

LTE AND BEYOND

LTE, 4G, EPC, MME, PGW, SGW, Interfaces and beyond tech-blog by Bart Barton

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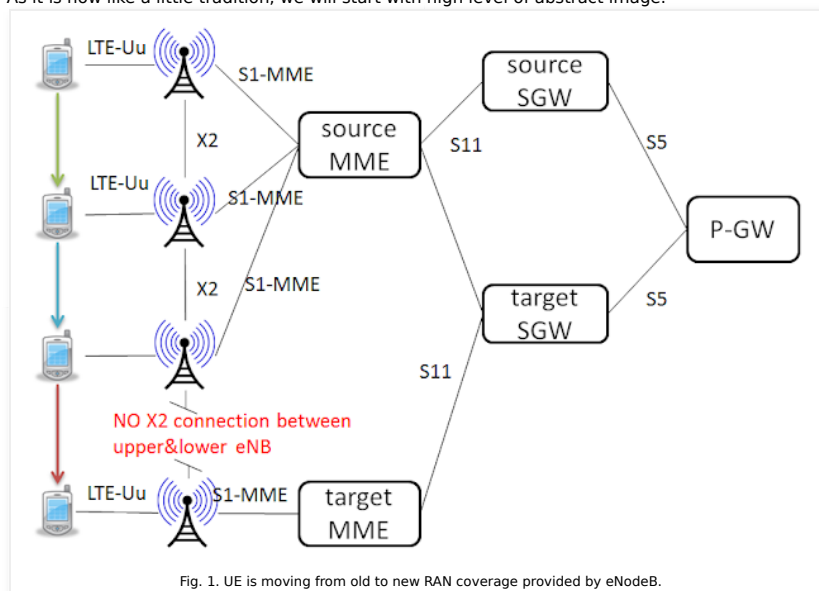
S1 interface based handover

Last two articles (you can find them [here1](#) and [here2](#)) were about handover in scenario where there is direct connectivity between eNB. But what happen when there is no X2 connection old and new eNodeB?

Answer to that is S1 based handover procedure which you can find described below.

All of this information you can find by reading specific section of [3GPP TS 23.401](#) document.

As it is now like a little tradition, we will start with high level of abstract image.



This image should look familiar for those who was reading about X2-based handover. The thing what has change in this scenario is that there is lack of connectivity between two eNBs between which UE moves.

That's why, to do the handover the MME has to be involved directly. If you compare previous cases with this one, the first thing that each one of you should notice is that here eNodeB is contacting with MME, and the target eNodeB address is found because of SGW.

Before we will see detailed call flow please keep in mind few general S1 handover information.

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GENERAL S1 BASED HANDOVER INFORMATION

The S1-based handover procedure is used when the X2-based handover cannot be used. The source eNodeB initiates a handover by sending Handover Required message over the S1-MME reference point. This procedure may relocate the MME and/or the Serving GW. The source MME selects the target MME. The MME should not be relocated during inter-eNodeB handover unless the UE leaves the MME Pool Area where the UE is served. The MME (target MME for MME relocation) determines if the Serving GW needs to be relocated. If the Serving GW needs to be relocated the MME selects the target Serving GW.

The source eNodeB decides which of the EPS bearers are subject for forwarding of downlink and optionally also uplink data packets from the source eNodeB to the target eNodeB. The EPC does not change the decisions taken by the RAN node. Packet forwarding can take place either directly from the source eNodeB to the target eNodeB, or indirectly from the source eNodeB to the target eNodeB via the source and target Serving GWs (or if the Serving GW is not relocated, only the single Serving GW).

The availability of a direct forwarding path is determined in the source eNodeB and indicated to the source MME. If X2 connectivity is available between the source and target eNodeBs, a direct forwarding path is available.

If a direct forwarding path is not available, indirect forwarding may be used. The source MME uses the indication from the source eNodeB to determine whether to apply indirect forwarding. The source MME indicates to the target MME whether indirect forwarding should apply. Based on this indication, the target MME determines whether it applies indirect forwarding.

If the MME receives a rejection to an S1 interface procedure (e.g. dedicated bearer establishment/modification/release; location reporting control; NAS message transfer; etc.) from the eNodeB with an indication that an S1 handover is in progress, the MME shall reattempt the same S1 interface procedure when either the handover is complete or is deemed to have failed if the MME is still the serving MME, except in case of Serving GW relocation.

