5G NR NSA Signaling (EN - DC) with EPC Call Flow

TP00005-V-1701 V0 - S05M02 Ed1

3GPP TS 37.340 Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity

Learning objectives

Upon completion of this module, you should be able to:

- Describe 5G NR NSA Signaling (EN-DC) with EPC Call Flow
- Describe Secondary Node Addition Procedure
- Describe Secondary Node Modification Procedure
- Describe Secondary Node Release Procedure

Table of contents

Secondary Node Addition Procedure

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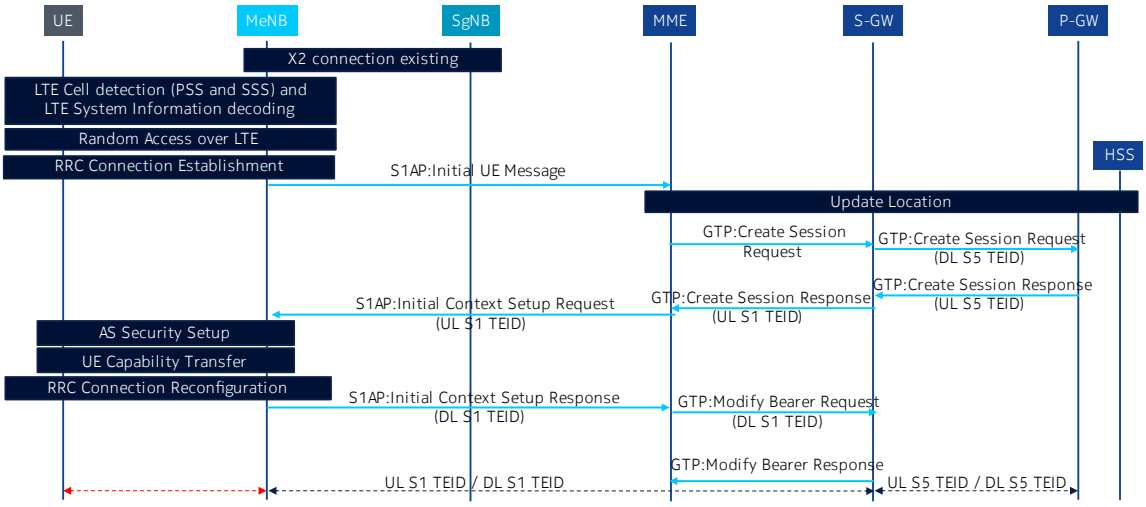
Dual Connectivity NSA Mode 3x Operation – Simplified Call Flow

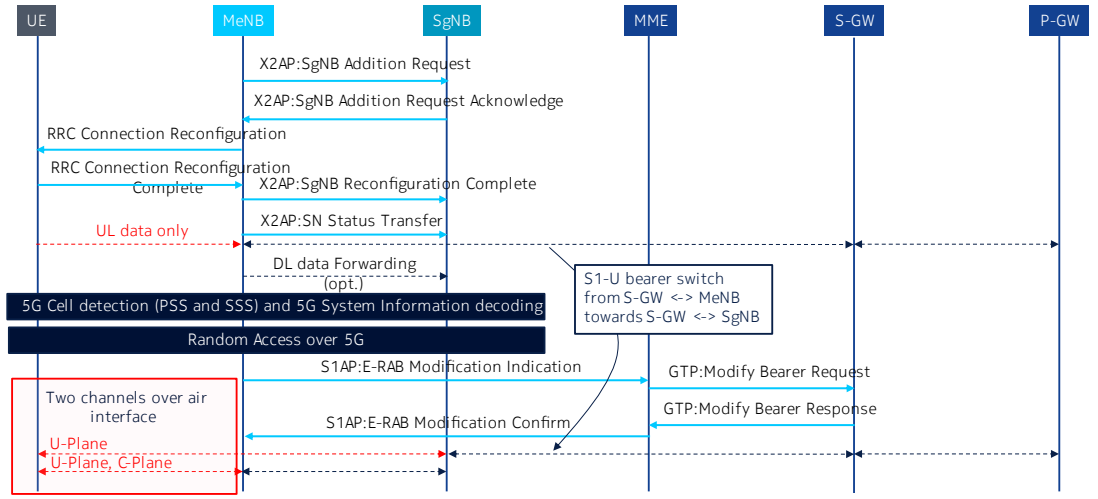


The Secondary Node Addition procedure is initiated by the MN and is used to establish a UE context at the SN to provide resources from the SN to the UE. For bearers requiring SCG radio resources, this procedure is used to add at least the first cell of the SCG. This procedure can also be used to configure an SN terminated MCG bearer (where no SCG configuration is needed).

This slide and the next slide show a simplified call flow of secondary Node Addition procedure. The procedure will be describe step by step in the upcoming slides.

Remember, MN (Master Node) and SN (Secondary Node) are generic names used in Dual Connectivity context. In EN-DC mode, the eNB takes the MN role as MeNB, the gNB takes the SN role as SgNB.

Secondary Node Addition Procedure
Dual Connectivity NSA Mode 3x Operation – Simplified Call Flow



