are decided by the network.

In LTE there are three types of handovers:

• Intra-LTE: Handover happens within the current LTE nodes (intra-MME and Intra-SGW)

• Inter-LTE: Handover happens toward the other LTE nodes (inter-MME and Inter-SGW)

• Inter-RAT: Handover between different radio technology networks, for example GSM/UMTS and UMTS

We'll look at Intra-LTE handovers with X2AP signaling and S1AP signaling first, then Inter-RAT handovers in LTE (i.e., handover between LTE and UMTS).

Intra-LTE (Intra-MME/SGW) Handover Using the X2 Interface

This procedure is used to handover a UE from a source eNodeB (S-eNB) to a target eNodeB (T-eNB) using the X2 interface when the Mobility Management Entity (MME) and Serving Gateway (SGW) are unchanged. It is possible only if direct connectivity exists between the source and target eNodeB's with the X2 interface.

The X2 handover procedure is performed without Evolved Packet Core (EPC) involvement, i.e. preparation messages are directly exchanged between the S-eNB
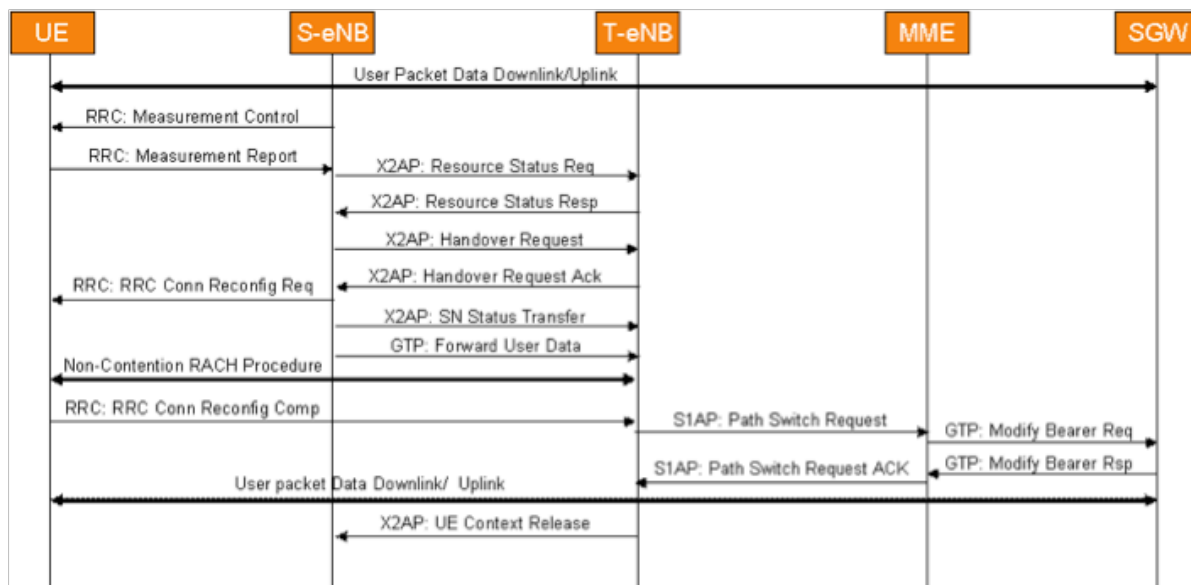

Figure 1. *Intra-LTE (Intra-MME/SGW) Handover Using the X2 Interface*

and T-eNB. The release of the resources at the source side during the handover completion phase is triggered by the T-eNB. The message flow is shown in Figure 1 followed by the description.

1. A data call is established between the UE, S-eNB and the network elements. Data packets are transferred to/from the UE to/from the network in both directions (DL as well as UL).

2. The network sends the MEASUREMENT CONTROL REQ message to the UE to set the parameters to measure and set thresholds for those parameters. Its purpose is to instruct the UE to send a measurement report to the network as soon as it detects the thresholds.

3. The UE sends the MEASUREMENT REPORT to the S-eNB after it meets the measurement report criteria communicated previously. The S-eNB makes the decision to hand off the UE to a T-eNB using the handover algorithm; each network operator could have its own handover algorithm.

4. The S-eNB issues the RESOURCE STATUS REQUEST message to determine the load on T-eNB (this is optional). Based on the received RESOURCE STATUS RESPONSE, the S-eNB can make the decision to proceed further in continuing the handover procedure using the X2 interface.

5. The S-eNB issues a HANDOVER REQUEST message to the T-eNB passing necessary information to prepare the handover at the target side (e.g., UE Context which includes the Security Context and RB Context (including E-RAB to RB Mapping) and the Target cell info).

6. The T-eNB checks for resource availability and, if available, reserves the resources and sends back the HANDOVER REQUEST ACKNOWLEDGE message including a transparent container to be sent to the UE as an RRC message to perform the handover. The container includes a new C-RNTI, T-eNB security algorithm identifiers for the selected security algorithms, and may include a dedicated RACH preamble and possibly some other parameters (i.e., access parameters, SIBs, etc.).

