LTE-5GNR UE	LTE eNodeB	5G-NR gNodeB	4G Core Network				
UE	MN-eNB	SN-gNB	MME	SGW	PGW	HSS	PCRF

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 eNB and 5G-NR 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.

4G-LTE attach procedure

1:Random Access Preamble (UE → MN-eNB)

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

2:Random Access Response (MN-eNB → UE)

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

3:RRC Connection Request (UE → MN-eNB)

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.

4:RRC Connection Setup (SRB1) (MN-eNB → UE)

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.

5:RRC Connection Setup Complete [NAS Attach Request (DCNR)] [PDN Connectivity Request] (UE → MN-eNB)

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.

6:S1AP Initial UE Message [Attach Request (DCNR)] [PDN Connectivity Request] (MN-eNB → MME)

UE Network Capability = {DCNR bit, ...}

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

7:Downlink NAS Transport [Authentication Request] (MME → UE)

MME initiates the authentication procedure

8:Uplink NAS Transport [Authentication Response] (UE → MME)

Authentication is successfully completed.

9:Downlink NAS Transport [Security Mode Command] (MME → UE)

MME initiates NAS level security procedure.

10:Uplink NAS Transport [Security Mode Complete] (UE → MME)

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

11:Diameter Update Location Request (MME → HSS)

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).

12:Confirm that UE is authorized for DCNR services (HSS)

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

13:Diameter Update Location Answer (HSS → MME)

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.

14:GTPv2 Create Session Request (MME → SGW)

AMBR IE {Extended APN-AMBR}

MME sends the extended APN-AMBR to the SGW.

LTE-5GNR UE	LTE eNodeB	5G-NR gNodeB	4G Core Network				
UE	MN-eNB	SN-gNB	MME	SGW	PGW	HSS	PCRF

15:GTPv2 Create Session Request
AMBR IE {Extended APN-AMBR}

The message is sent to the PGW.

16:Diameter Credit Control Request-Initial (CCR-I)
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.

17:Accept the Extended-BW-NR request

The user session is authorized for EN-DC service.

18:Diameter Credit Control Answer-Initial (CCA-I)
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

19:Honor the APN-AMBR offer

20: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.

21: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.

22:GTPv2 Create Session Response
AMBR IE {Extended APN-AMBR}

MME is notified about the APN data rate.

23:Compute UE-AMBR

MME computes the UE level data rates (APN-AMBR).

24: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.

25:RRC UE Capability Enquiry

MME has not sent UE capabilities so the eNodeB asks the UE for "UE Capabilities".

26:RRC UE Capability Information
UE-CapabilityRAT-ContainerList { rat-Type = EUTRA-NR, ue-CapabilityRAT-Container = UE-MRDC-Capability}

UE reports that it supports the EUTRA-NR radio access technology. EUTRA-NR specific capabilities are specified in the UE-MRDC-Capability container.

27:Save UE-MRDC-Capability container for EUTRA-NR

28: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.

29:RRC Security Mode Command

Setup security between the eNodeB and the UE

30:RRC Security Mode Complete

Ciphering is enabled in both directions.

31:RRC Connection Reconfiguration (SRB2, DRB)
[Attach Accept]
[Activate Default Bearer Request]
EPS Radio Bearer Identity,
RLC Mode,
PDCP Sequence Number

The RRC Connection Reconfiguration message is sent to activate the default radio bearer. The message also carries the Attach Accept message as NAS Payload.

32:RRC Connection Reconfiguration Complete

UE signals the completion of the RRC Connection Reconfiguration.

