LTE eNB - 5G gNB dual connectivity (EN-DC) with EPC flow

E-UTRAN New Radio - Dual Connectivity (EN-DC) is a technology that enables introduction of 5G services and data rates in a predominantly 4G network. UEs supporting EN-DC can connect simultaneously to LTE Master Node eNB (MN-eNB) and 5G-NR Secondary Node gNB (SN-gNB). This approach permits cellular providers to roll out 5G services without the expense of a full scale 5G Core Network. 5G gNBs can be introduced early in areas with high traffic congestion.

An EN-DC enabled UE first registers for service with the 4G EPC. The UE also starts reporting measurements on 5G frequencies. If the signal quality for the UE will support a 5G service, the LTE eNB communicates with the 5G-NR gNB to assign resources for a 5G bearer. The 5G-NR resource assignment is then signaled to the UE via an LTE RRC Connection Reconfiguration message. Once the RRC Connection Reconfiguration procedure is completed, the UE simultaneously connects to the 4G and 5G networks.

Click on message interactions involving UE, MN-eNB and SN-gNB for a detailed description.

4G-LTE attach procedure

1:Prepare the list of PLMNs that support 5G-NR

This list will be included in the SIB2 transmission.

2:System Information Information Block Type 2
PLMN-InfoList-r15

The SIB2 broadcast from the MN-eNB signals the presence of 5G-NR PLMNs via the PLMN-InfoList-r15.

3:Random Access Preamble

The terminal initiates a new session with the randomly selected preamble.

4:PDCCH DCI Format 1A

5:Random Access Response

The eNodeB responds to the preamble with the "Random Access Response" message on the DL-SCH.

6:RRC Connection Request
UL-SCH,
C-RNTI,
UE-Identity = S-TMSI,
Establishment Cause = mo-Signalling

The UE uses a UL-SCH allocation to send the RRC Connection Request message.

7:RRC Connection Setup (SRB1)
DL-SCH,
C-RNTI,
SRB Identity,
DL AM RLC,
UL AM RLC,
UL-SCH Config,
PHR Config,
Uplink Power Control

eNodeB responds with an RRC Connection Setup message on the DL-SCH.

8:RRC Connection Setup Complete
[NAS Attach Request (DCNR)]
[PDN Connectivity Request]
UE Network Capability = {DCNR bit, ...}

The UE signals the completion of the RRC connection. The message carries the NAS Attach Request. The DCNR bit in the "UE Network Capability" IE is set. This signals to the 4G Core Network that the UE supports dual connectivity with 4G-LTE and 5G-NR.

9:S1AP Initial UE Message
[Attach Request (DCNR)]
[PDN Connectivity Request]
UE Network Capability = {DCNR bit, ...}

The NAS messages from the UE are signaled to the Core Network via the Initial UE message.

10:Downlink NAS Transport
[Authentication Request]

MME initiates the authentication procedure

11:Uplink NAS Transport
[Authentication Response]

Authentication is successfully completed.

12:Downlink NAS Transport
[NAS Security Mode Command]

MME initiates NAS level security procedure.

13:Uplink NAS Transport
[NAS Security Mode Complete]

NAS level security procedure is completed. From this point, all communication between MME and UE will be encrypted.

