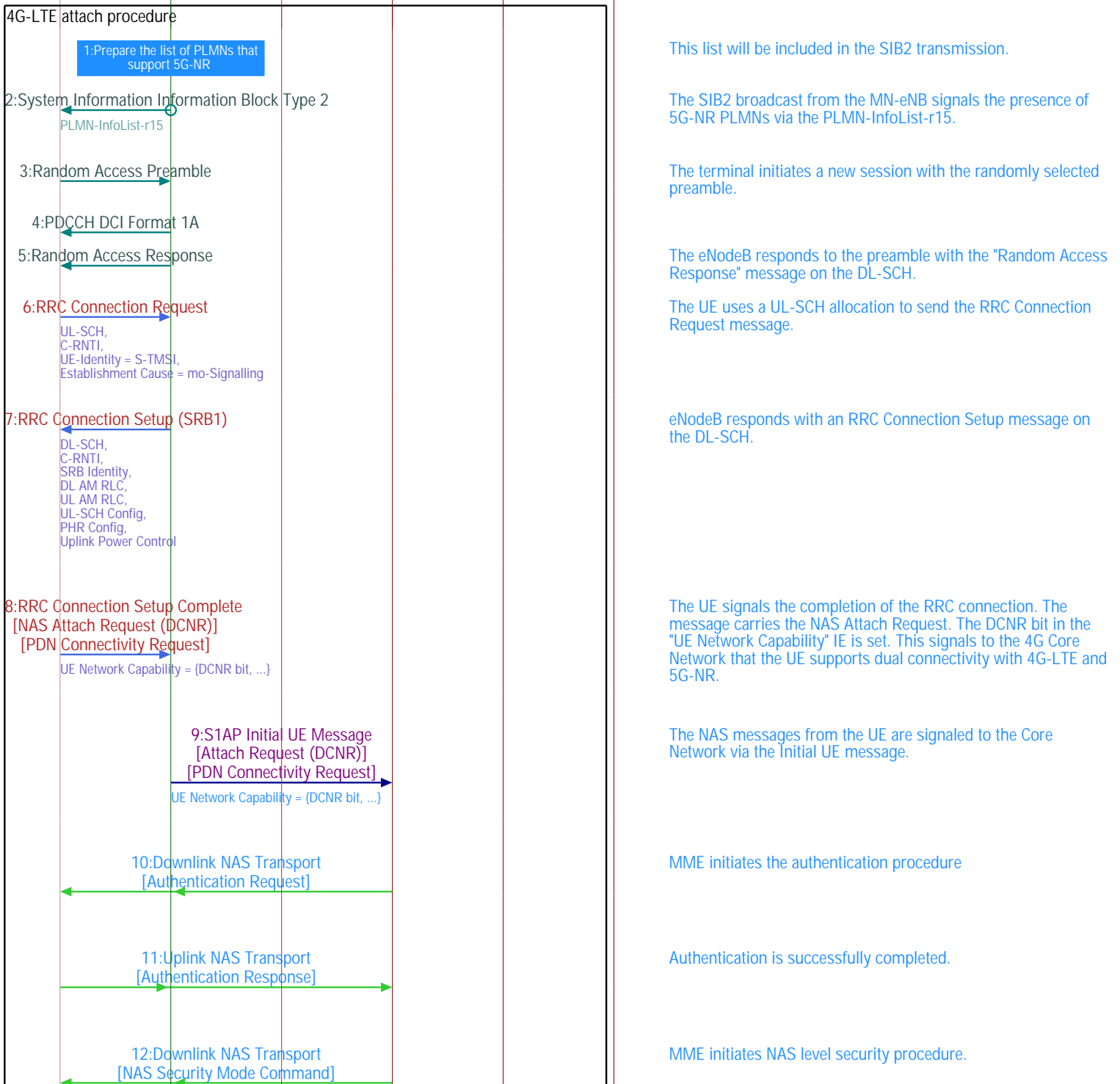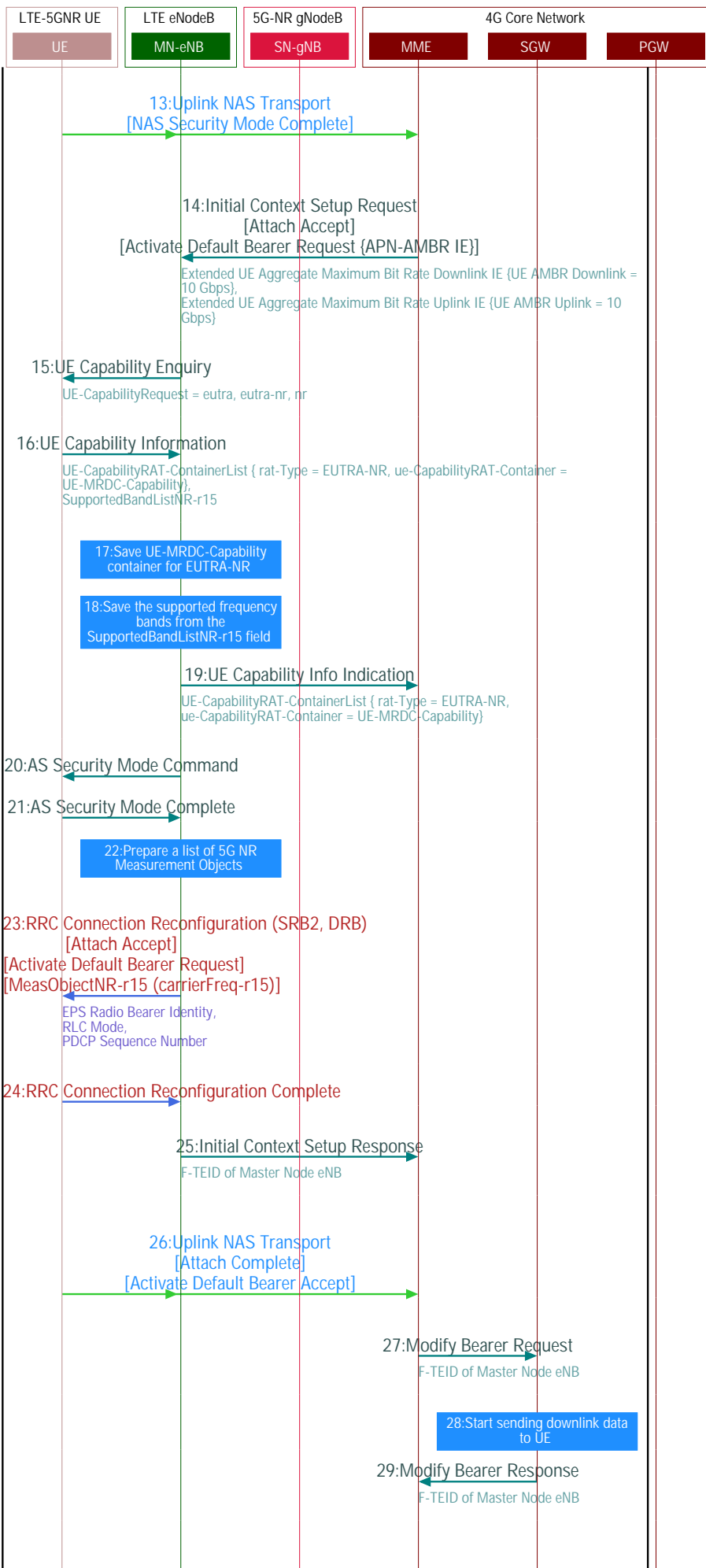| LTE-5GNR UE	LTE eNodeB	5G-NR gNodeB	4G Core Network		
UE	MN-eNB	SN-gNB	MME	SGW	PGW