33:Initial Context Setup Response
F-TEID of Master Node eNB

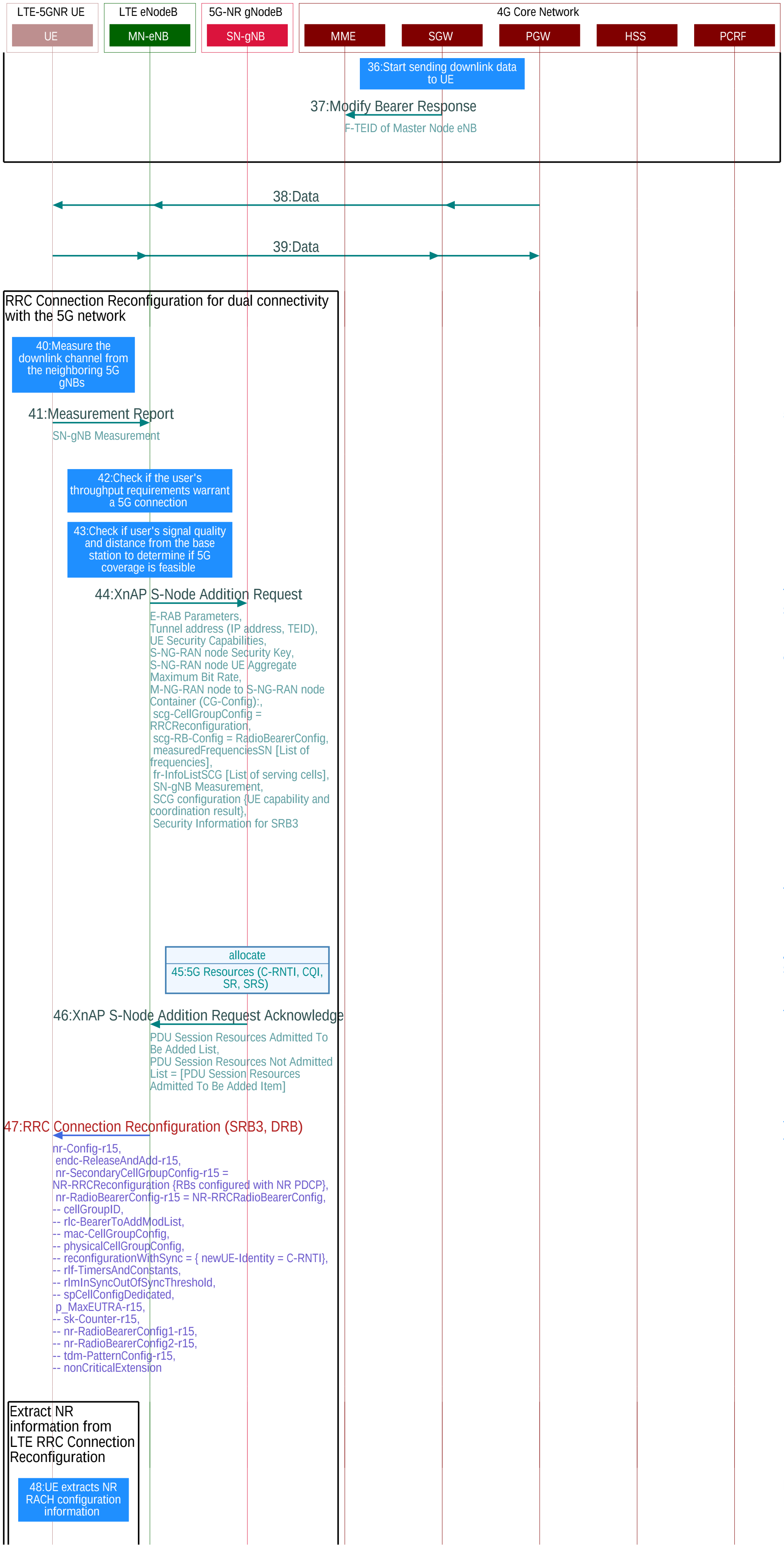
eNodeB responds back to the Initial Context Setup message. The message also contains the GTP TEID that should be used for sending downlink data to the eNodeB.

34:Uplink NAS Transport
[Attach Complete]
[Activate Default Bearer Accept]

UE signals the completion of Attach and default bearer activation.

35:Modify Bearer Request
F-TEID of Master Node eNB

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.

UE measures 5G-AN cell 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.