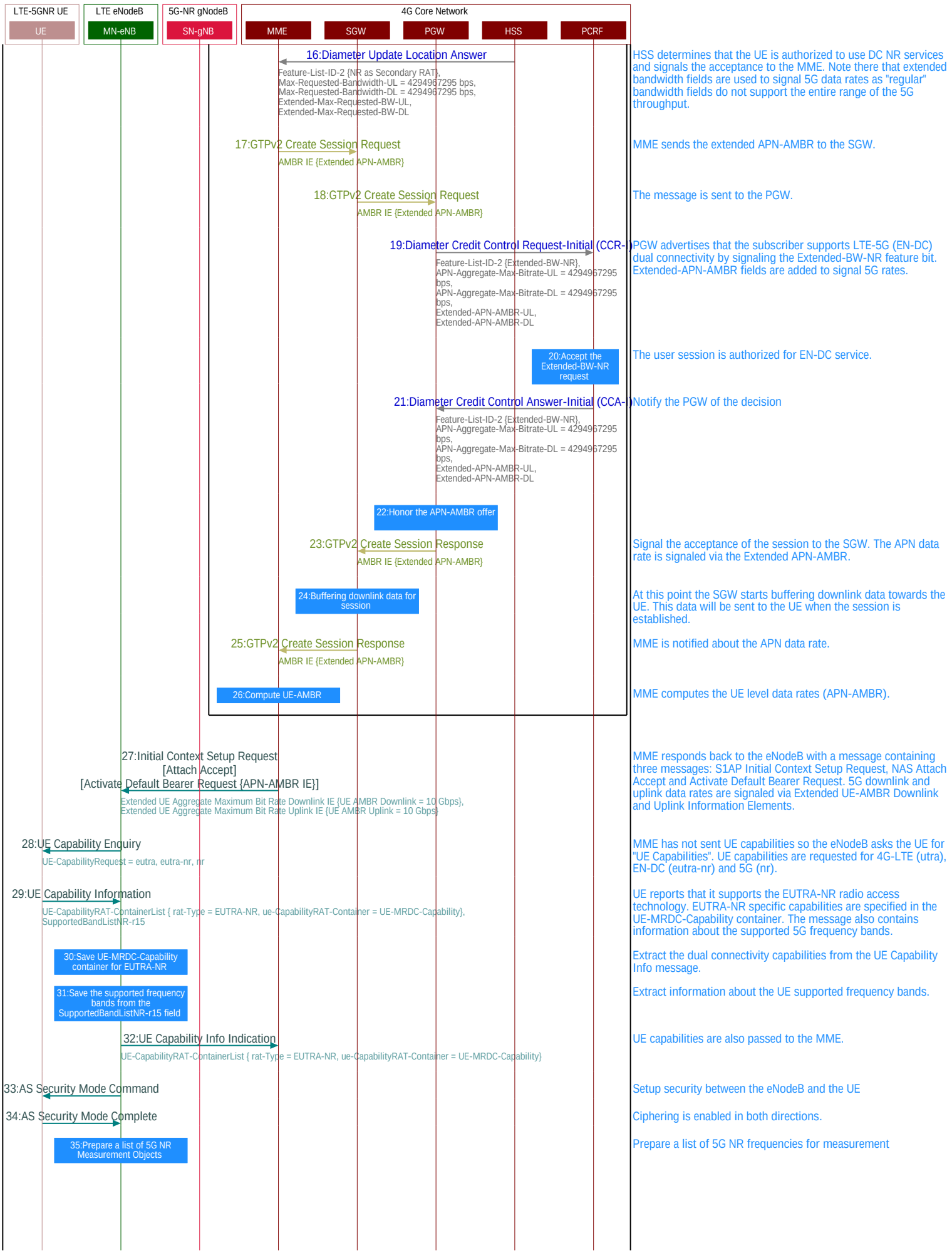
Activating NR-DC Dual 5G connectivity at the Core Network