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

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.

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

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.

14: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.

15: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).

16: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.

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

Extract the dual connectivity capabilities from the UE Capability Info message.

18:Save the supported frequency bands from the SupportedBandListNR-r15 field

Extract information about the UE supported frequency bands.

19: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.

20:AS Security Mode Command

Setup security between the eNodeB and the UE

21:AS Security Mode Complete

Ciphering is enabled in both directions.

22:Prepare a list of 5G NR Measurement Objects

Prepare a list of 5G NR frequencies for measurement

23:RRC Connection Reconfiguration (SRB2, DRB)
[Attach Accept]
[Activate Default Bearer Request]
[MeasObjectNR-r15 (carrierFreq-r15)]

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. The message includes measurement objects for 5G NR frequencies.
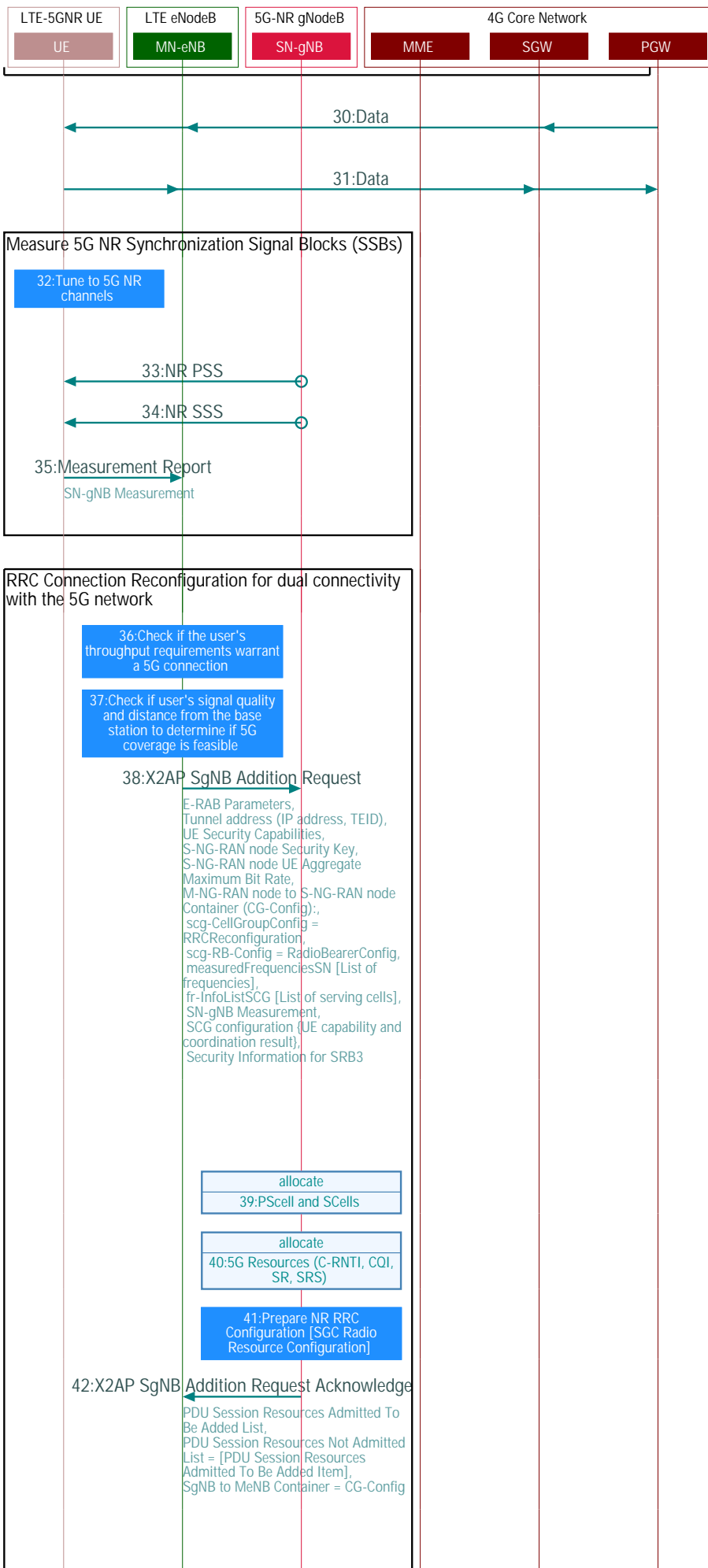
24:RRC Connection Reconfiguration Complete

UE signals the completion of the RRC Connection Reconfiguration.

25: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.

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

UE signals the completion of Attach and default bearer activation.

27:Modify Bearer Request

F-TEID of Master Node eNB

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

28:Start sending downlink data to UE

29:Modify Bearer Response

F-TEID of Master Node eNB

Respond back to MME.

LTE-5GNR UE
UE

LTE eNodeB
MN-eNB

5G-NR gNodeB
SN-gNB

4G Core Network
MME | **SGW** | **PGW**

30:Data

Downlink data is flowing on the default bearer.

31:Data

Uplink data is flowing on the default bearer.