In order to minimise the number of procedures rejected by the eNodeB, the MME should pause non-handover related S1 interface procedures (e.g. downlink NAS message transfer, E-RAB Setup/Modify/Release, etc.) while a handover is ongoing (i.e. from the time that a Handover Required has been received until either the Handover procedure has succeeded (Handover Notify) or failed (Handover Failure)) and continue them once the Handover procedure has completed if the MME is still the serving MME, except in case of Serving GW relocation.

If during the handover procedure the MME detects that the Serving GW or/and the MME needs be relocated, the MME shall reject any PDN GW initiated EPS bearer(s) request received since handover started and shall include an indication that the request has been temporarily rejected due to handover procedure in progress. The rejection is forwarded by the Serving GW to the PDN GW, with the same indication.

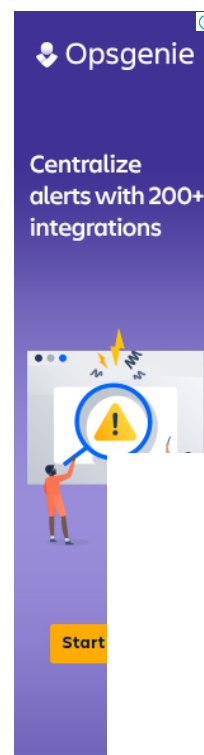
Upon receipt of a rejection for an EPS bearer(s) PDN GW initiated procedure with an indication that the request has been temporarily rejected due to handover procedure in progress, the PDN GW shall start a locally configured guard timer. The PDN GW shall re-attempt the procedure, up to a pre-configured number of times, when either it detects that the handover is completed or has failed using message reception or at expiry of the guard timer.

If emergency bearer services are ongoing for the UE, handover to the target eNodeB is performed independent of the Handover Restriction List. The MME checks, as part of the Tracking Area Update in the execution phase, if the handover is to a restricted area and if so MME releases the non-emergency bearers.

If the MME receives a rejection to a UE Context modification Request message with a CS Fallback indication from the eNodeB with an indication that an S1 handover is in progress, the MME shall resend a UE Context Modification Request message with CS Fallback indicator to the target eNodeB when either the handover is complete or to the source eNodeB when the handover is deemed to have failed if the MME is still the serving MME.

S1-BASED HANDOVER SCENARIO

This procedure describes the S1-based handover in the normal case, below I will describe when the procedure is rejected by the target eNodeB or the target MME and later here describe when the procedure is canceled by the source eNodeB.



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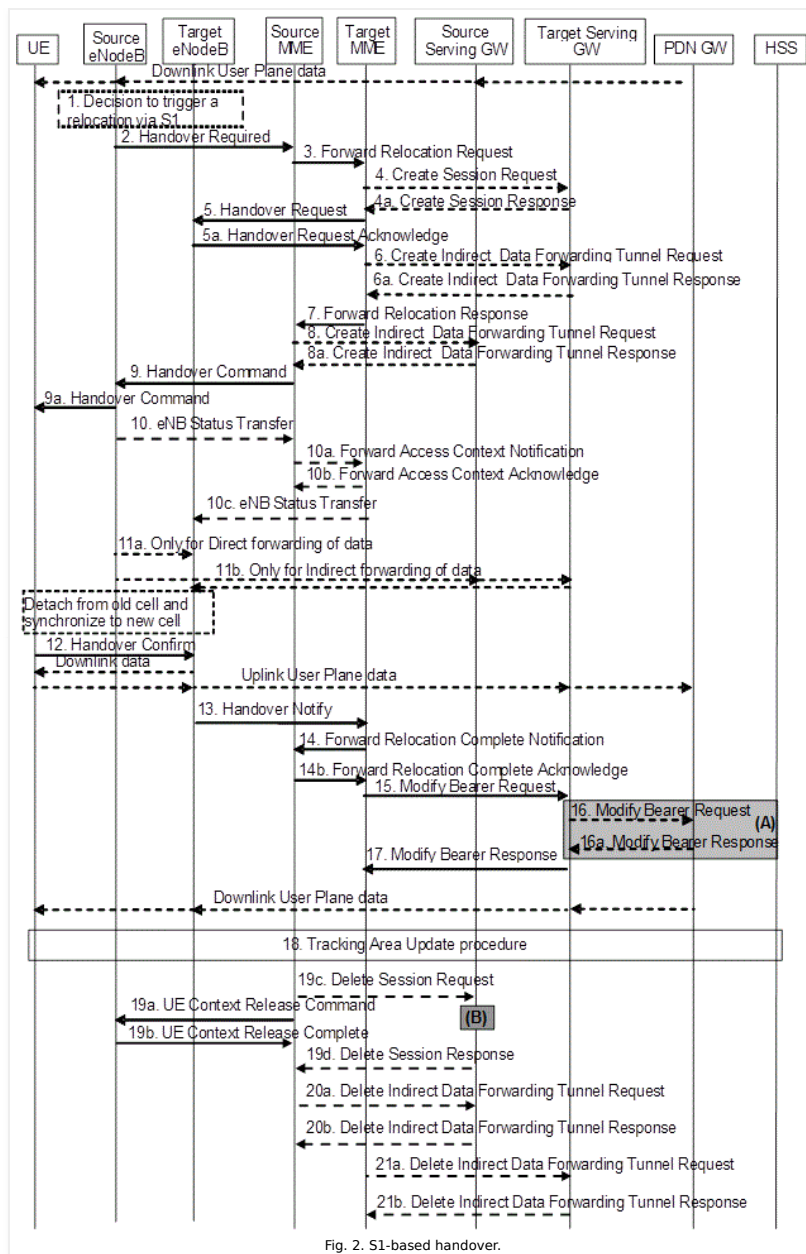