7. The S-eNB generates the RRC message to perform the handover, i.e, RRCCONNECTION RECONFIGURATION message including the *mobilityControlInformation.* The S-eNB performs the necessary integrity protection and ciphering of the message and sends it to the UE.

8. The S-eNB sends the eNB STATUS TRANSFER message to the T-eNB to convey the PDCP and HFN status of the E-RABs.

9. The S-eNB starts forwarding the downlink data packets to the T-eNB for all the data bearers (which are being established in the T-eNB during the HANDOVER REQ message processing).

10. In the meantime, the UE tries to access the T-eNB cell using the non-contention-based Random Access Procedure. If it succeeds in accessing the target cell, it sends the RRC CONNECTION RECONFIGURATION COMPLETE to the T-eNB.

11. The T-eNB sends a PATH SWITCH REQUEST message to the MME to inform it that the UE has changed cells, including the TAI+ECGI of the target. The MME determines that the SGW can continue to serve the UE.

12. The MME sends a MODIFY BEARER REQUEST (eNodeB address and TEIDs for downlink user plane for the accepted EPS bearers) message to the SGW. If the PDN GW requested the UE's location info, the MME also includes the User Location Information IE in this message.

13. The SGW sends the downlink packets to the target eNB using the newly received addresses and TEIDs (path switched in the downlink data path to T-eNB) and the MODIFY BEARER RESPONSE to the MME.

14. The SGW sends one or more "end marker" packets on the old path to the S-eNB and then can release any user plane / TNL resources toward the S-eNB.

15. The MME responds to the T-eNB with a PATH SWITCH REQ ACK message to notify the completion of the handover.

16. The T-eNB now requests the S-eNB to release the resources using the X2 UE CONTEXT RELEASE message. With this, the handover procedure is complete.
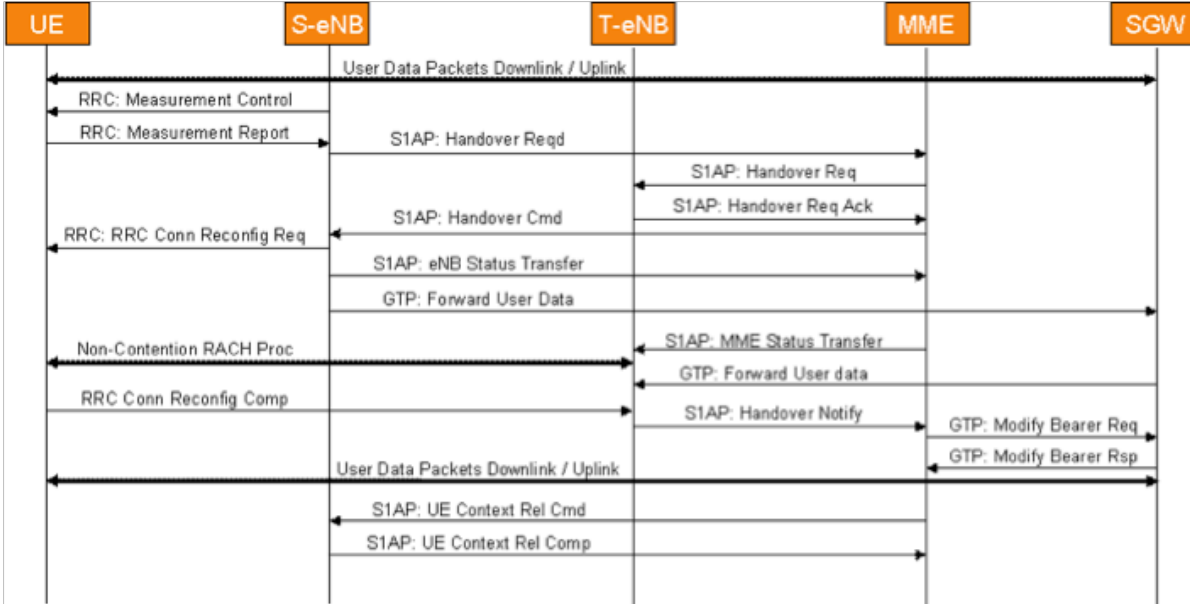
Figure 2. *Intra-LTE (Intra-MME/SGW) Handover Using the S1 Interface*

Intra-LTE (Intra-MME/SGW) Handover Using the S1 Interface

The S1-based handover procedure is used when the X2-based handover cannot be used—e.g., no X2 connectivity to the target eNodeB; by an error indication from the T-eNB after an unsuccessful X2-based handover; or by dynamic information learnt by the S-eNB using the STATUS TRANSFER procedure. The S-eNB initiates the handover by sending a Handover required message over the S1-MME reference point. The EPC does not change the decisions taken by the S-eNB.