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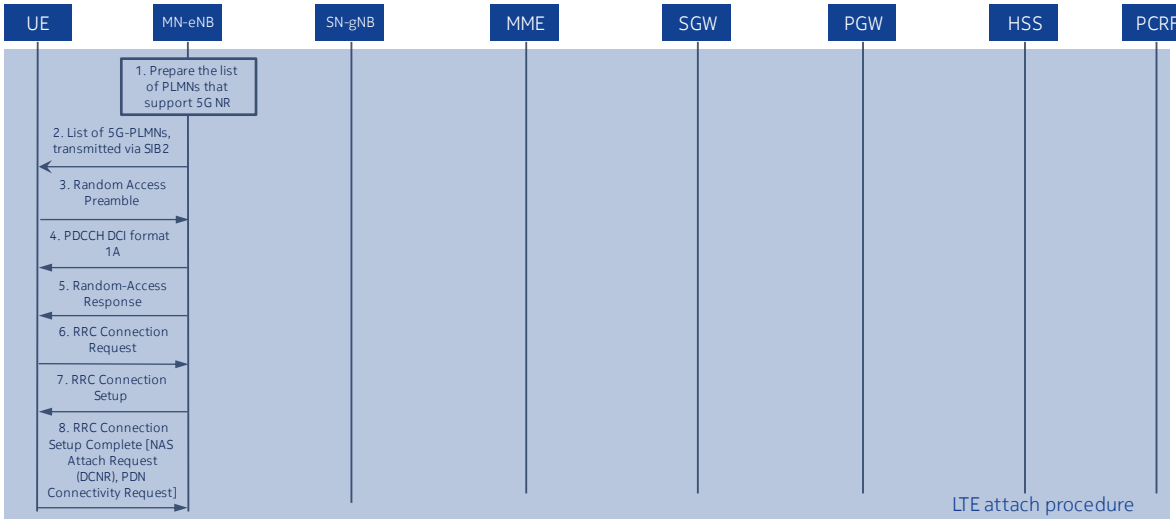
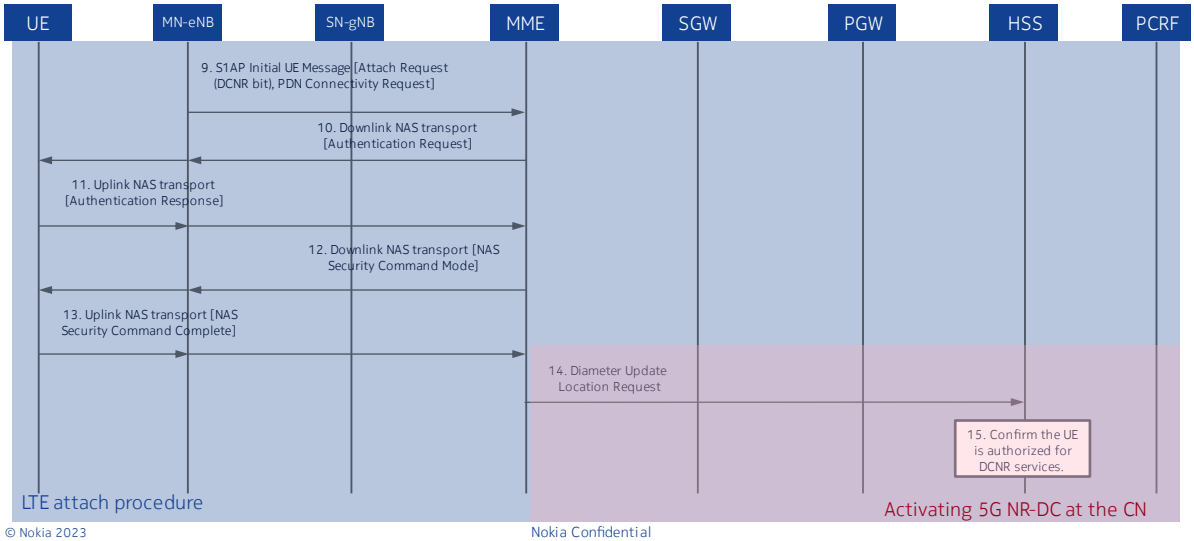
Secondary Node Addition Procedure
LTE Attach procedure



1. Preparing the list of PLMNs is based on: PLMN-InfoList-r15 (Presence of PLMN-InfoList-r15 signals that PLMNs supporting 5G-NR services are available).
2. The SIB2 broadcast from the eNB signals the presence of 5G-NR PLMNs via the PLMN-InfoList-r15.
3. The UE picks a random preamble. The preamble is referenced with the Random-Access Preamble Id (RAPID). The preamble transmission is a Zadoff-Chu sequence. Each preamble transmission is associated with an RA-RNTI.
4. PDCCH DCI format 1A is used for scheduling a PDSCH codeword. Only a single transport block can be scheduled here using resource allocation type2. 3GPP 36.212
5. The eNodeB responds to the preamble with the "Random Access Response" message on the DL-SCH. The UE listens on the PDCCH addressed by the RA-RNTI. Once the PDCCH with the RA-RNTI is decoded, the UE uses the RB resources in the message to receive the downlink transport block. The downlink transport block contains the MAC PDU.
6. The UE uses a UL-SCH allocation to send the RRC Connection Request message. RRC Connection Request info to be exchanged according to 36.331: UL-SCH, C-RNTI, ue-identity, InitialUE-Identity (S-TMSI), EstablishmentCause.
7. eNodeB responds with an RRC Connection Setup message on the DL-SCH. DL-SCH, C-RNTI, SRB Identity, DL AM RLC, UL AM RLC, UL-SCH Config, PHR Config, Uplink Power Control, according to TS36.331.
8. The UE signals the completion of the RRC connection, this 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.

Secondary Node Addition Procedure
LTE attach procedure / Activating 5G NR -DC at the CN