Fig. 2. S1-based handover.

Step 1. The source eNodeB decides to initiate an S1-based handover to the target eNodeB. This can be triggered e.g. by no X2 connectivity to the target eNodeB, or by an error indication from the target eNodeB after an unsuccessful X2-based handover, or by dynamic information learnt by the source eNodeB.

Step 2. The source eNodeB sends Handover Required (Direct Forwarding Path Availability, Source to Target transparent container, target eNodeB Identity, CSG ID, CSG access mode, target TAI, S1AP Cause) to the source MME. The source eNodeB indicates which bearers are subject to data forwarding. Direct Forwarding Path Availability indicates whether direct forwarding is available from the source eNodeB to the target eNodeB. This indication from source eNodeB can be based on e.g. the presence of X2. The target TAI is sent to MME to facilitate the selection of a suitable target MME. When the target cell is a CSG cell or a hybrid cell, the source eNodeB shall include the CSG ID of the target cell. If the target cell is a hybrid cell, the CSG access mode shall be indicated.

Step 3. The source MME selects the target MME and if it has determined to relocate the MME, it sends a Forward Relocation Request (MME UE context, Source to Target transparent container, RAN Cause, target eNodeB Identity, CSG ID, CSG Membership Indication, target TAI, MS Info Change Reporting Action (if available), CSG Information Reporting Action (if available), UE Time Zone, Direct Forwarding Flag) message to the target MME. The target TAI is sent to the target MME to help it to determine whether S GW relocation is needed (and, if needed, aid SGW selection). The source MME shall perform access control by checking the UE's CSG subscription when CSG ID is provided by the source eNodeB. If there is no subscription data for this CSG ID or the CSG subscription is expired, and the target cell is a CSG cell, the source MME shall reject the handover with an appropriate cause.

The MME UE context includes IMSI, ME Identity, UE security context, UE Network Capability, AMBR, Selected CN operator ID, APN restriction, Serving GW address and TEID for control signalling, and EPS Bearer context(s).

An EPS Bearer context includes the PDN GW addresses and TEIDs (for GTP-based S5/S8) or GRE keys (for PMIP-based S5/S8) at the PDN GW(s) for uplink traffic, APN, Serving GW addresses and

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TEIDs for uplink traffic, and TI.

RAN Cause indicates the S1AP Cause as received from source eNodeB.

The source MME includes the CSG ID in the Forward Relocation Request when the target cell is a CSG or hybrid cell. When the target cell is a hybrid cell, the CSG Membership Indication indicating whether the UE is a CSG member shall be included in the Forward Relocation Request message. The Direct Forwarding Flag indicates if direct forwarding is applied, or if indirect forwarding is going to be set up by the source side.