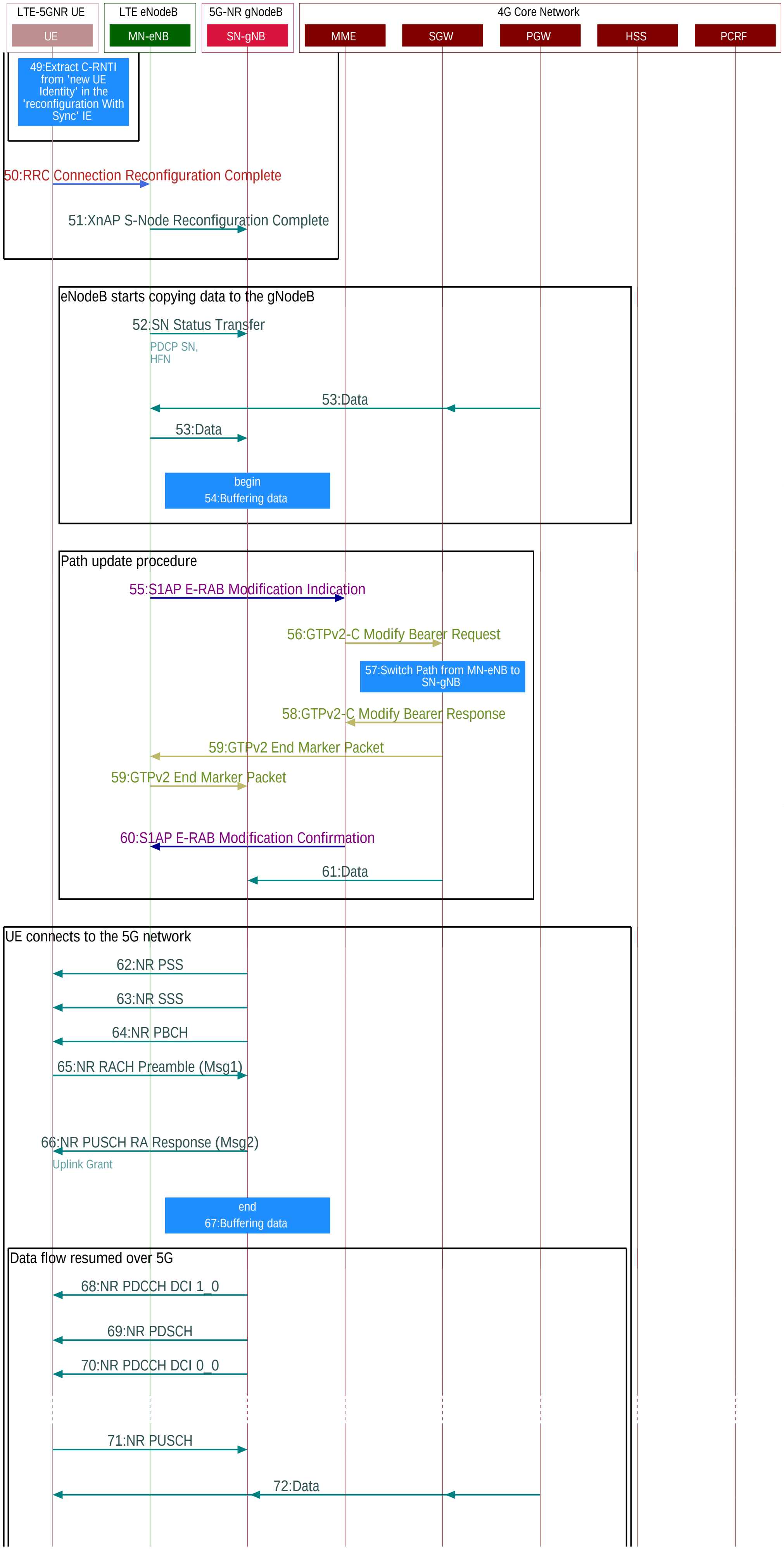
The network indicates whether the UE shall use either KeNB (master node key) or S-KgNB (secondary node key) for the 5G DRB.

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

The gNodeB responds with information about the radio resources and bearers admitted with the 5G network.

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.

The UE signals the receipt of the RRC Connection Reconfiguration to the LTE eNodeB.

The 4G eNodeB informs the secondary node (gNodeB) about the reconfiguration complete.

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.

UE acquires the 5G-NR Secondary Synchronization Signal.

UE acquires the 5G-NR Broadcast Channel.

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.

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.