9. The NAS messages from the UE are signaled to the Core Network via the Initial UE message. Described by TS 36.413.

10. MME initiates the authentication procedure according to TS 24.301

11. Authentication is successfully completed

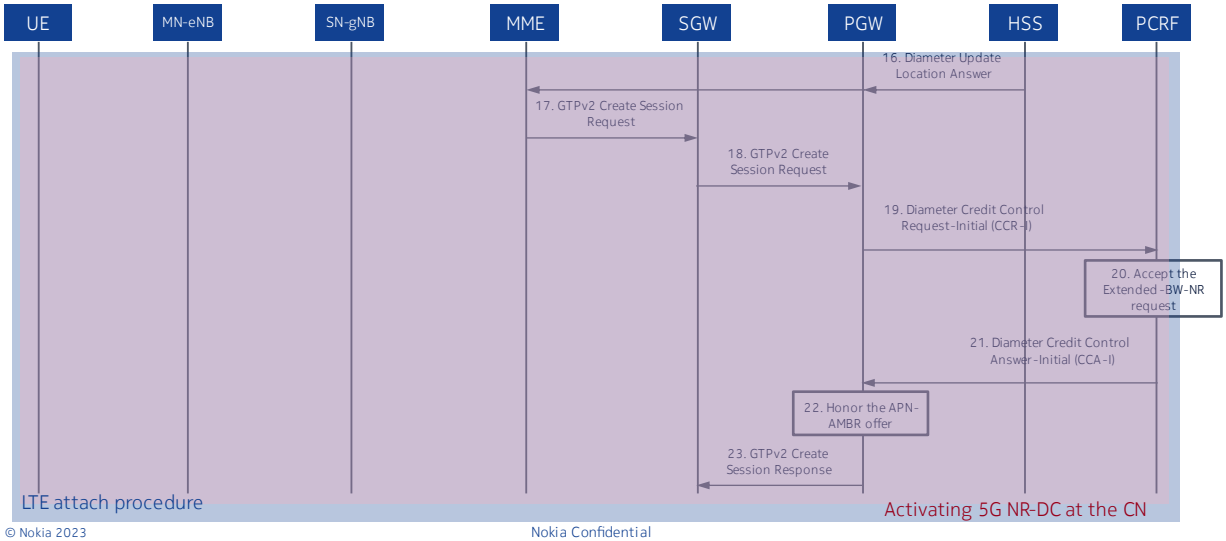
12. MME initiates NAS level security procedure, purpose is to secure all the communications between the MME and the UE, according to TS 24.301.

13. NAS level security procedure is completed. TS 23.401.

14. According to TS 29.272, MME initiates the Update Location Request (ULR) and signals to the HSS the UE has requested that 5G-NR may be used as a secondary RAT (Feature-List-ID-2)

15. Verification in the HSS to authorize DC for 5G NR services.

Secondary Node Addition Procedure
LTE attach procedure / Activating 5G NR-DC at the CN



16. HSS determines that the UE is authorized to use DC NR services and signals the acceptance to the MME. As the designed bandwidth for 5G is higher than LTE, Max-Requested-Bandwidth for UL and DL is transmitted, along with Extended-Max-Requested-BW (UL & DL).

17. MME sends the Create Session Request message to the SGW with the Extended APN-AMBR values in existing AMBR IE. As the APN-AMBR values in GTPv2 interface are encoded in kbps, the existing AMBR IE handles the 5G NSA bit rates.

18. Message forwarded to the PGW.

19. P-GW sends CCR-I to PCRF advertising the DCNR by sending Extended-BW-NR feature bit in Feature-List-ID-2, APN-Aggregate-Max-Bitrate-UL, APN-Aggregate-Max-Bitrate-DL (both for 4294967295 bps), along with Extended-APN-AMBR UL and DL, according to TS 32.299.

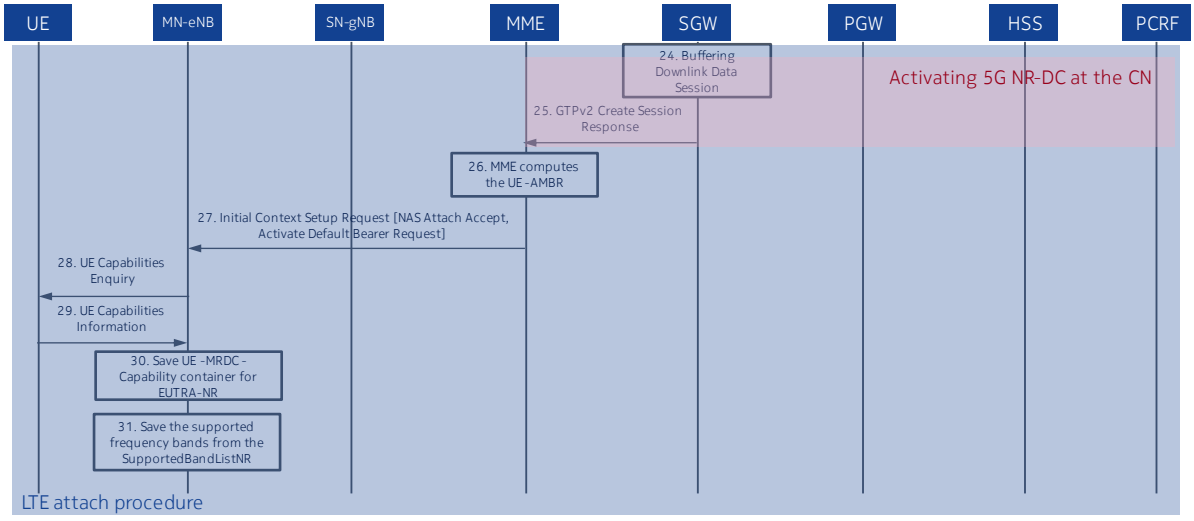
20. The user session is authorized for EN-DC service, upon the reception of the CCR-I message.

21. PCRF replies back with CCA-I and it can offer the same extended APN-AMBR values that are requested by PCRF or modify the extended APN-AMBR values. P-GW enforces the APN-AMBR values accordingly.

22. P-GW honors the APN-AMBR values as offered by PCRF.

23. Signal the acceptance of the session to the SGW. The APN data rate is signaled via the Extended APN-AMBR

Secondary Node Addition Procedure
LTE attach procedure / Activating 5G NR-DC at the CN



24. SGW starts to buffer downlink data towards the UE. This data will be sent to the UE when the session is established.

25. SGW forwards the GTPv2 message to the MME which is notified about the APN data rate by using the Extended APN-AMBR IE.