The target MME shall determine the Maximum APN restriction based on the APN Restriction of each bearer context in the Forward Relocation Request, and shall subsequently store the new Maximum APN restriction value.

If the UE receives only emergency services and the UE is UICCless, IMSI can not be included in the MME UE context in Forward Relocation Request message. For emergency attached UEs, if the IMSI cannot be authenticated, then the IMSI shall be marked as unauthenticated. Also, in this case, security parameters are included only if available.

Step 4. If the MME has been relocated, the target MME verifies whether the source Serving GW can continue to serve the UE. If not, it selects a new Serving GW. If the MME has not been relocated, the source MME decides on this Serving GW re-selection.

If the source Serving GW continues to serve the UE, no message is sent in this step. In this case, the target Serving GW is identical to the source Serving GW.

If a new Serving GW is selected, the target MME sends a Create Session Request (bearer context(s) with PDN GW addresses and TEIDs (for GTP-based S5/S8) or GRE keys (for PMIP-based S5/S8) at the PDN GW(s) for uplink traffic, Serving Network, UE Time Zone) message per PDN connection to the target Serving GW. The target Serving GW allocates the S GW addresses and TEIDs for the uplink traffic on S1-U reference point (one TEID per bearer). The target Serving GW sends a Create Session Response (Serving GW addresses and uplink TEID(s) for user plane) message back to the target MME.

Step 5. The Target MME sends Handover Request (EPS Bearers to Setup, AMBR, S1AP Cause, Source to Target transparent container, CSG ID, CSG Membership Indication, Handover Restriction List) message to the target eNodeB. This message creates the UE context in the target eNodeB, including information about the bearers, and the security context. For each EPS Bearer, the Bearers to Setup includes Serving GW address and uplink TEID for user plane, and EPS Bearer QoS. If the direct forwarding flag indicates unavailability of direct forwarding and the target MME knows that there is no indirect data forwarding connectivity between source and target, the Bearers to Setup shall include "Data forwarding not possible" indication for each EPS bearer. Handover Restriction List is sent if available in the Target MME.

S1AP Cause indicates the RAN Cause as received from source MME.

The Target MME shall include the CSG ID and CSG Membership Indication when provided by the source MME in the Forward Relocation Request message.

The target eNodeB sends a Handover Request Acknowledge (EPS Bearer Setup list, EPS Bearers failed to setup list Target to Source transparent container) message to the target MME. The EPS Bearer Setup list includes a list of addresses and TEIDs allocated at the target eNodeB for downlink traffic on S1-U reference point (one TEID per bearer) and addresses and TEIDs for receiving forwarded data if necessary. If the UE AMBR is changed, e.g. all the EPS bearers which are associated to the same APN are rejected in the target eNodeB, the MME shall recalculate the new UE-AMBR and signal the modified UE AMBR value to the target eNodeB.

If none of the default EPS bearers have been accepted by the target eNodeB, the target MME shall reject the handover.

If the target cell is a CSG cell, the target eNodeB shall verify the CSG ID provided by the target MME, and reject the handover with an appropriate cause if it does not match the CSG ID for the target cell. If the target eNodeB is in hybrid mode, it may use the CSG Membership Indication to perform differentiated treatment for CSG and non-CSG members.

Step 6. If indirect forwarding applies and the Serving GW is relocated, the target MME sets up forwarding parameters by sending Create Indirect Data Forwarding Tunnel Request (target eNodeB addresses and TEIDs for forwarding) to the Serving GW. The Serving GW sends a Create Indirect Data Forwarding Tunnel Response (target Serving GW addresses and TEIDs for forwarding) to the target MME. If the Serving GW is not relocated, indirect forwarding may be set up in **step 8** below. Indirect forwarding may be performed via a Serving GW which is different from the Serving GW used as the anchor point for the UE.

Step 7. If the MME has been relocated, the target MME sends a Forward Relocation Response (Cause, Target to Source transparent container, Serving GW change indication, EPS Bearer Setup List, Addresses and TEIDs) message to the source MME. For indirect forwarding, this message includes Serving GW Address and TEIDs for indirect forwarding (source or target). Serving GW change indication indicates a new Serving GW has been selected.

Step 8. If indirect forwarding applies, the source MME sends Create Indirect Data Forwarding Tunnel Request (addresses and TEIDs for forwarding) to the Serving GW. If the Serving GW is relocated it includes the tunnel identifier to the target serving GW.