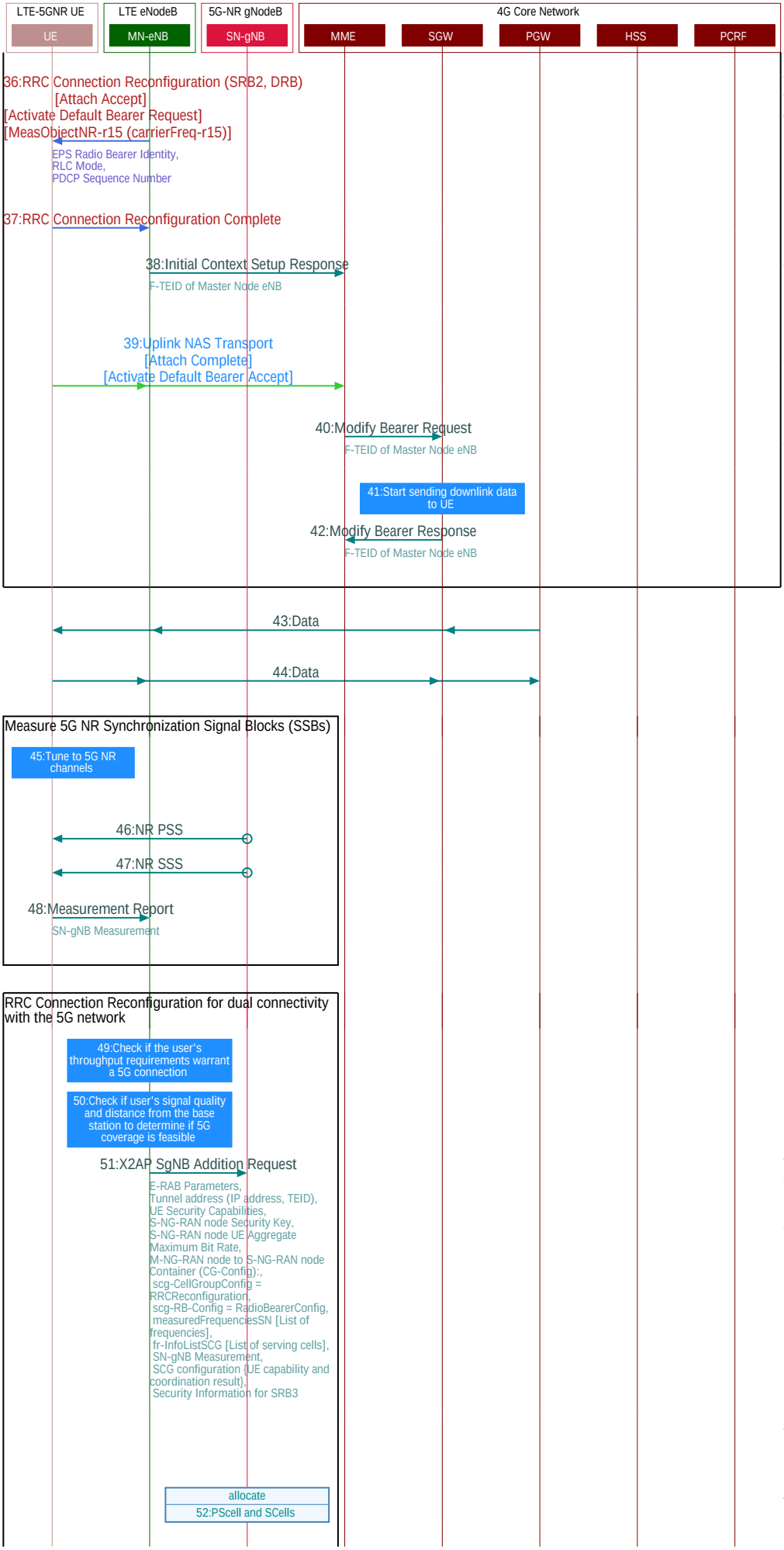
14:Diameter Update Location Request
Feature-List-ID-2 {NR as Secondary RAT}

MME initiates the Location Request and signals to the HSS that the UE has requested that 5G-NR may be used as a secondary radio access technology (RAT).

15:Confirm that UE is authorized for DCNR services

The HSS checks if the UE is permitted to use Dual Connectivity to 5G NR services.