26. MME computes the UE-AMBR values

27. According to TS 36.413, MME responds back to the eNodeB with a message containing 3 messages: S1AP Initial Context Setup Request, NAS Attach Accept (24.301) and Activate Default Bearer Request. MME sends the extended UE-AMBR values in new IEs Extended UE-AMBR for both UL & DL by setting the legacy UE AMBR Uplink and UE AMBR Downlink values to the maximum allowed value 10 Gbps in the Initial Context Setup Request message. MME sends the APN-AMBR values up to 65.2 Gbps in existing APN-AMBR IE in NAS Activate Default EPS Bearer Context Request – Attach Accept. If the APN-AMBR values are beyond 65.2 Gbps, MME sends the extended APN-AMBR values in Extended APN-AMBR IE.

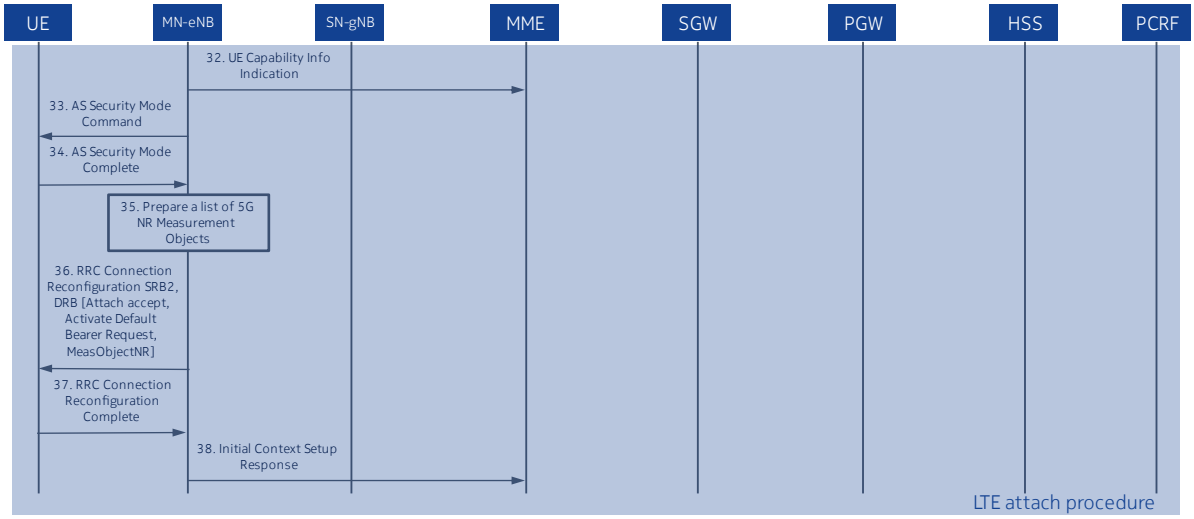
28. Based on TS36.331, MME has not sent UE capabilities so the eNodeB performs the UECapabilityEnquiry. UE capabilities are requested for 4G-LTE (eutra),EN-DC (eutra-nr) and 5G (nr).

29. The response to the enquiry contains: UECapabilityInformation-r8-Ies, UE-CapabilityRAT-ContainerList (UE-MRDC-Capability - signals that the UE supports EN-DC and can simultaneously connect to a 4G as well as 5G base station), UE-EUTRA-Capability-v15 IEs and the SupportedBandListNR.

30. MN-gNB saves the UE-MRDC-Capability from the message delivered by the UE, based on TS 36.331.

31. MN-gNB saves the SupportedBandListNR from the message delivered by the UE, based on TS 36.331.

Secondary Node Addition Procedure
LTE Attach Procedure



32. MN-eNB is forwarding the UE-CapabilityRAT-ContainerList to the MME, according to TS 36.431. This is rat-Type, ue-CapabilityRAT-Container.

33. According to TS 36.331, ciphering procedure is to be set between the MN-eNB and the UE. AS Security Mode Command is sent to the UE.

34. The UE shall cipher the SECURITY MODE COMPLETE message with the selected NAS ciphering algorithm and the EPS NAS ciphering key based on the KASME/K'ASME.

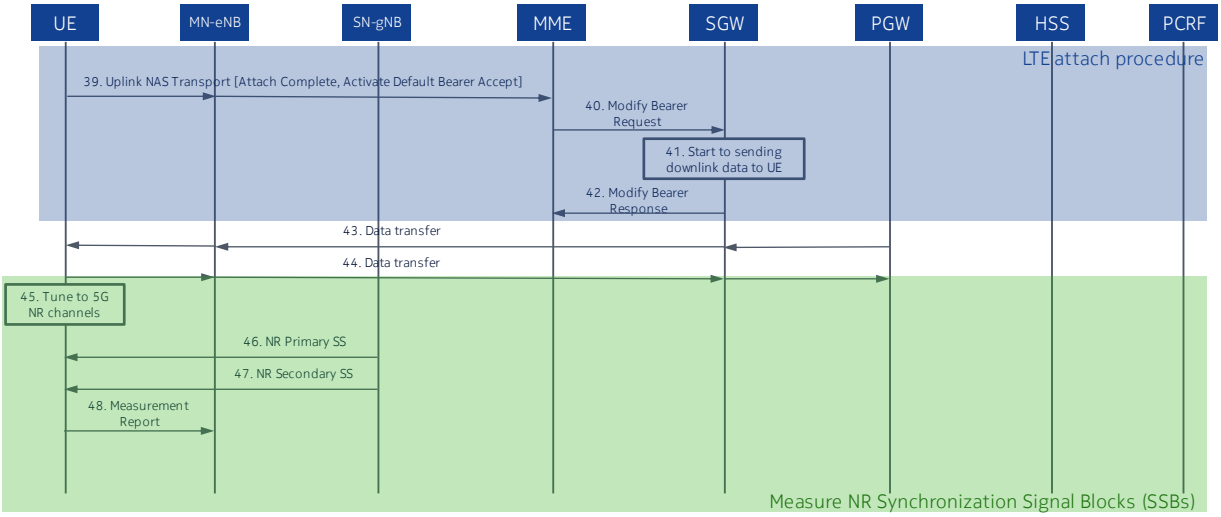
35. The IE MeasObjectNR specifies information applicable for inter-RAT NR neighboring cells.