Measure 5G NR Synchronization Signal Blocks (SSBs)

32:Tune to 5G NR channels

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

33:NR PSS

UE acquires the 5G-NR Primary Synchronization Signal.

34:NR SSS

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

35:Measurement Report

SN-gNB Measurement

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

RRC Connection Reconfiguration for dual connectivity with the 5G network

36:Check if the user's throughput requirements warrant a 5G connection

37:Check if user's signal quality and distance from the base station to determine if 5G coverage is feasible

38:X2AP SgNB Addition Request

E-RAB Parameters,
Tunnel address (IP address, TEID),
UE Security Capabilities,
S-NG-RAN node Security Key,
S-NG-RAN node UE Aggregate Maximum Bit Rate,
M-NG-RAN node to S-NG-RAN node Container (CG-Config):,
 scg-CellGroupConfig = RRCReconfiguration,
 scg-RB-Config = RadioBearerConfig,
 measuredFrequenciesSN [List of frequencies],
 fr-InfoListSCG [List of serving cells],
 SN-gNB Measurement,
 SCG configuration (UE capability and coordination result),
 Security Information for SRB3

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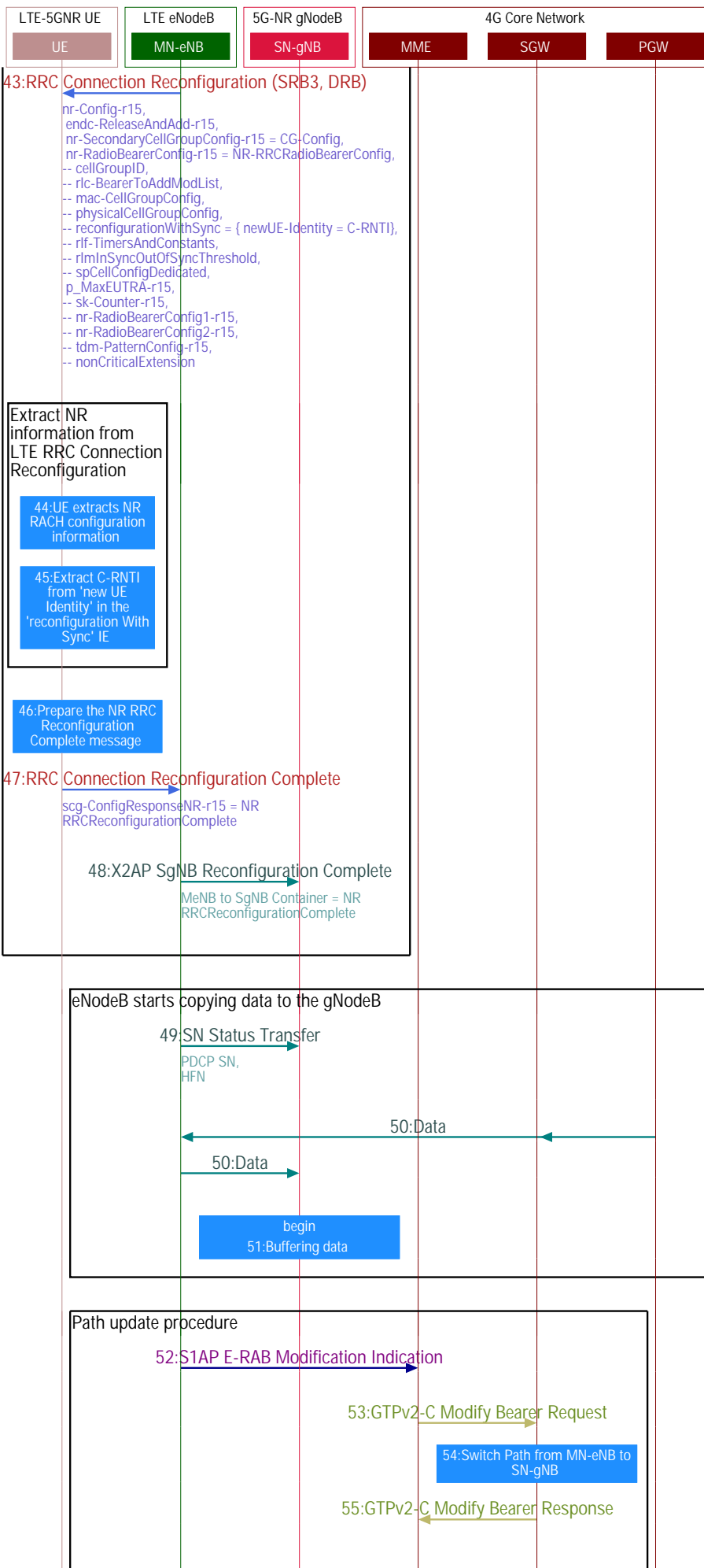
The network indicates whether the UE shall use either KeNB (master node key) or S-KgNB (secondary node key) for the 5G DRB.