The availability of a direct forwarding path is determined in the S-eNB (based on the X2 connectivity with the T-eNB) and indicated to the source MME. If a direct forwarding path is not available, indirect forwarding will be used. The source MME uses the indication from the S-eNB to determine whether to apply indirect forwarding or not. The message flow is depicted in Figure 2 followed by the description of the procedures.

Intra-LTE Handover (Intra-MME/SGW)

- As mentioned in the previous section, based on the MEASUREMENT REPORT from the UE, the S-eNB decides to Handover the UE to another eNodeB (T-eNB). The handover procedure in this section is very similar to that in the previous section (Intra-LTE Handover Using the X2 Interface), except the involvement of the MME in relaying the handover signaling between the S-eNB and T-eNB.

- There are two differences here:

  - No need for the PATH SWITCH Procedure between the T-eNB and MME, as MME is aware of the Handover.

  - The SGW is involved in the DL data forwarding if there is no direct forwarding path available between the S-eNB and T-eNB.

- Once the Handover is complete, the MME clears the logical S1 connection with the S-eNB by initiating the UE CONTEXT RELEASE procedure.
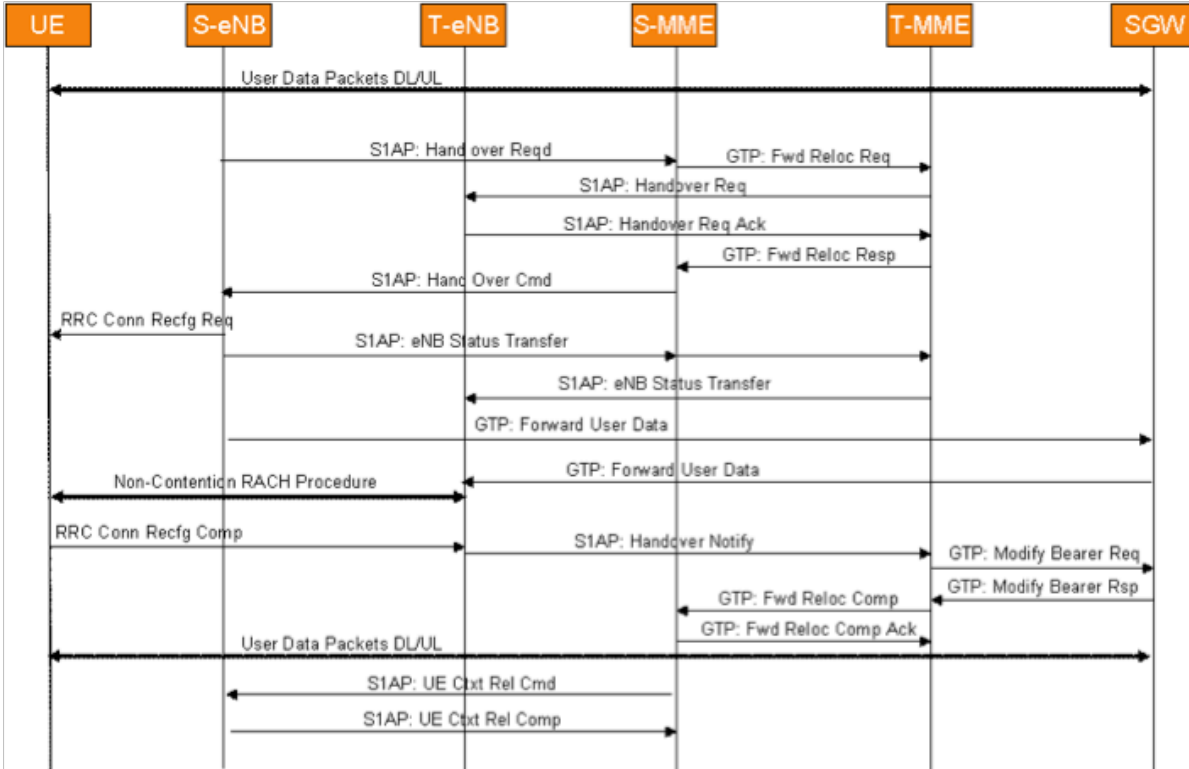
Figure 3. *Inter-MME Handover (Intra-SGW)*

Inter–MME Handover Using the S1 Interface (Without Changing S-GW)

In an inter-MME handover, two MMEs are involved in the handover, the source MME (S-MME) and target MME (T-MME). The S-MME controls the S-eNB and the T-MME controls the T-eNB; both MMEs are connected to the same SGW. This handover is triggered when the UE moves from one MME area to another MME area.

1. As mentioned in the previous section (Intra-MME/ SGW handover), based on the MEASUREMENT REPORT from the UE, the S-eNB decides to handover the UE to another eNodeB (T-eNB). The handover procedure in this section is very similar to that in the previous section except for the involvement of two MMEs coordinating the handover signaling between the source and target eNodeBs.