36. 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 that were prepared in the previous step. IEs such as EPS RB ID, RLC mode, PDCP Sequence Number, according to TS 36.331

37. UE confirms and forwards the completion of the RRC ConnectionReconfiguration command. Information transmitted: rrcTransactionIdentifier, registeredMME, selectedPLMN-Identity, etc.

38. TS 36.413 lays out the MeNB sends an E-RAB Modification Indication message to the MME. The MeNB indicates if each bearer is modified or not. The E-RAB to be Modified List contains both E-RAB to Be Modified Item and E-RAB not to Be Modified Item IEs. For the bearer that need to be switched to secondary eNodeB/gNodeB, the E-RAB to Be Modified Item IE contains the transport layer address of gNodeB and TEID of gNodeB.

Secondary Node Addition Procedure
LTE Attach Procedure / Measure NR Synchronization Signal Blocks



39. UE signals the completion of Attach and default bearer activation, based on TS 24.301
40. The MME sends a Modify Bearer Request message (eNodeB address and TEIDs for downlink user plane for all the EPS bearers) per involved PDN connection to the S-GW.
41. SGW begins to transfer downlink data to the UE.
42. The S-GW returns a Modify Bearer Response message (S-GW address and TEID for uplink traffic) to the MME as a response to the Modify Bearer Request message.
43. Data transfer from PGW to UE
44. Data transfer from UE to PGW
45. The IE MeasObjectNR specifies information applicable for inter-RAT NR neighboring cells. Initiate measurement of 5G NR channels specified in the Measurement Objects received during RRC ConnectionReconfiguration. These measurements are scheduled during measurement gaps. RRC Connection Reconfiguration messages in step 36 and 37.
46. The Primary Synchronization Signal (PSS) is used for radio frame level synchronization. The PSS is a Linear Feedback Shift Register sequence that is designed to provide a long non-repeating sequence.

The PSS is mapped to 127 sub-carriers around the lower end of the system bandwidth.

The PSS helps the UE locate the first symbol of a downlink radio frame.

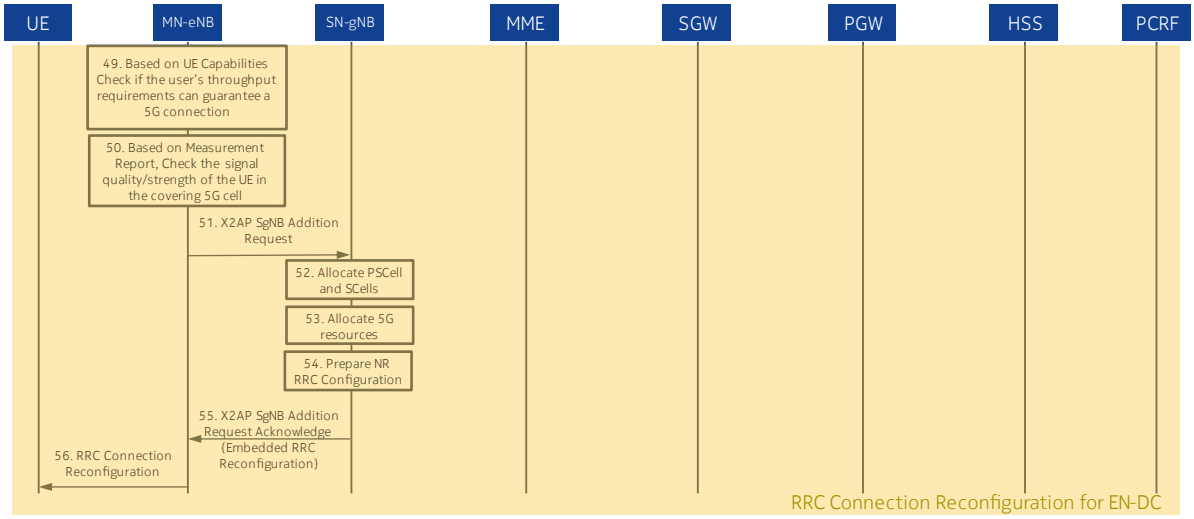
47. The Secondary Synchronization Signal (SSS) is used to subframe synchronization.

The SSS helps the UE locate the first symbol in a downlink subframe.

The PSS and the SSS are used to obtain the Physical Layer Cell Id (PCI).

48. 5G signal quality is reported back to 4G eNB, using SN-gNB Measurement according to TS 36.331

Secondary Node Addition Procedure
RRC Connection Reconfiguration for EN-DC



49. Check if the user's throughput requirements can guarantee a 5G connection.

50. Check the signal quality/strength of the UE in the covering 5G cell.

51. MN-eNB send SN-gNB Addition Request to SN. The message carries the RRC and Radio Bearer configuration. UE capabilities and security information are also included in the message, according to TS 36.423. E-RAB Parameters, IP address, TEID, UE Security Capabilities, S-NG-RAN node Security Key, S-NG-RAN node UE Aggregate Maximum Bit Rate, Security Information for SRB3, etc.

52. Allocate 5G cells.

53. Prepare and allocate 5G resources like C-RNTI, Channel Quality Indication, Scheduling Request, Sounding Reference Signal according to TS 37.340

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

55. According to TS 36.423, as the SN-gNB accepts the request, it responds back with the SgNB Addition Request Acknowledge:

Allocate the necessary radio resources transport network resources

Decides PSCell and other SCG SCells and provide the new SCG radio resource configuration to MN