The Serving GW responds with a Create Indirect Data Forwarding Tunnel Response (Serving GW addresses and TEIDs for forwarding) message to the source MME.

Indirect forwarding may be performed via a Serving GW which is different from the Serving GW used as the anchor point for the UE.

Step 9. The source MME sends a Handover Command (Target to Source transparent container, Bearers subject to forwarding, Bearers to Release) message to the source eNodeB. The Bearers subject to forwarding includes list of addresses and TEIDs allocated for forwarding. The Bearers to Release includes the list of bearers to be released.

Step 9a. The Handover Command is constructed using the Target to Source transparent container and is sent to the UE. Upon reception of this message the UE will remove any EPS bearers for which it did not receive the corresponding EPS radio bearers in the target cell.

Step 10. The source eNodeB sends the eNodeB Status Transfer message to the target eNodeB via the MME(s) to convey the PDCP and HFN status of the E-RABs for which PDCP status preservation applies. The source eNodeB may omit sending this message if none of the E-RABs of the UE shall be treated with PDCP status preservation.



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If there is an MME relocation the source MME sends this information to the target MME via the Forward Access Context Notification message which the target MME acknowledges. The source MME or, if the MME is relocated, the target MME, sends the information to the target eNodeB via the eNodeB Status Transfer message.

Step 11. The source eNodeB should start forwarding of downlink data from the source eNodeB towards the target eNodeB for bearers subject to data forwarding. This may be either direct (**step 11a**) or indirect forwarding (**step 11b**).

Step 12. After the UE has successfully synchronized to the target cell, it sends a Handover Confirm message to the target eNodeB. Downlink packets forwarded from the source eNodeB can be sent to the UE. Also, uplink packets can be sent from the UE, which are forwarded to the target Serving GW and on to the PDN GW.

Step 13. The target eNodeB sends a Handover Notify (TAI+ECGI) message to the target MME.

Step 14. If the MME has been relocated, the target MME sends a Forward Relocation Complete Notification () message to the source MME. The source MME in response sends a Forward Relocation Complete Acknowledge () message to the target MME. Regardless if MME has been relocated or not, a timer in source MME is started to supervise when resources in Source eNodeB and if the Serving GW is relocated, also resources in Source Serving GW shall be released. Upon receipt of the Forward Relocation Complete Acknowledge message the target MME starts a timer if the target MME allocated S GW resources for indirect forwarding.

Step 15. The MME sends a Modify Bearer Request (eNodeB address and TEID allocated at the target eNodeB for downlink traffic on S1 U for the accepted EPS bearers, ISR Activated) message to the target Serving GW for each PDN connection, including the PDN connections that need to be released. If the PDN GW requested UE's location and/or User CSG information (determined from the UE context), the MME also includes the User Location Information IE and/or User CSG Information IE in this message. If the UE Time Zone has changed, the MME includes the UE Time Zone IE in this message. For the case that neither MME nor S-GW changed, if ISR was activated before this procedure MME should maintain ISR. The UE is informed about the ISR status in the Tracking Area Update procedure.

The MME releases the non-accepted dedicated bearers by triggering the bearer release 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 MME.

If the default bearer of a PDN connection has not been accepted by the target eNodeB and there are other PDN connections active, the MME shall handle it in the same way as if all bearers of a PDN connection have not been accepted. The MME releases these PDN connections by triggering the MME requested PDN disconnection procedure.

When the Modify Bearer Request does not indicate ISR Activated the Serving GW deletes any ISR resources by sending a Delete Bearer Request to the other CN node that has bearer resources on the Serving GW reserved.

Step 16. If the Serving GW is relocated, the target Serving GW assigns addresses and TEIDs (one per bearer) for downlink traffic from the PDN GW. It sends a Modify Bearer Request (Serving GW addresses for user plane and TEID(s), Serving Network) message per PDN connection to the PDN GW(s). The S GW also includes User Location Information IE and/or UE Time Zone IE and/or User CSG Information IE if they are present in **step 15**. The Serving GW allocates DL TEIDs on S5/S8 even for non-accepted bearers. The PDN GW updates its context field and returns a Modify Bearer Response (Charging Id, MSISDN) message to the target Serving GW. The MSISDN is included if the PDN GW has it stored in its UE context. The PDN GW starts sending downlink packets to the target GW using the newly received address and TEIDs. These downlink packets will use the new downlink path via the target Serving GW to the target eNodeB.