LTE-5GNR UE
UE
LTE eNodeB
MN-eNB
5G-NR gNodeB
SN-gNB
4G Core Network
MME
SGW
PGW
HSS
PCRF
16:Diameter Update Location Answer
Feature-List-ID-2 {NR as Secondary RAT},
Max-Requested-Bandwidth-UL = 4294967295 bps,
Max-Requested-Bandwidth-DL = 4294967295 bps,
Extended-Max-Requested-BW-UL,
Extended-Max-Requested-BW-DL
HSS determines that the UE is authorized to use DC NR services and signals the acceptance to the MME. Note there that extended bandwidth fields are used to signal 5G data rates as "regular" bandwidth fields do not support the entire range of the 5G throughput.
17:GTPv2 Create Session Request
AMBR IE {Extended APN-AMBR}
MME sends the extended APN-AMBR to the SGW.
18:GTPv2 Create Session Request
AMBR IE {Extended APN-AMBR}
The message is sent to the PGW.
19:Diameter Credit Control Request-Initial (CCR-)
Feature-List-ID-2 {Extended-BW-NR},
APN-Aggregate-Max-Bitrate-UL = 4294967295 bps,
APN-Aggregate-Max-Bitrate-DL = 4294967295 bps,
Extended-APN-AMBR-UL,
Extended-APN-AMBR-DL
PGW advertises that the subscriber supports LTE-5G (EN-DC) dual connectivity by signaling the Extended-BW-NR feature bit. Extended-APN-AMBR fields are added to signal 5G rates.
20:Accept the Extended-BW-NR request
The user session is authorized for EN-DC service.
21:Diameter Credit Control Answer-Initial (CCA-)
Feature-List-ID-2 {Extended-BW-NR},
APN-Aggregate-Max-Bitrate-UL = 4294967295 bps,
APN-Aggregate-Max-Bitrate-DL = 4294967295 bps,
Extended-APN-AMBR-UL,
Extended-APN-AMBR-DL
Notify the PGW of the decision
22:Honor the APN-AMBR offer
23:GTPv2 Create Session Response
AMBR IE {Extended APN-AMBR}
Signal the acceptance of the session to the SGW. The APN data rate is signaled via the Extended APN-AMBR.
24:Buffering downlink data for session
At this point the SGW starts buffering downlink data towards the UE. This data will be sent to the UE when the session is established.
25:GTPv2 Create Session Response
AMBR IE {Extended APN-AMBR}
MME is notified about the APN data rate.
26:Compute UE-AMBR
MME computes the UE level data rates (APN-AMBR).
27:Initial Context Setup Request
[Attach Accept]
[Activate Default Bearer Request {APN-AMBR IE}]
Extended UE Aggregate Maximum Bit Rate Downlink IE {UE AMBR Downlink = 10 Gbps},
Extended UE Aggregate Maximum Bit Rate Uplink IE {UE AMBR Uplink = 10 Gbps}
MME responds back to the eNodeB with a message containing three messages: S1AP Initial Context Setup Request, NAS Attach Accept and Activate Default Bearer Request. 5G downlink and uplink data rates are signaled via Extended UE-AMBR Downlink and Uplink Information Elements.
28:UE Capability Enquiry
UE-CapabilityRequest = eutra, eutra-nr, nr
MME has not sent UE capabilities so the eNodeB asks the UE for "UE Capabilities". UE capabilities are requested for 4G-LTE (utra), EN-DC (eutra-nr) and 5G (nr).
29:UE Capability Information
UE-CapabilityRAT-ContainerList { rat-Type = EUTRA-NR, ue-CapabilityRAT-Container = UE-MRDC-Capability},
SupportedBandListNR-r15
UE reports that it supports the EUTRA-NR radio access technology. EUTRA-NR specific capabilities are specified in the UE-MRDC-Capability container. The message also contains information about the supported 5G frequency bands.
30:Save UE-MRDC-Capability container for EUTRA-NR
Extract the dual connectivity capabilities from the UE Capability Info message.
31:Save the supported frequency bands from the SupportedBandListNR-r15 field
Extract information about the UE supported frequency bands.
32:UE Capability Info Indication
UE-CapabilityRAT-ContainerList { rat-Type = EUTRA-NR, ue-CapabilityRAT-Container = UE-MRDC-Capability}
UE capabilities are also passed to the MME.
33:AS Security Mode Command
Setup security between the eNodeB and the UE
34:AS Security Mode Complete
Ciphering is enabled in both directions.
35:Prepare a list of 5G NR Measurement Objects
Prepare a list of 5G NR frequencies for measurement



The RRC Connection Reconfiguration message is sent to activate the default radio bearer. The message also carries the Attach Accept message as NAS Payload. The message includes measurement objects for 5G NR frequencies.

UE signals the completion of the RRC Connection Reconfiguration.

eNodeB responds back to the Initial Context Setup message. The message also contains the GTP TEID that should be used for sending downlink data to the eNodeB.

UE signals the completion of Attach and default bearer activation.

MME modifies the bearer and sends the TEID to use for downlink data.

Respond back to MME.

Downlink data is flowing on the default bearer.

Uplink data is flowing on the default bearer.

Initiate measurement of 5G NR channels specified in the Measurement Objects received in the RRC Connection Reconfiguration. These measurements are scheduled during measurement gaps.

UE acquires the 5G-NR Primary Synchronization Signal.