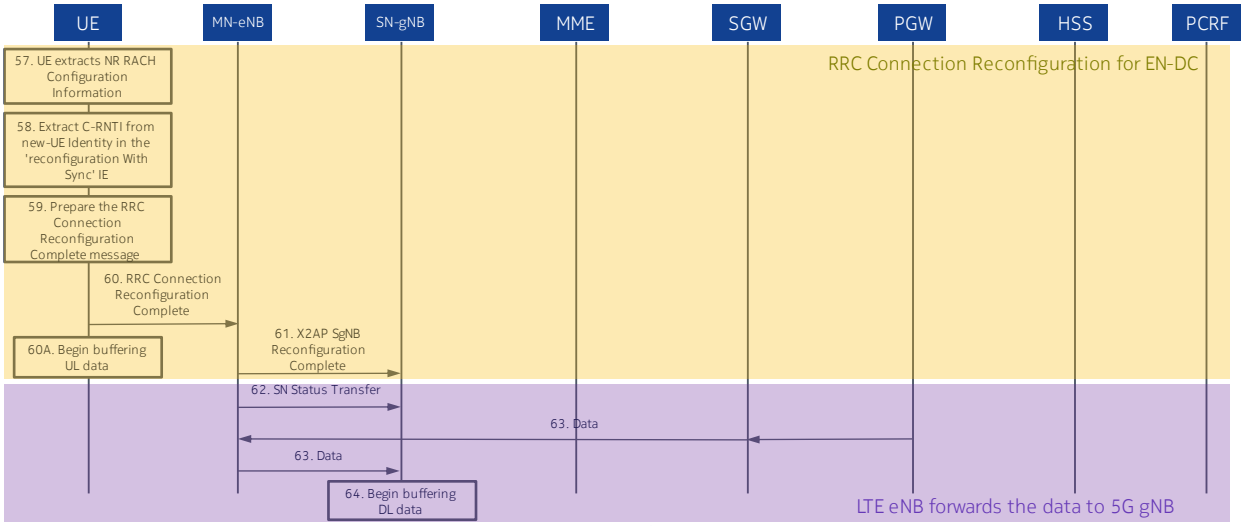
In case of bearer options that requires X2-U between MN and SN, it provides X2-U TNS address info.

In case of SCG radio resources being requested provide SCG radio resource configuration.

56. LTE eNB generate RRC Connection Reconfiguration message carrying all the necessary information and send it to UE, based on TS 36.331. This message carries NR RRC Configuration in it so that UE can figure out the necessary configuration information for NR gNB: nr-Config, endc-ReleaseandAdd, nr-SecondaryCellGroupConfig, nr-RadioBearerConfig, etc.

Secondary Node Addition Procedure

RRC Connection Reconfiguration for EN-DC / LTE eNB forwards the data to 5G gNB



57. Extract the 5G NR RACH parameter values required to access the 5G network.

58. Extract the assigned C-RNTI for 5G access.

59. LTE RRC ConnectionReconfiguration Complete message to be transmitted.

60. After UE received RRCReconfiguration, it checks if all the configurations in the message is doable in UE side, it sends RRCReconfigurationComplete message, based on TS 36.331. scg-ConfigResponseNR and RRCReconfigurationComplete.

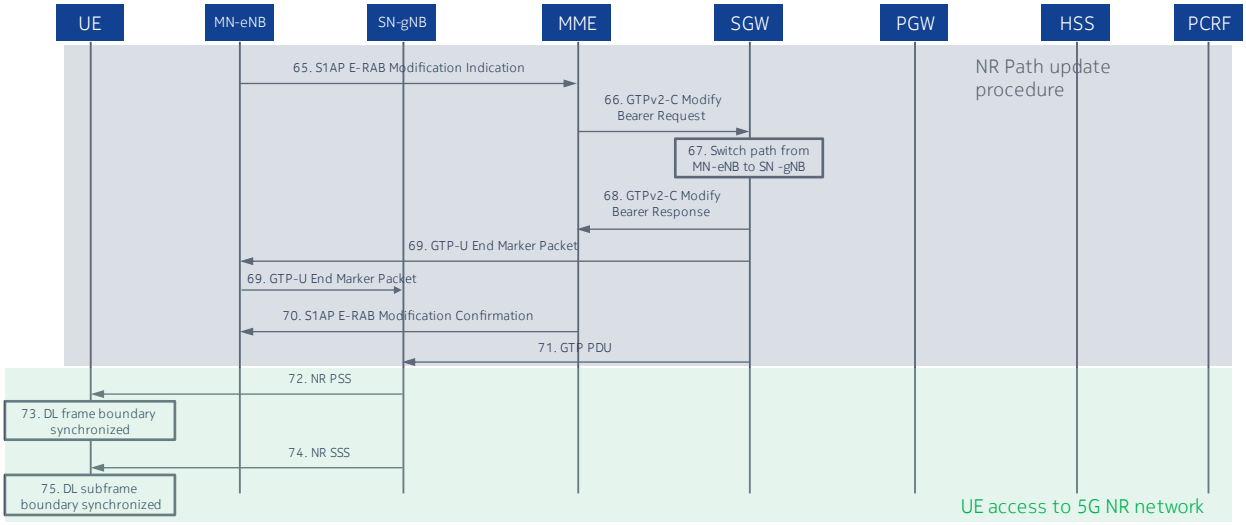
61. The MN-eNB informs the SN-gNB about the reconfiguration being completed. The NR RRCReconfigurationComplete message is delivered to the SN-gNB via the MeNB to SgNB container, as explained in TS 36.423.

62. TS 36.423 lays out the MN-eNB to SN-gNB communication that includes info about the PDCP SN and HFN for all the bearers that are being transferred to 5G.