2. The S-MME uses GTP signaling to communicate the handover signaling to the T-MME and vice versa. The FORWARD RELOCATION procedure in GTP-C is being used here.

3. After receiving the S1 HANDOVER REQUIRED, the S-MME detects that the target cell requested for handover belongs to another MME and initiates the GTP FORWARD RELOCATION REQ message to the T-MME.

4. The T-MME creates the S1 logical connection toward the T-eNB and sends the S1 HANDOVER REQ on it.

5. The T-eNB prepares the requested resources and responds with a HANDOVER REQ ACK to the T-MME.

6. The T-MME sends a GTP FORWARD RELOCATION RESP to the S-MME, to notify the resource reservation at the T-eNB. From this point onwards, the interaction between the S-MME and S-eNB is very similar to the S1-based Intra-MME/SGW handover described in the previous section.
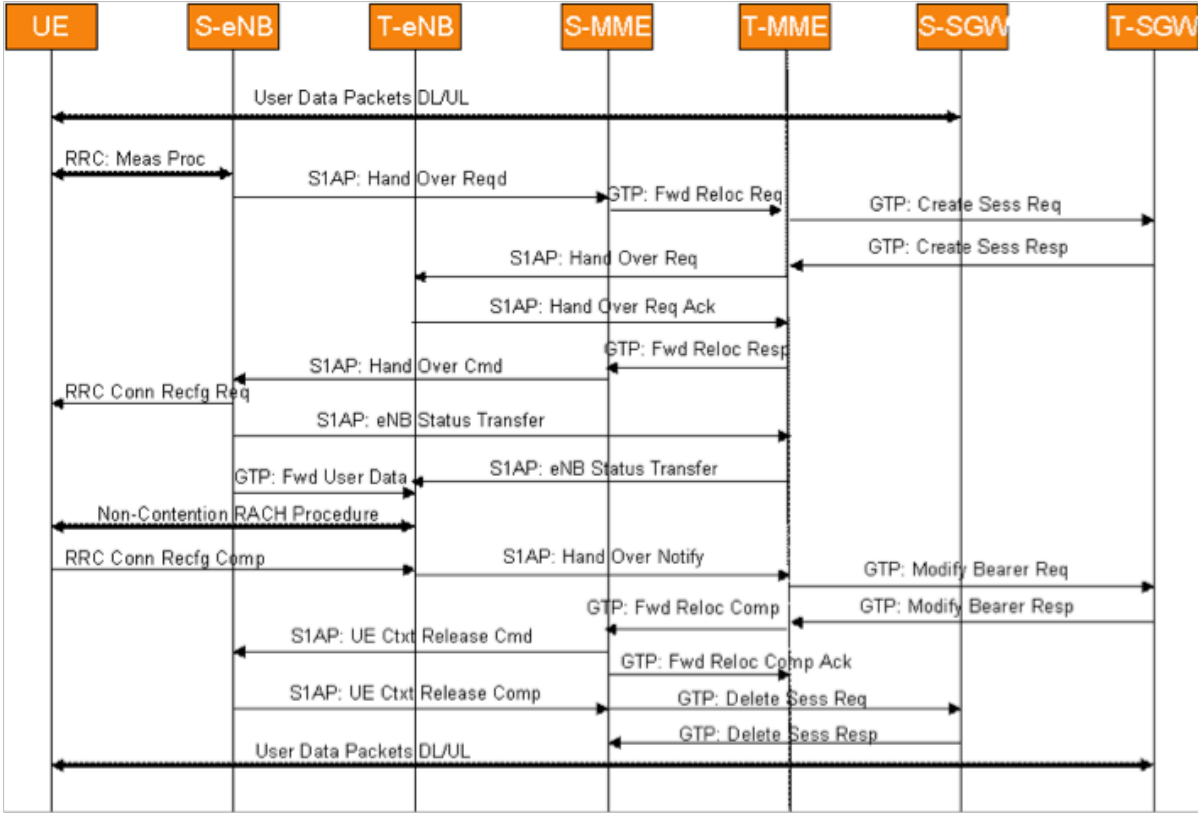
Figure 4. *Inter-MME/SGW Handover*

7. DL data packets are forwarded from the S-eNB to T-eNB via the SGW during the handover as the SGW is not changed here.

8. Once the T-eNB detects the UE in its area, it notifies the T-MME with a S1 HANDOVER NOTIFY message.

9. The T-MME notifies the completion of the handover to the S-MME with a GTP FORWARD RELOCATION COMPLETE NOTIFY message.

10. The S-MME acknowledges the GTP FORWARD RELOCAION COMPLETE NOTIFY to the T-MME and proceeds with clearing the S1 logical connection and the associated bearer resources.

Inter-MME/SGW Handover Using the S1 Interface

This scenario is similar to the previous section with the difference being the Source and Target eNodeBs are served by different MME/SGW nodes. Figure 4 depicts the procedures and is followed by the explanation.