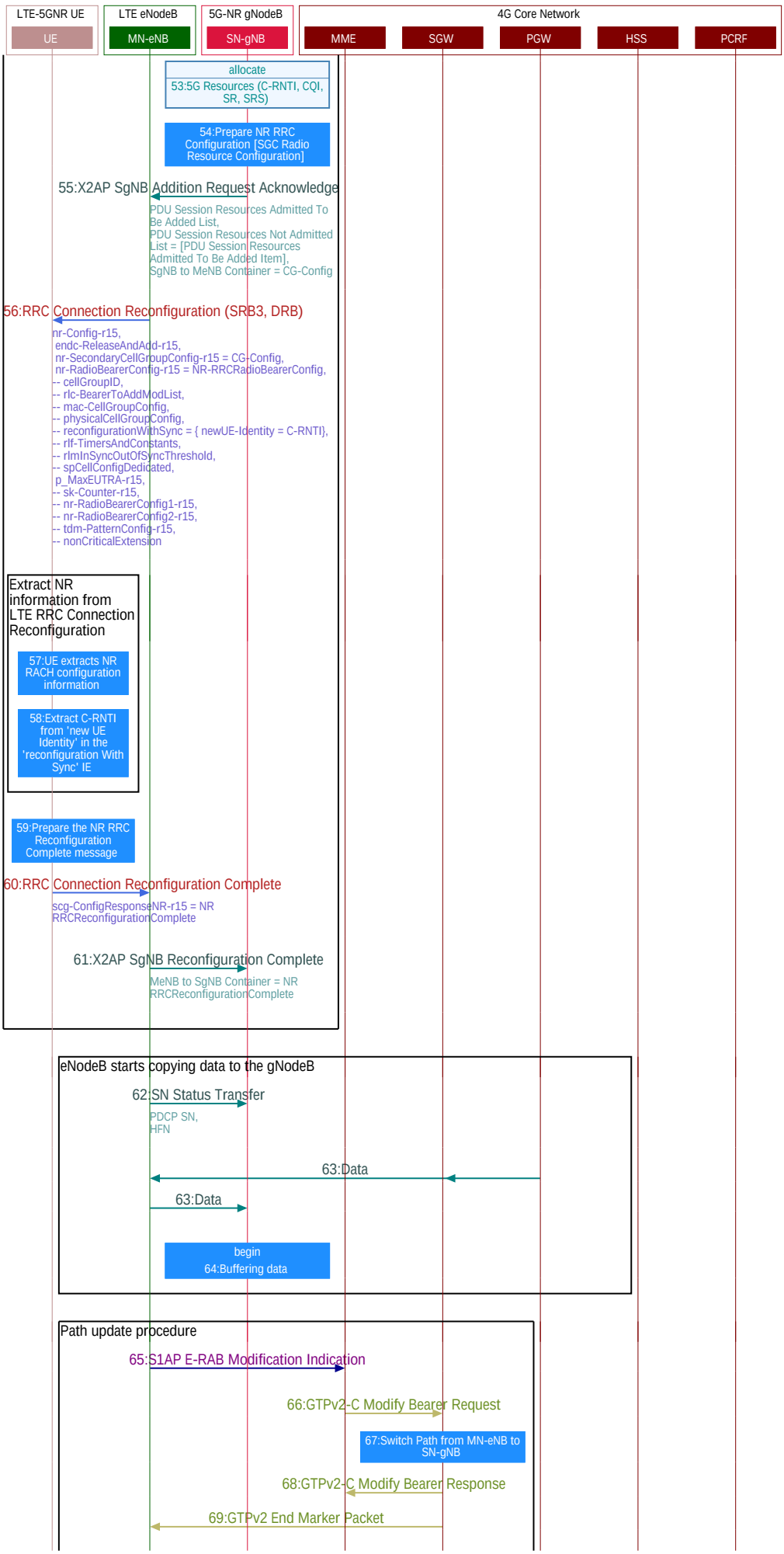
UE acquires the 5G-NR Secondary Synchronization Signal and measures the signal quality.

5G signal quality is reported back to 4G eNB.

The 4G LTE eNodeB decides to add the 5G-NR base station as a secondary node. The eNodeB sends a Secondary Node Addition Request to the gNodeB. The message carries the RRC and Radio Bearer configuration. UE capabilities and security information are also included in the message.