If the Serving GW is not relocated, but has received the User Location Information IE and/or UE Time Zone IE and/or User CSG Information IE from the MME in **step 15**, the Serving GW shall inform the PDN GW(s) about these information that e.g. can be used for charging, by sending the message Modify Bearer Request (User Location Information IE, UE Time Zone IE, User CSG Information IE) to the PDN GW(s) concerned. A Modify Bearer Response message is sent back to the Serving GW.

If the Serving GW is not relocated and it has not received User Location Information IE nor UE Time Zone IE nor User CSG Information IE from the MME in **step 15**, no message is sent in this step and downlink packets from the Serving GW are immediately sent on to the target eNodeB.

Step 17. The target Serving GW sends a Modify Bearer Response message to the target MME. The message is a response to a message sent at **step 15**.

If the Serving GW does not change, the Serving GW shall send one or more "end marker" packets on the old path immediately after switching the path in order to assist the reordering function in the target eNodeB.

Step 18. The UE initiates a Tracking Area Update procedure when one of the conditions listed in clause "Triggers for tracking area update" applies.

The target MME knows that it is a Handover procedure that has been performed for this UE as it received the bearer context(s) by handover messages and therefore the target MME performs only a subset of the TA update procedure, specifically it excludes the context transfer procedures between source MME and target MME.

Step 19. When the timer started in **step 14** expires the source MME sends a UE Context Release Command () message to the source eNodeB. The source eNodeB releases its resources related to the UE and responds with a UE Context Release Complete () message. When the timer started in **step 14** expires and if the source MME received the Serving GW change indication in the Forward Relocation Response message, it deletes the EPS bearer resources by sending Delete Session Request (Cause, LBI) messages to the Source Serving GW. Cause indicates to the Source Serving GW that the Serving GW changes and the Source Serving GW shall not initiate a delete procedure towards the PDN GW. The Source Serving GW acknowledges with Delete Session Response () messages. If ISR has been activated before this procedure, the cause also indicates to the Source S GW that the Source S GW shall delete the bearer resources on the other old CN node by sending Delete Bearer Request message(s) to that CN node.

Step 20. If indirect forwarding was used then the expiry of the timer at source MME started at **step 14** triggers the source MME to send a Delete Indirect Data Forwarding Tunnel Request

message to the S GW to release the temporary resources used for indirect forwarding that were allocated at **step 8**.

Step 21. If indirect forwarding was used and the Serving GW is relocated, then the expiry of the timer at target MME started at **step 14** triggers the target MME to send a Delete Indirect Data Forwarding Tunnel Request message to the target S GW to release temporary resources used for indirect forwarding that were allocated at **step 6**.

S1-BASED HANDOVER REJECT SCENARIO

The Target eNodeB rejects the use of the Handover procedure if none of the requested bearers in the Handover Request message could be established. In this case no UE context is established in the target MME/eNodeB and no resources are allocated. Further, the Target MME rejects the handover request and clears all resource in Target eNodeB and Target MME if the Target eNodeB accepts the handover request but none of the default EPS bearers gets resources allocated. In both cases, the UE remains in the Source eNodeB/MME.

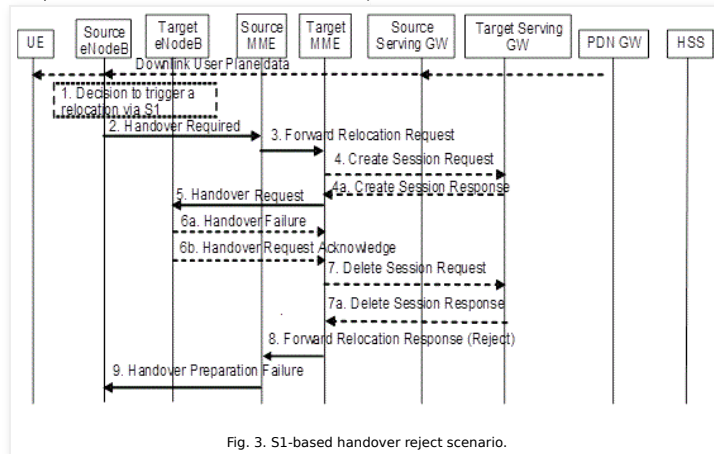


Fig. 3. S1-based handover reject scenario.