1. As described in the previous section (Inter-MME, Intra-SGW handover), based on the MEASUREMENT REPORT from the UE, the S-eNB decides to handover the UE to another eNodeB (T-eNB). The handover procedure in this section is very similar to that in the previous section, except for the involvement of two SGWs (S-SGW and T-SGW) to transfer the data packets during the handover.
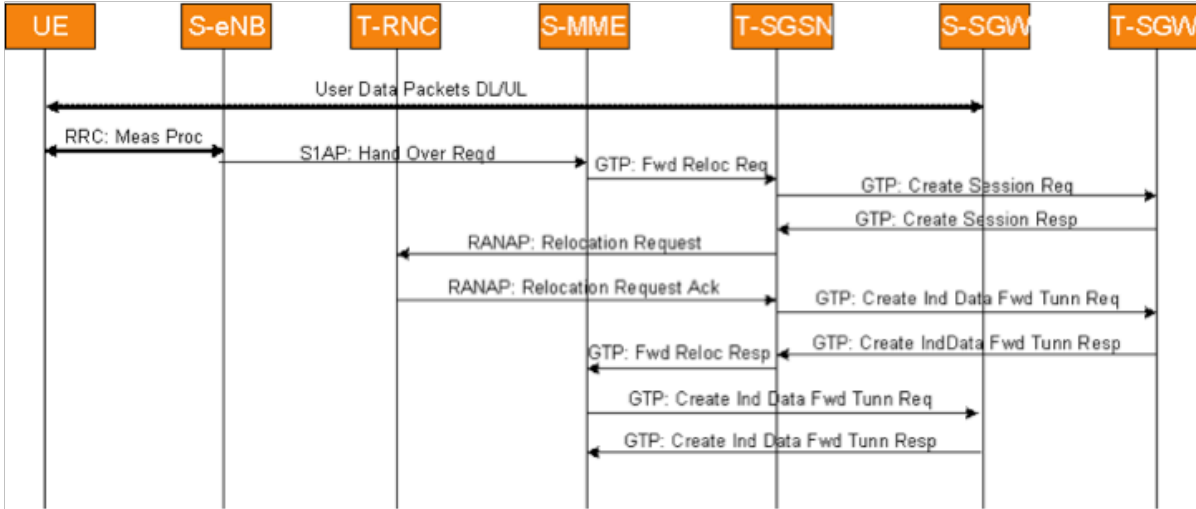
Figure 5. *Inter-RAT LTE-to-UMTS Handover: Preparation Phase*

2. After receiving the GTP: FORWARD RELOCATION REQ from the S-MME, the T-MME detects the SGW change and initiates the bearer creation toward the target SGW (T-SGW) using a GTP: CREATE SESSION REQ message.

3. After the creation of the requested bearers, the T-SGW responds back to the MME with a GTP: CREATE SESSION RESPONSE message.

4. From this point onward, the message flow is very similar to that in the previous section (Inter-MME, Intra-SGW handover) except for the following differences:

   - While processing the S1 HANDOVER NOTIFY message from the T-eNB, the T-MME updates the T-eNB endpoint information to the T-SGW using GTP: MODIFY BEARER REQ.

   - After updating the T-eNB information in the bearers (successfully set up during the handover), the T-SGW responds with a GTP: MODIFY BEARER RESPONSE message to the T-MME.

   - After successful completion of the handover, the S-MME takes care of releasing bearer resources with the S-SGW for this UE by initiating the GTP: DELETE SESSION procedure.

Inter-RAT Handover: E-UTRAN to UTRAN Iu Mode
Preparation Phase

In the LTE-to-UMTS Inter RAT handover, the source eNodeB connects to the S-MME and S-SGW while the target RNC connects to the T-SGSN and T-SGW; both the source and target SGWs connect to the same PGW. This procedure is divided into two parts for clarity, Preparation and Execution. In the Preparation phase, resources are reserved in the target network. In the Execution phase, the UE is handed over to the target network from the source network. The Preparation phase message flow is given in Figure 5, followed by the description.

1. Once the inter-RAT handover is decided at the S-eNB based on the measurement report procedure, it prepares and sends a HANDOVER REQUIRED message to the S-MME.

2. The S-MME detects that it is an Inter-RAT handover from the message contents, retrieves the target SGSN details from the database based on the information in the message. It now prepares and sends a GTP-C: FORAWRD RELOCATION REQUEST to the T-SGSN.