allocate
39:PScell and SCells

Allocate 5G cells

allocate
40:5G Resources (C-RNTI, CQI, SR, SRS)

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

41:Prepare NR RRC Configuration [SGC Radio Resource Configuration]

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

42:X2AP SgNB Addition Request Acknowledge

PDU Session Resources Admitted To Be Added List,
PDU Session Resources Not Admitted List = [PDU Session Resources Admitted To Be Added Item],
SgNB to MeNB Container = CG-Config

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.

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

43:RRC Connection Reconfiguration (SRB3, DRB)

nr-Config-r15,
endc-ReleaseAndAdd-r15,
nr-SecondaryCellGroupConfig-r15 = CG-Config,
nr-RadioBearerConfig-r15 = NR-RRCRadioBearerConfig,
-- cellGroupID,
-- rlc-BearerToAddModList,
-- mac-CellGroupConfig,
-- physicalCellGroupConfig,
-- reconfigurationWithSync = { newUE-Identity = C-RNTI},
-- rlf-TimersAndConstants,
-- rlmInSyncOutOfSyncThreshold,
-- spCellConfigDedicated,
p_MaxEUTRA-r15,
-- sk-Counter-r15,
-- nr-RadioBearerConfig1-r15,
-- nr-RadioBearerConfig2-r15,
-- tdm-PatternConfig-r15,
-- nonCriticalExtension

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

Extract NR information from LTE RRC Connection Reconfiguration

44:UE extracts NR RACH configuration information

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

45:Extract C-RNTI from 'new UE Identity' in the 'reconfiguration With Sync' IE

Extract the C-RNTI assigned for 5G access.

46:Prepare the NR RRC Reconfiguration Complete message

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

47:RRC Connection Reconfiguration Complete

scg-ConfigResponseNR-r15 = NR
RRCReconfigurationComplete

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.

48:X2AP SgNB Reconfiguration Complete

MeNB to SgNB Container = NR
RRCReconfigurationComplete

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 starts copying data to the gNodeB

49:SN Status Transfer

PDCP SN,
HFN

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

50:Data

50:Data

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

begin
51:Buffering data

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

Path update procedure

52:S1AP E-RAB Modification Indication

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

53:GTPv2-C Modify Bearer Request

MME updates the bearer at the SGW.

54:Switch Path from MN-eNB to SN-gNB

Switching the data path from the eNodeB to gNodeB.

55:GTPv2-C Modify Bearer Response

Respond back to the MME.