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

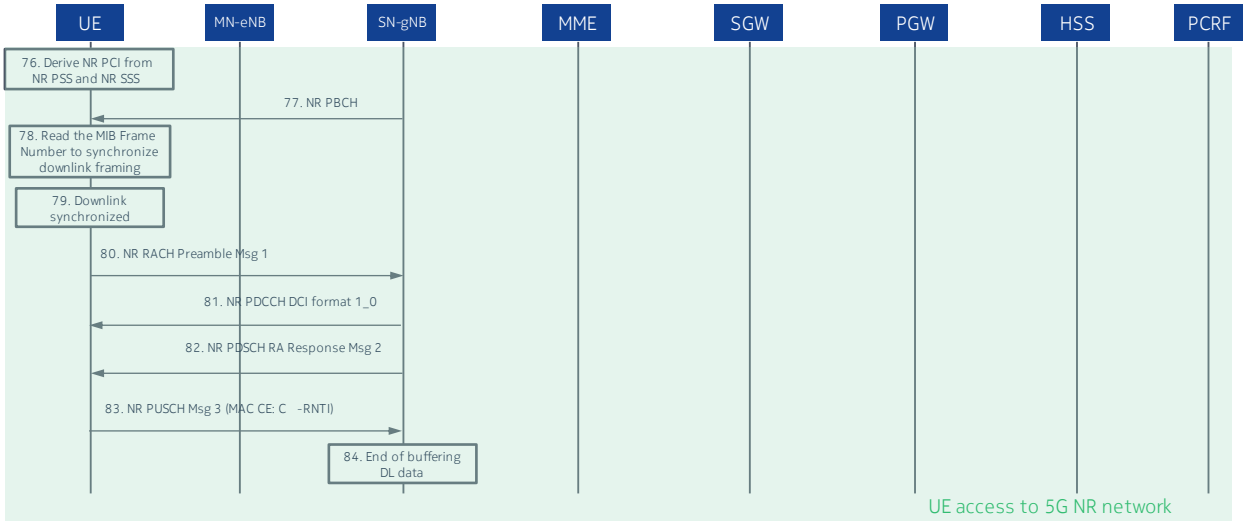
64. The gNodeB is buffering the data as the UE has not established the 5G path.

Secondary Node Addition Procedure
NR Path update procedure / UE access to 5G NR network



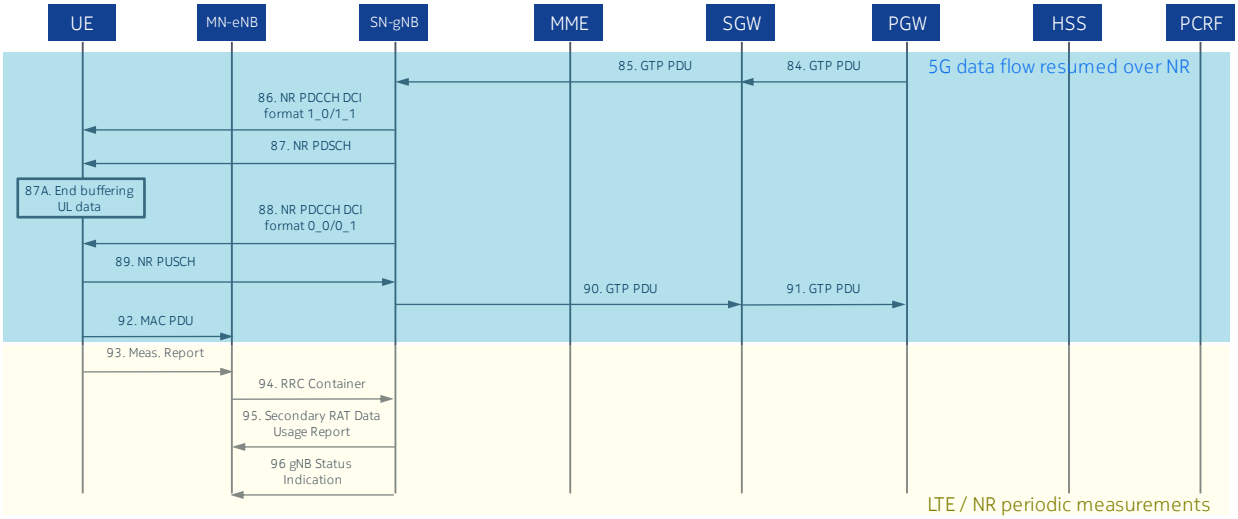
65. Notify the MME that the data bearer is being switched from 4G-LTE to 5G-NR.
66. MME updates the bearer at the SGW.
67. Switching the data path from the eNodeB to gNodeB.
68. SGW responds back to the MME about the bearer info been updated.
69. Send the End Marker to the eNodeB. This marks the end of data transmission to the MN-eNB. Subsequent data transmissions will be forwarded via the 5G gNB.
70. MME confirms the E-RAB modification sent by the MN-eNB.
71. SGW starts forwarding the PDUs directly to the SN-gNB.
72. Based on TS 38.211, SN-gNB provides the Primary Synchronization Signal which is acquired by the UE.
73. The UE is synchronized with the NR downlink frame boundary.
74. Based on TS 38.211, SN-gNB provides the Secondary Synchronization Signal which is acquired by the UE.
75. The UE is synchronized with the NR downlink subframe boundary.

Secondary Node Addition Procedure
UE access to 5G NR network



76. UE calculates the Physical Cell Identifier by using the PSS and SSS info.
77. 5G gNB broadcasts the MIB contained in the PBCH, which is acquired by the UE.
78. The UE extracts the MIB Frame number from the PBCH in order to synchronize the downlink framing.
79. Downlink path is synchronized by using the Frame Number
80. The UE initiates the Random-Access procedure with the 5G gNB. Non-contention based random-access will be attempted if the preamble assignment was received in the RRC ConnectionReconfiguration message.
81. NR PDCCH signals downlink resource allocation for the RA Response.
82. The 5G secondary node gNodeB responds with an RA Response. The message also carries an uplink grant for Msg3 transmission.
83. UE transmits the assigned C-RNTI for 5G access in NR PUSCH.
84. The gNodeB stops buffering data and starts data forwarding, as the UE initiated the RA procedure.

Secondary Node Addition Procedure
5G data flow resumed over NR / LTE / NR periodic measurements



84. PDU data is forwarded from PGW to relevant SGW.

85. PDU data is forwarded directly from SGW to gNB.

86. Based on TS 38.212, DCI Format 1_0/1_1 is used to assign downlink resources. NR PDCCH signals downlink resource block allocations for PDSCH.