3. The T-SGSN detects the change of SGW and creates the bearer resources in the T-SGW by initiating the GTP: CREATE SESSION procedure.
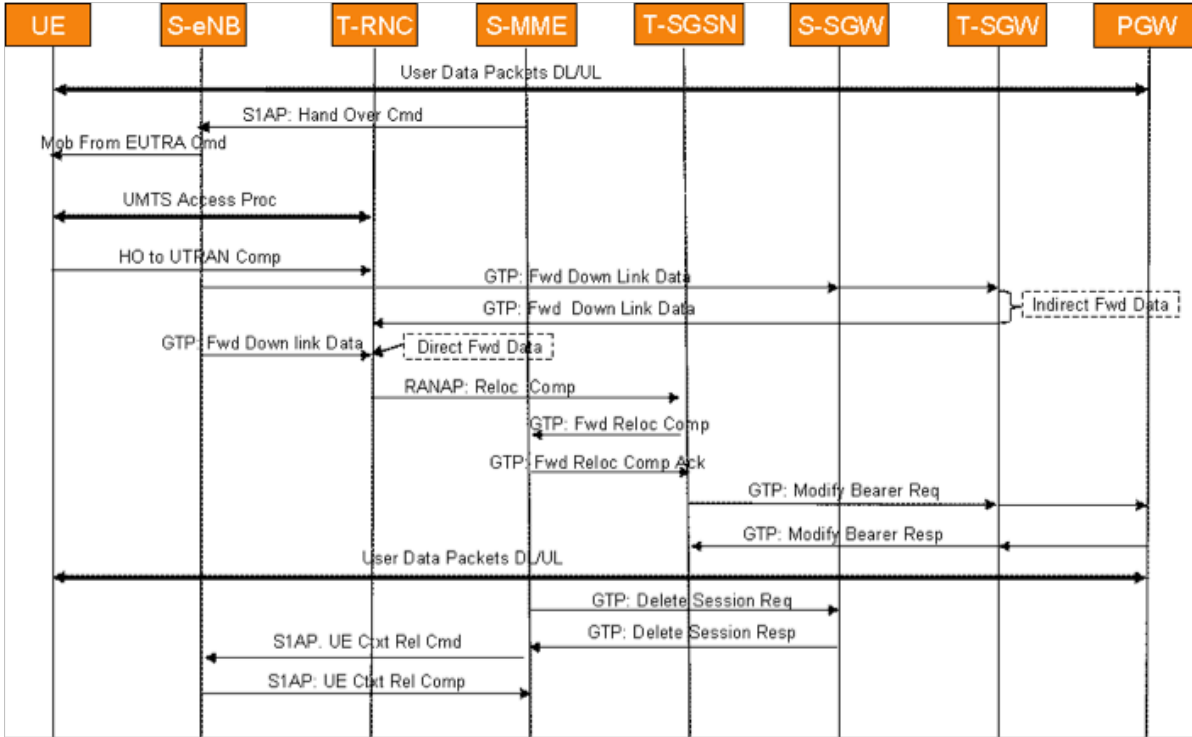
Figure 6. *Inter-RAT LTE-to-UMTS Handover: Execution Phase*

4. Once the resources are reserved at the T-SGW, it responds to the T-SGSN with a GTP: CREATE SESSION RESPONSE message.

5. The T-SGSN now reserves the resources at the T-RNC by sending a RANAP: RELOCATION REQUEST message to it.

6. The T-RNC reserves the radio resources and responds to the T-SGSN with a RANAP: RELOCATION REQUEST ACK message.

7. The T-SGSN creates the indirect data forwarding tunnels in the T-SGW for the DL packets transfer from the S-SGW to T-SGW during the handover.

8. After the Indirect Data forwarding tunnel creation, the T-SGSN responds with a GTP: FORWARD RELOCATION RESPONSE message to the S-MME.

9. The S-MME has to create the indirect data forwarding tunnels as the resources are reserved successfully in the target network to forward the DL packets to the target network. With this, the preparation phase is complete.

Execution Phase

1. The S-MME sends the HANDOVER COMMAND message to the S-eNB with the target to source transparent container (i.e., it has the reserved resource information at the target).

2. The S-eNB prepares and sends the MOBILITY FROM EUTRA COMMAND message to prepare the UE for the handover toward the target network.

3. After accessing the target UMTS cell, the UE sends a HO TO UTRAN COMPLETE message to the T-RNC signaling the successful handover.