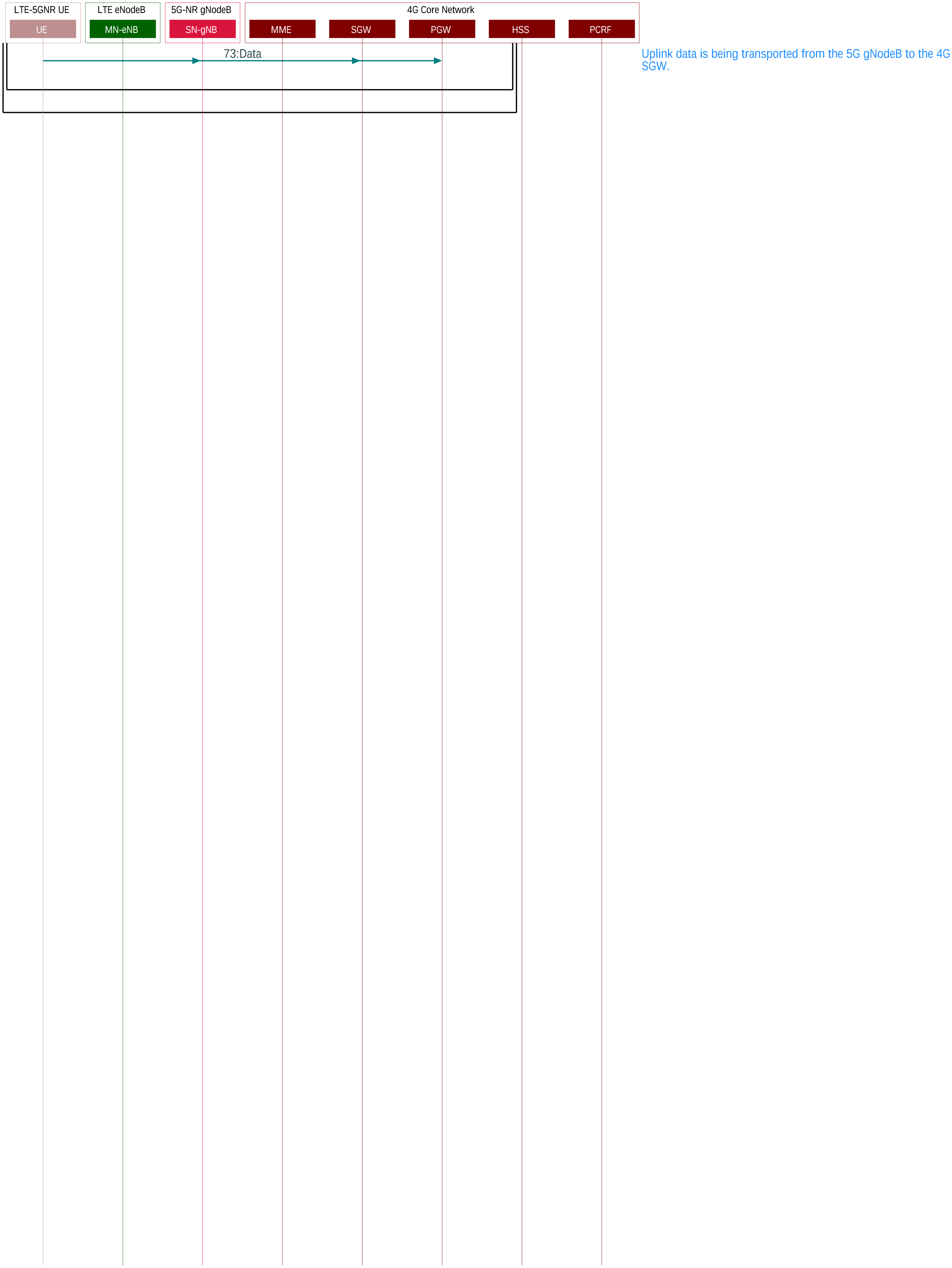
NR PDCCH signals downlink resource block allocations for PDSCH

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.

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


LTE-5GNR UE
UE
LTE eNodeB
MN-eNB
5G-NR gNodeB
SN-gNB
4G Core Network
MME
SGW
PGW
HSS
PCRF
73:Data
Uplink data is being transported from the 5G gNodeB to the 4G SGW.