The network indicates whether the UE shall use either KeNB (master node key) or S-KgNB (secondary node key) for the 5G DRB.

Allocate 5G cells



Allocate the 5G radio resources needed for the secondary session.

The NR RRC Configuration will be transmitted to the UE via the MN-eNB.

The gNodeB responds with information about the radio resources and bearers admitted with the 5G network. The NR RRC configuration message is included in the message.

The 4G eNodeB sends an RRC Connection Reconfiguration to the UE. The message assigns 5G radio resources to the UE.

Extract the 5G NR RACH information parameters that will be needed to access the 5G network.

Extract the C-RNTI assigned for 5G access.

This message will be sent via the LTE RRC Connection Reconfiguration Complete message.

The UE signals the receipt of the RRC Connection Reconfiguration to the LTE eNodeB. The message carries the "NR RRC Reconfiguration Complete" message meant for the SN-gNB.

The 4G eNodeB informs the secondary node (gNodeB) about the reconfiguration complete. The "NR RRC Reconfiguration Complete" message is delivered to the SN-gNB via the "MeNB to SgNB" container.

eNodeB informs the gNodeB about the PDCP SN and HFN for all the bearers that are being transferred to 5G.

SGW is sending data to the MN-eNB. The MN-eNB keeps forwarding that data to the SN-gNB.

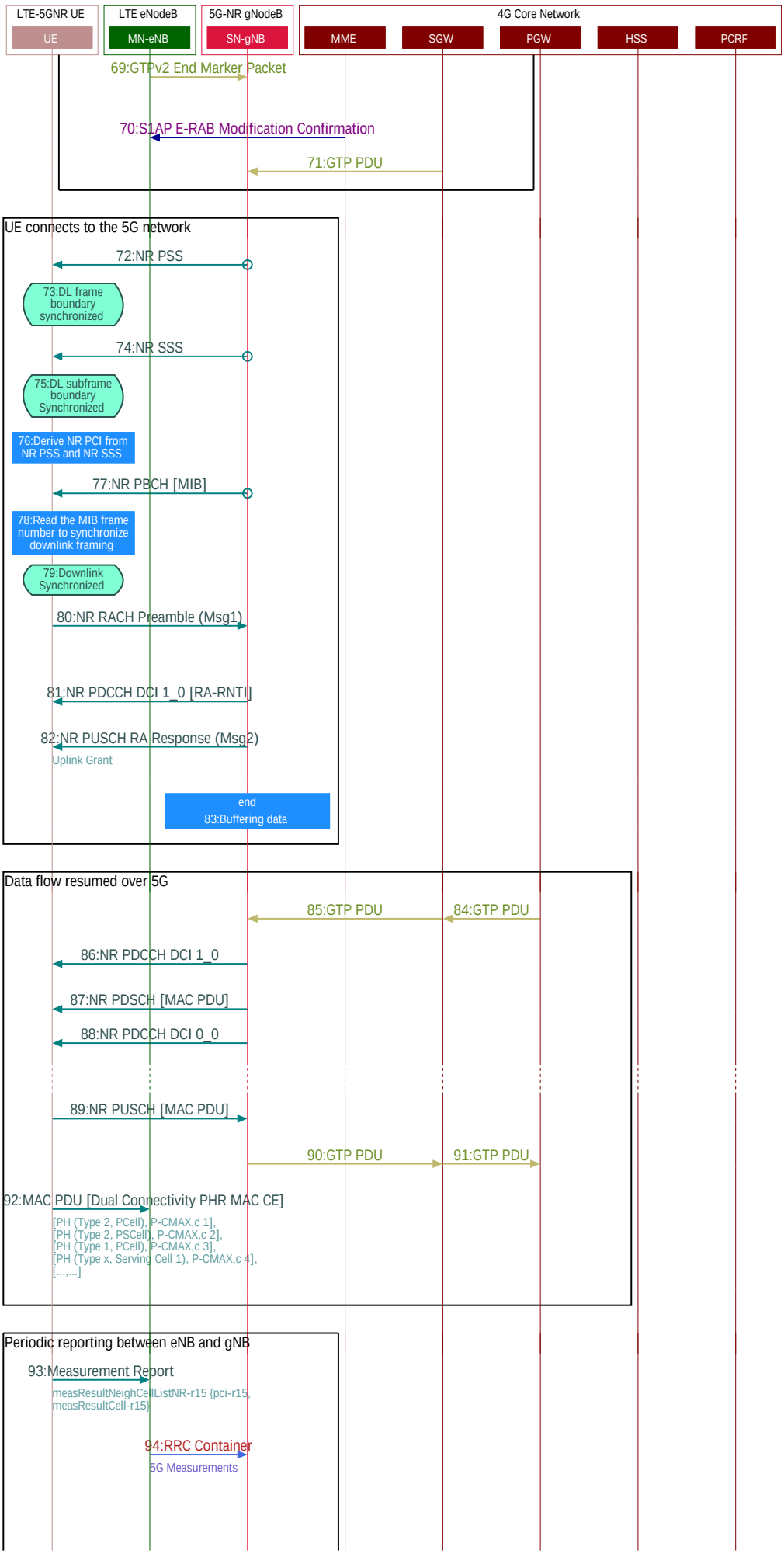
At this point, the gNodeB is buffering the data as the UE has not established the 5G path.