4. The S-eNB forwards the DL data packets toward the T-SGW via the S-SGW during the handover. This step can happen any time after it receives the S1AP HANDOVER COMMAND message from the S-MME. This step is executed in case a direct forwarding path is not available with the T-RNC, otherwise it will forward the DL data packets to the T-RNC directly. Both the options are shown in Figure 6.
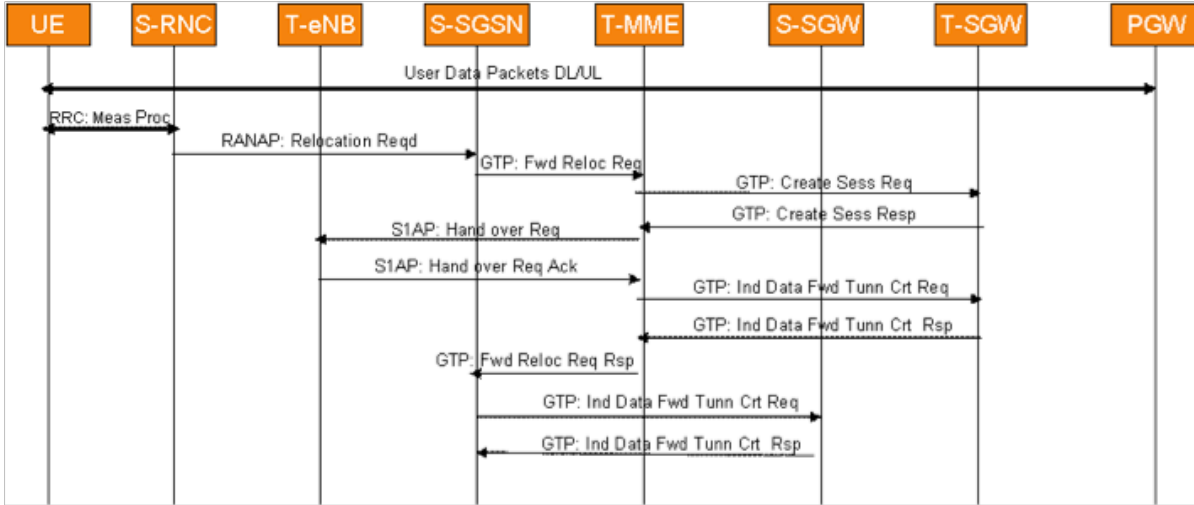
Figure 7. *Inter-RAT UMTS-to-LTE Handover: Preparation Phase*

5. Once the T-RNC detects the UE in its area, it notifies the T-SGSN about the completion of the handover by sending a RANAP: RELOCATION COMPLETE message.

6. The T-SGSN notifies the completion of handover to the S-MME by sending a GTP: FORWARD RELOCATION COMPLETE NOTIFICATION ACK message. The S-MME acknowledges this message and proceeds with release of the resources associated with this UE at the S-SGW and S-eNB.

7. The T-SGSN modifies the E-RAB resources at the T-SGW by initiating the GTP MODIFY BEARER procedure.

8. The T-SGW notifies the bearer parameters with the PGW by initiating the GTP MODIFY BEARER procedure.

Inter–RAT Handover: UTRAN to E-UTRAN

Preparation Phase

In the UMTS-to-LTE Inter-RAT handover, the S-RNC connects to the S-SGSN and S-SGW, the T-eNB connects to the T-MME and T-SGW, and both the source and target SGWs connect to the same PGW. As above, this procedure is divided into two parts for clarity, Preparation and Execution. In the Preparation phase, resources are reserved in the target network, while in the execution phase the UE is handed over to the target network from the source network. The Preparation phase message flow is given in Figure 7, followed by the description.

1. Once the inter-RAT handover is decided at the S-RNC based on the measurement report procedure, it prepares and sends a RANAP RELOCATION REQUIRED message to the S-SGSN.

2. The S-SGSN detects that it is an Inter-RAT handover from the message contents and retrieves the T-MME details from the database based on the information in the message. It now prepares and sends a GTP-C: FORAWRD RELOCATION REQUEST to the T-MME.

3. The T-MME detects the change of SGW and creates the bearer resources in the T-SGW by initiating the GTP: CREATE SESSION procedure.

4. Once the resources are reserved at the T-SGW, it responds to the T-MME with a GTP: CREATE SESSION RESPONSE message.

5. The T-MME now reserves the resources at the T-eNB by sending aS1AP: HANDOVER REQUEST message to it.

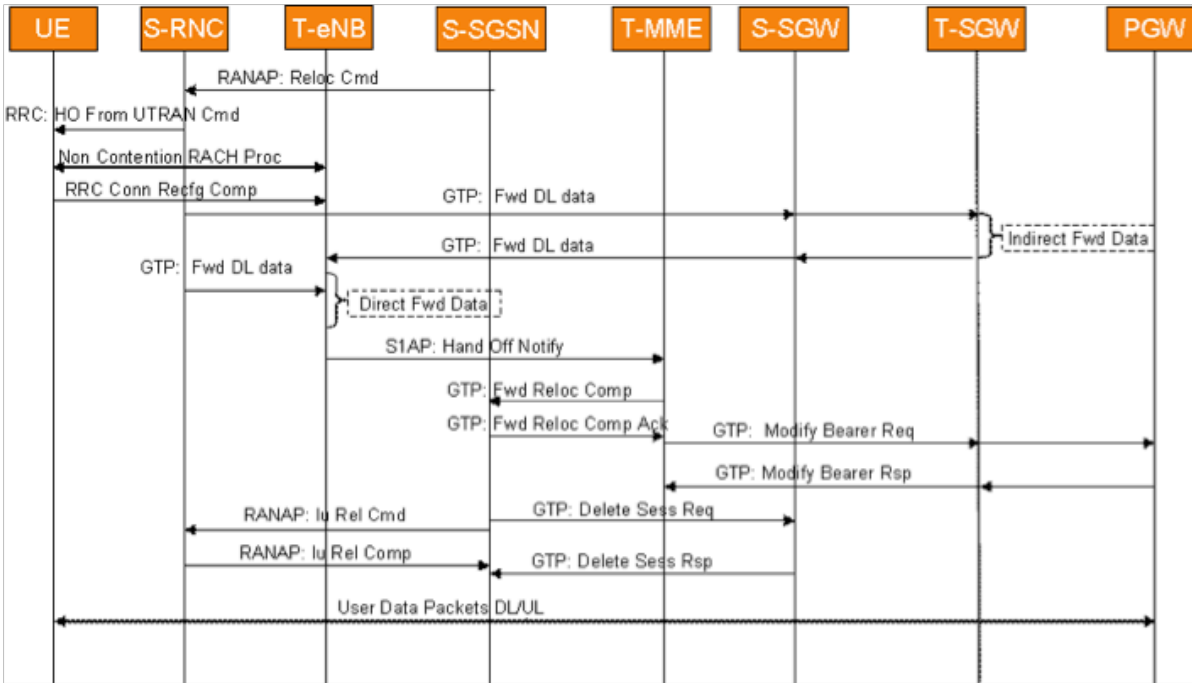6. The T-eNB reserves the radio resources and responds to the T-MME with a S1AP: HANDOVER REQUEST ACK message.