Step 1-5. Steps 1 to 5 in the flow are identical to **steps 1-5** mentioned in above scenario.

Step 6a. If the Target eNodeB fails to allocate any resources for any of the requested EPS bearers it sends a Handover Failure (Cause) message to the Target MME. The Target MME clears any reserved resources for this UE in the target MME.

Step 6b. If the Target MME receives a Handover Request Acknowledge message from the Target eNodeB but none of the default EPS bearers are in the EPS Bearer Setup list IE, the Target MME clears any reserved resources for this UE in both the Target MME and the Target eNodeB.

Step 7. This step is only performed for Serving GW relocation, i.e. if steps 4/4a have been performed. The Target MME deletes the EPS bearer resources by sending Delete Session Request (Cause) messages to the Target Serving GW. The Target Serving GW acknowledges with Delete Session Response (Cause) messages.

Step 8. The Target MME sends the Forward Relocation Response (Cause) message to the Source MME.

Step 9. When the Source MME receives the Forward Relocation Response message, it sends a Handover Preparation Failure (Cause) message to the Source eNodeB.

S1-BASED HANDOVER CANCEL SCENARIO

Instead of completing the handover procedure, the source eNodeB may at any time during the handover procedure, up to the time when a handover command message is sent to the UE cancel the handover.

The MME shall cancel the handover resources for case the source RAN is eNodeB.

Source(s):
3GPP TS 23.401

Posted by Unknown at 8:10 PM

Labels: Handover, S1
Location: Budapest, Hungary

9 comments:

Anonymous April 11, 2012 at 12:29 PM

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Unknown April 11, 2012 at 1:56 PM

Yep and next time if you will read more carefully in one of the first 10-15 lines you see this stand-alone note:
"All of this information you can find by reading specific section of 3GPP TS 23.401 document."

Please remember that (almost) any of your comments are welcome here.

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RF WIRELESS WORLD September 6, 2012 at 1:05 PM

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Unknown January 24, 2013 at 9:11 AM

Hi Bart, I'm new to LTE and to PS Core as well.
Could you please correct me if I'm wrong, during S1 handover there always will be indirect forwarding in use, as I understood direct forwarding is possible only over X2 interface.

Also I have question, which interface is used during indirect forwarding between S-GWs?

Thank you.

Yuriy from Ukraine.

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Unknown February 24, 2013 at 1:06 PM

Hii..
May I help you.. As I reading there are specific situtaion in which
using of S1 handover is mandatory even if there is X2 avalibility.

Regards

[Reply](#)



Unknown January 31, 2013 at 2:20 PM

Hi Bart, even my understanding is same. Direct forwarding in S1 based handover is same like X2 based handover. Please correct me if I am wrong. As of now, there is no specific interface name specified between two SGW incase on indirect forwarding.

Thanks,
manas from bangalore

[Reply](#)



Unknown February 24, 2013 at 1:08 PM

Hii Bart..
Thank you very much..
I have some question if you can help me..
what is the mean of "source to target tranparent container"?
why you do not mention a security and keys?

Regards

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[Replies](#)



Unknown February 24, 2013 at 2:05 PM

Hi Omar, thanks for your previous comment.
I skipped the security and keys, because I'm not very interested in radio part. But obviously those need to be exchanged when/slightly before syncing with new eNB.

The "Source to target transparent container" consists Radio Network part information (like RRC message to perform the HO and info about security) which is transparent form Core Point of view, and also the Core Network part. Look closely to 5th point above.
In case of S1 inter-eNB HO, the "Source (eNB) to Target (eNB) Transparent Container" is included. Try google for this, with or without brackets, I'm sure you will find detailed answer.

In general about Transparent Containers you can find here:
http://www.etsi.org/deliver/etsi_ts/143100_143199/143129/08.00.00_60/ts_143129v080000p.pdf on p.62, as it was in GERAN.
Or similar in 3GPP 29.280.

Hope this helps.

[Reply](#)**Unknown** April 2, 2020 at 8:18 PM

Hi Bart,,
Will the delete indirect data tunnel will happen when there is no MME change during s1 handover, if yes , why cant the same tunnel can be served for uplink and downlink , can you please help me

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