Notify the MME that the data bearer is being switched from 4G-LTE to 5G-NR.

MME updates the bearer at the SGW.

Switching the data path from the eNodeB to gNodeB.

Respond back to the MME.



Send the End Marker to the eNodeB. This marks the end of data transmission to the 4G-eNodeB. Subsequent data transmissions will be towards the 5G-gNodeB.

MME responds back the eNodeB.

Data is now being sent directly to the 5G-gNodeB.

UE acquires the 5G-NR Primary Synchronization Signal.

The UE is synchronized with the NR downlink frame boundary.

UE acquires the 5G-NR Secondary Synchronization Signal.

The UE is synchronized with the NR downlink subframe boundary.

The UE derives the NR Physical Cell Identifier from the NR PSS and NR SSS.

UE acquires the 5G-NR Broadcast Channel.

The UE has achieved complete downlink synchronization.

The UE initiates the random-access procedure with the 5G gNodeB. Non-contention based random-access will be attempted if the preamble assignment was received in the RRC Connection Reconfiguration message.

NR PDCCH signals downlink resource allocation for the RA Response.

The 5G secondary node gNodeB responds with an RA Response. The message also carries an uplink grant for Msg3 transmission.

The gNodeB stops buffering data and starts data transmission.

Data is now being directly routed from the 4G SGW to the 5G gNodeB.

NR PDCCH signals downlink resource block allocations for PDSCH.

The eNodeB transmits the PDSCH.

gNodeB assigns uplink resource blocks.

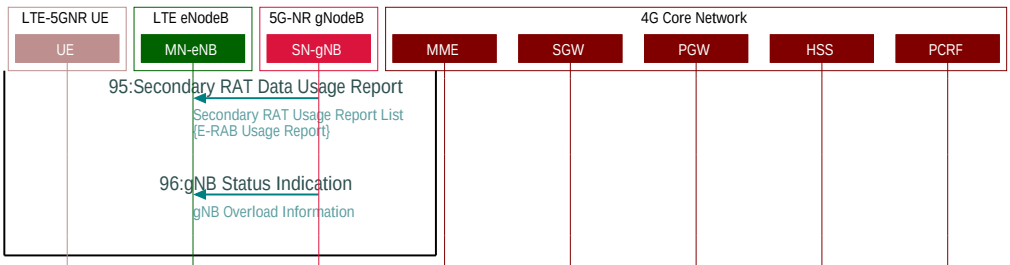
The UT receives the DCH 0_0 grant and transmits the PUSCH in the uplink direction.

Uplink data is being transported from the 5G gNodeB to the 4G SGW.

Periodically, the UE reports the Power Headroom to the the MN-eNB. The PHR MAC CE contains the power headroom for the cells on the MN-eNB and SN-gNB cells.

The UE reports measurements to the MN-eNB. The measurements include results from 5G NR cells.

The MN-eNB reports these measurements to the SN-gNB.



Periodically, the SN-gNB reports the usage statistics for 5G NR bearers to the MN-eNB.

The SN-gNB also reports any overload information to the MN-eNB.

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