Figure 8. *Inter-RAT UMTS-to-LTE Handover: Execution Phase*

7. The T-MME creates the indirect data forwarding tunnels in the T-SGW for the DL packets transfer from the S-SGW to the T-SGW during the handover if there is no direct forwarding path available from source to target.

8. After the Indirect Data forwarding tunnel creation, the T-MME responds with a GTP: FORWARD RELOCATION RESPONSE message to the S-SGSN.

9. The S-SGSN has to create the indirect data forwarding tunnels, as the resources are reserved successfully in the target network to forward the DL packets to the target network. With this, the preparation phase is complete.

Execution Phase

1. The S-SGSN sends the RANAP RELOCATION COMMAND message to the S-RNC with the target to source transparent container (it has the reserved resource information at the target).

2. The S-RNC prepares and sends the HO FROM UTRAN COMMAND message to prepare the UE for the handover toward the target network.

3. After accessing the T-eNB, the UE sends an RRC CONNECTION RECONFIGURATION COMPLETE message to the T-eNB signaling the successful handover.

4. The S-RNC forwards the DL data packets toward the T-SGW via the S-SGW during the handover. This step can happen any time after it receives the RANAP RELOCATION COMMAND message from the S-SGSN. This step is executed in case a direct forwarding path is not available with the T-eNB, otherwise it will forward the DL data packets to the T-eNB directly. Both the options are shown above in Figure 8.

5. Once the T-eNB detects the UE in its area, it notifies the T-MME about the completion of the handover by sending an S1AP: HANDOVER NOTIFY message.

6. The T-MME notifies the completion of handover to the S-SGSN by sending a GTP: FORWARD RELOCATION COMPLETE NOTIFICATION ACK message. The S-SGSN acknowledges this message and proceeds with the release of the resources associated with this UE at the S-SGW and S-RNC.

7. The T-MME modifies the E-RAB resources at the T-SGW by initiating the GTP MODIFY BEARER procedure.

8. The T-SGW notifies the bearer parameters with the PGW by initiating the GTP MODIFY BEARER procedure.

Conclusions

Inter-network mobility is a key facilitator for any communications technology to become more successful, and LTE is no exception. It can serve as a powerful tool for maximizing the value of existing access resources and assist in quickly realizing revenue from the deployment of new wireless broadband access technologies. In this paper we covered the interoperability to and from LTE and UMTS technologies.

References

[1] 3GPP TS 23.401: "GPRS Enhancements for E-UTRAN Access."

[2] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol Specification."

[3] 3GPP TS 36.413: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)."

[4] 3GPP TS 36.423: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)."

[5] 3GPP TS 25.331: "UMTS Radio Resource Control (RRC) Protocol specification."

[6] 3GPP TS 25.413 "UMTS: UTRAN Iu Interface RANAP Signaling."

[7] 3GPP TS 29.274: "3G PP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunneling Protocol for Control Plane (GTPv2-C)."

[8] 3GPP TS 29.060: "General Packet Radio Service (GPRS); GPRS Tunneling Protocol (GTP) Across the Gn and Gp Interface."

[9] 3GPP TS 24.301: "Non-Access-Stratum (NAS) Protocol for Evolved Packet System (EPS)."

[10] "LTE E-UTRAN and its Access Side Protocols" white paper by Suyash Tripathi, Vinay Kulkarni, and Alok Kumar.

[11] "Signaling Procedures in LTE" white paper by V. Srinivasa Rao and Rambabu G.

radisys

(intel)
**Embedded
Alliance
Premier**