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

56:GTPv2 End Marker Packet

56:GTPv2 End Marker Packet
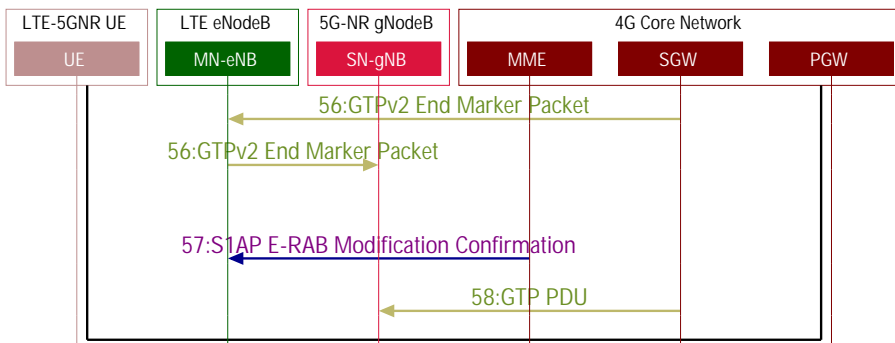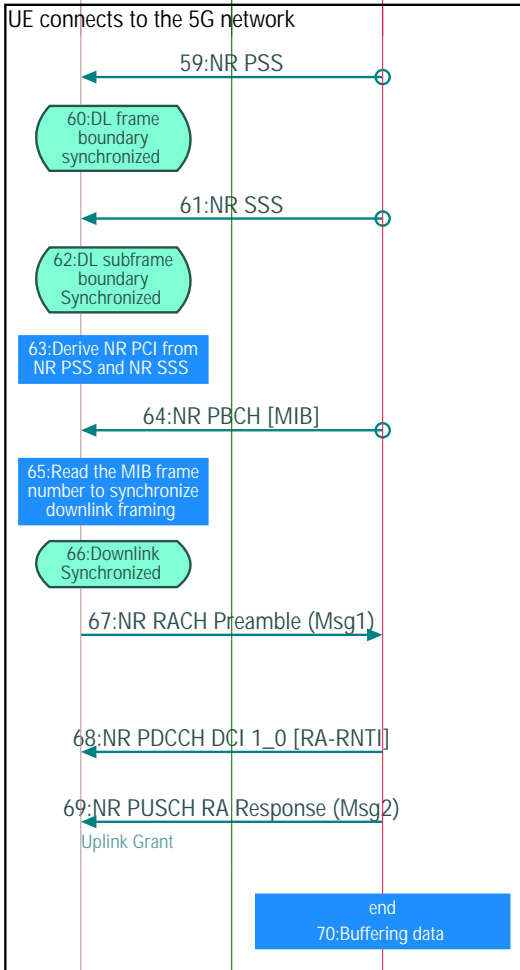
Send the End Marker to the eNodeB. This marks the end of data transmission to the 4G-eNodeB. Subsequent data transmissions will be towards the 5G-gNodeB.

57:S1AP E-RAB Modification Confirmation

MME responds back the eNodeB.

58:GTP PDU

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

UE connects to the 5G network

59:NR PSS

UE acquires the 5G-NR Primary Synchronization Signal.

60:DL frame boundary synchronized

The UE is synchronized with the NR downlink frame boundary.

61:NR SSS

UE acquires the 5G-NR Secondary Synchronization Signal.

62:DL subframe boundary Synchronized

The UE is synchronized with the NR downlink subframe boundary.

63:Derive NR PCI from NR PSS and NR SSS

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

64:NR PBCH [MIB]

UE acquires the 5G-NR Broadcast Channel.

65:Read the MIB frame number to synchronize downlink framing

66:Downlink Synchronized

The UE has achieved complete downlink synchronization.

67:NR RACH Preamble (Msg1)

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.

68:NR PDCCH DCI 1_0 [RA-RNTI]

NR PDCCH signals downlink resource allocation for the RA Response.

69:NR PUSCH RA Response (Msg2)
Uplink Grant

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

end
70:Buffering data

The gNodeB stops buffering data and starts data transmission.

Data flow resumed over 5G

72:GTP PDU   **71:GTP PDU**
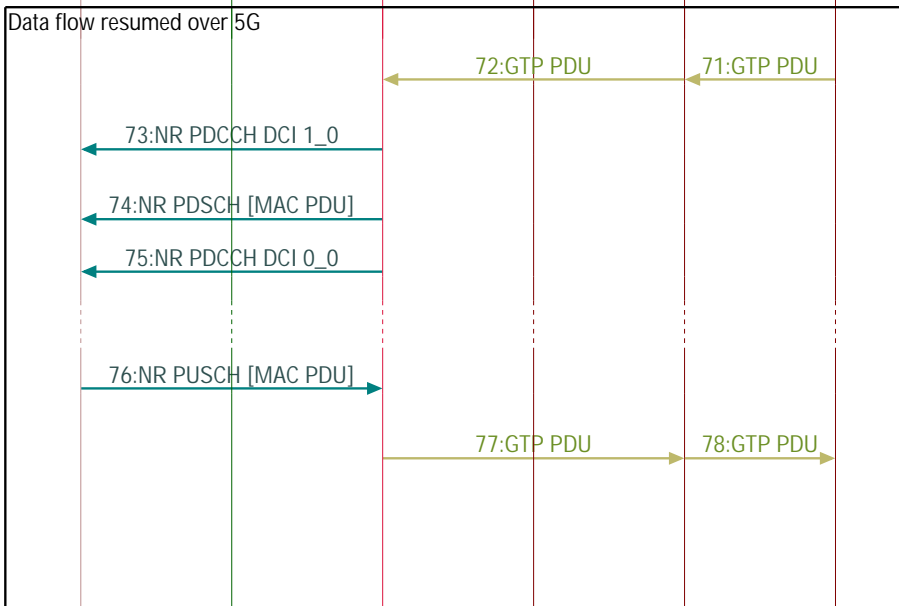
Data is now being directly routed from the 4G SGW to the 5G gNodeB.

