This sequence diagram was generated with EventStudio Sytem Designer - http://www.EventHelix.com/EventStudio/

eNodeBs in LTE are interconnected with the X2 interface. If two eNodeBs are served by the same MME, handover from the source to the target eNodeB will take place over the X2 interface.

Downlink data is flowing from the SGW to the UE via the Source eNodeB.

Uplink data is flowing from the UE to the SGW via the Source eNodeB.

Handover preparation

X2AP Handover Request

x2ap → x2ap

ECGI of the Target Cell (of Target eNB),
UE-AMBR,
UE Security Capability,
KeNB*,
E-RAB to be setup (E-RAB ID, QCI, ARP, S1 S-GW TEID

The Source eNodeB initiates the handover with the Handover Request message. Information about active E-RABs, security keys is included in the message. (Click on the message name above the arrow to see message details)

Generate AS keys from KeNB (KeNB = KeNB*)

Uplink S1 Bearer Establishment

s1_teid_ul2 ↔ s1_teid_ul2

GTP connect for the uplink side is established between the Target eNodeB and the serving SGW.

Perform admission control the E-RABs in the message

Check if resources are available at the target eNodeB to accept this session.

Create DRB ID (Uplink / Downlink)

Assign Dedicated Radio Bearer ids for Uplink and Downlink.

RRC: Reserve downlink and uplink radio resources for the session

The Target eNodeB allocates radio resources for the UE that will be handed in.

allocate
RACH Preamble

The Target eNodeB allocates a RACH preamble to the UE. The UE will use this preamble to send a contention free RACH.

allocate
C-RNTI

A new C-RNTI is assigned to the UE.

RRC: Prepare the Handover Command message (RRC Connection Reconfiguration Request)

This message includes the RACH preamble that needs to be sent to the terminal. This message includes information about the assigned radio resources.

X2AP Handover Request Acknowledge

x2ap → x2ap

E-RAB ID,
Target X2 eNB TEID,
Transparent container = Handover Command

The Target eNodeB responds back to the source eNodeB with a Handover Request Acknowledge message. This message carries the Handover Command message (RRC Connection Reconfiguration Request) in a transparent container. (Click on the message name above the arrow to see message details)

X2 Bearer Esablishment

x2_teid ↔ x2_teid

An X2 GTP connection is established between the Source and the Target eNodeBs. This channel will carry the user data during the handover.

begin
Buffering downlink data

At this point, the UE is ready to buffer downlink data that will be received during the handover.

Handover execution

X2AP SN Transfer Status

x2ap ← x2ap

Downlink PDCP Sequence Number,
Uplink PDCP Sequence Number

The PDCP sequence numbers are sent from the source to the target eNodeB. (Click on the message name above the arrow to see message details)

Downlink data flow during handover preparation

At this point all downlink data is getting rerouted from the source eNodeB to the target eNode. The data is being buffered at the target as the UE is yet to connect to the target.

Downlink Data

x2_teid ← x2_teid

Buffer the received downlink data

The uplink data is still being sent from the UE to the SGW via the Source eNodeB.

Synchronizing with target cell

RACH Preamble

rrc → rrc

UE uses the preamble assigned in the handover command to send a RACH to the target eNodeB.

Random Access Response

rrc ← rrc

Timing Advance,
Target C-RNTI,
Uplink grant

The target eNodeB accepts the request and responds back with a timing adjustment and an uplink resource grant.

RRC Connection Reconfiguration Complete

rrc → rrc

Target C-RNTI

The UE uses the assigned resources to transmit the Handover Confirm message (RRC Connection Reconfiguration Complete).

AS layer security procedure

RRC-Connected

The UE is not connected to the Target eNodeB. Thus it transitions to the RRC-Connected state.

Transmit transmission of queued downlink data

The UE is now connected to the target eNodeB. All the queued messages are now transmitted towards the UE.

Downlink Data

Downlink Data

Downlink Data

Downlink data flow during handover execution

During handover execution the data being routed from the SGW to the UE via the source and the target eNodeBs.

Downlink Data

x2_teid ← x2_teid

Downlink Data

Uplink data flow during handover execution

The uplink data is now being transmitted from the UE to the SGW via the target eNodeB.

Uplink Data

Uplink Data

s1_teid_ul2 → s1_teid_ul2

Handover completion

Switching path

At this point, the UE is receiving and transmitting data. The downlink data transmission towards the terminal is still being routed via the source eNodeB. The path will now be switched to remove the source eNodeB from the path.

S1AP Path Switch Request

ECGI,
TAI,
UE Security Capability,
E-RAB to be switched in DL (E-RAB ID, S1 Target eNB TEID)

The target eNodeB requests the MME to switch the path from the source eNodeB to the target eNodeB. (Click on the message name above the arrow to see message details)

Send end marker

The SGW also inserts an end marker towards the source eNodeB. This marker will be used to sequence the data received from the source eNodeB and the new data received from the target eNodeB.

End Marker

x2_teid ← x2_teid

Keep receiving the data from the source eNodeB until the end marker is received

The target eNodeB will buffer data directly received from the SGW until all the data received via the source eNodeB has been transmitted. This is needed to maintain the transmission order.

Downlink data flow after handover

Downlink Data

s1_teid_dl2 ← s1_teid_dl2

SGW is now sending the data using the target eNodeB TEID.

Downlink Data

S1AP Path Switch Request Ack

E-RAB to be switched in UL (E-RAB ID)

MME responds back to signal the completion of the path swiitch. (Click on the message name above the arrow to see message details)

X2AP UE Context Release

x2ap → x2ap

The end marker has been received at the Target eNodeB. At this point

the target asks the source eNodeB to release resources for the UE. (Click on the message name above the arrow to see message details)