73:NR PDCCH DCI 1_0

NR PDCCH signals downlink resource block allocations for PDSCH.

74:NR PDSCH [MAC PDU]

The eNodeB transmits the PDSCH.

75:NR PDCCH DCI 0_0

gNodeB assigns uplink resource blocks.

76:NR PUSCH [MAC PDU]

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

77:GTP PDU   **78:GTP PDU**

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

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

79:MAC PDU [Dual Connectivity PHR MAC CE]

[PH (Type 2, PCell), P-CMAX,c 1],
[PH (Type 2, PSCell), P-CMAX,c 2],
[PH (Type 1, PCell), P-CMAX,c 3],
[PH (Type x, Serving Cell 1), P-CMAX,c 4],
[...,...]
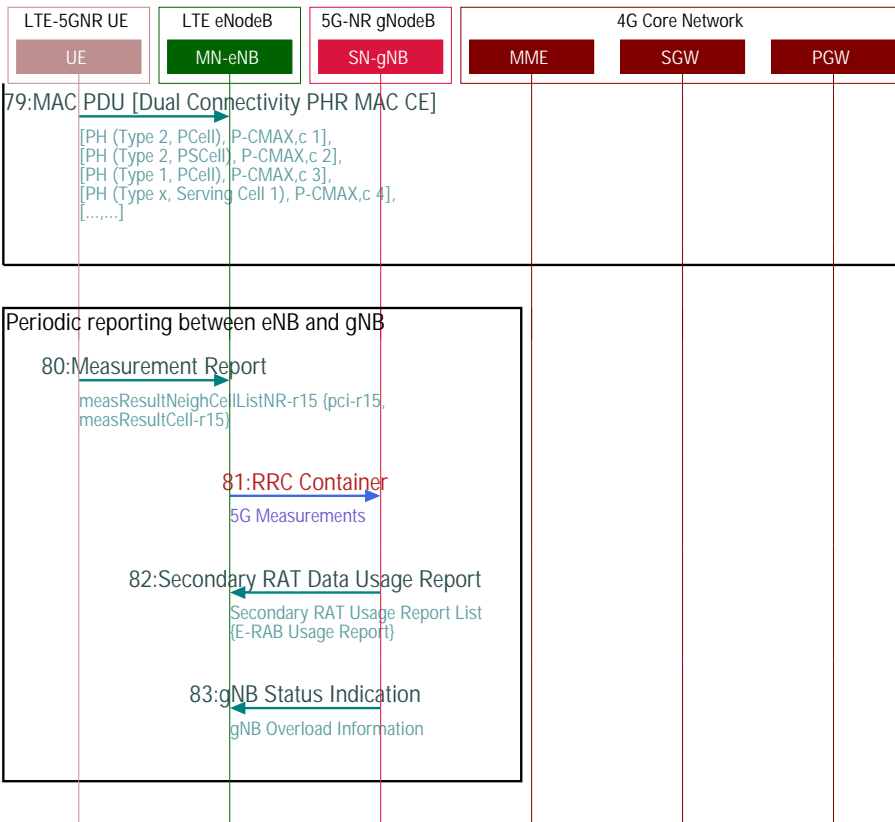
Periodically, the UE reports the Power Headroom to the the MN-eNB. The PHR MAC CE contains the power headroom for the cells on the MN-eNB and SN-gNB cells.

Periodic reporting between eNB and gNB

80:Measurement Report

measResultNeighCellListNR-r15 {pci-r15, measResultCell-r15}

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

81:RRC Container

5G Measurements

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

82:Secondary RAT Data Usage Report

Secondary RAT Usage Report List {E-RAB Usage Report}

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

83:gNB Status Indication

gNB Overload Information

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

EXPLORE MORE

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