87. According to TS 38.321, the gNodeB transmits the PDSCH.

88. DCI Format 0_0/0_1 is used to assign uplink resources to the UE. gNodeB assigns uplink resource blocks.

89. The UE receives the DCH 0_0/0_1 grant and transmits the PUSCH in the uplink direction.

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

91. SGW forwards the Uplink PDU data to the PGW.

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

93. The UE reports measurements to the MN-eNB. The measurements include results from 5G NR cells, as indicated by TS 36.331.

94. The MN-eNB reports these measurements to the SN-gNB. 5G Measurements.

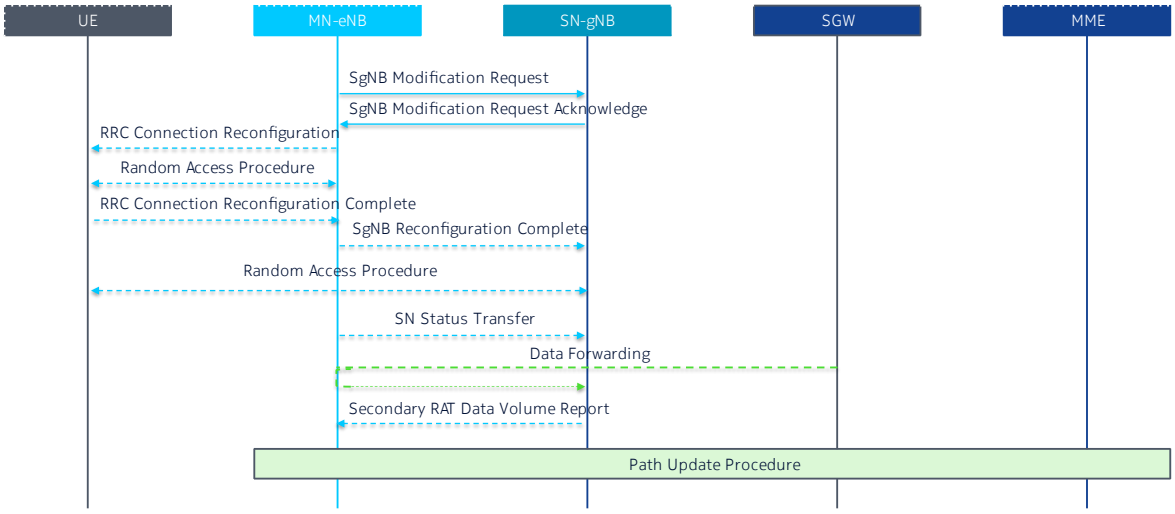
95. TS 36.423 lists that periodically, the SN-gNB reports the usage statistics for 5G NR bearers to the MN-eNB. Secondary RAT Usage Report List.

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

Secondary Node Modification Procedure

MR-DC with EPC Operation

Secondary Node Modification Procedure - MN Initiated



The Secondary Node Modification procedure could be triggered by either MN or SN. It does not necessarily need to involve signaling towards the UE.

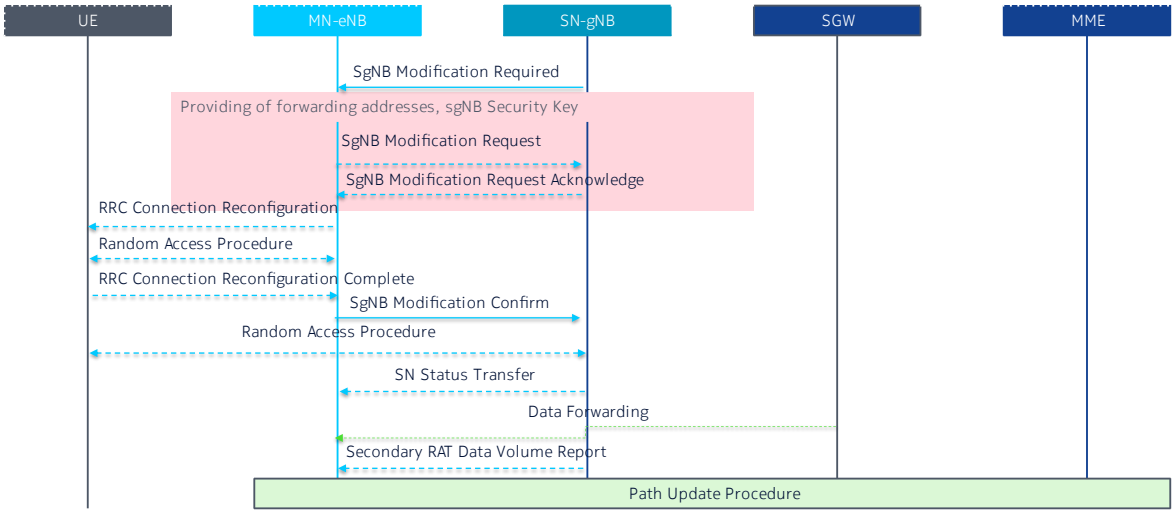
The Secondary Node Modification procedure is used by MN-eNB to initiate configuration changes of the SCG within the same SN, e.g. the addition, modification or release of SCG bearer(s) and the SCG RLC bearer of split bearer(s), as well as configuration changes for SN terminated MCG bearers. Bearer termination point change is realized by adding the new bearer configuration and releasing the old bearer configuration within a single MN initiated SN Modification procedure for the respective E-RAB.

To perform the MN-eNB initiated Secondary Node Modification:

The MN-eNB sends the SgNB Modification Request message, which may contain bearer context related or other UE context related information, data forwarding address information (if applicable) and the requested SCG configuration information, including the UE capability coordination result to be used as basis for the reconfiguration by the SN.

- The SN-gNB responds with the SgNB Modification Request Acknowledge message, which may contain SCG radio resource configuration information within a NR RRC configuration message and data forwarding address information (if applicable).
- The MN-eNB initiates the RRC connection reconfiguration procedure, including the NR RRC configuration message. The UE applies the new configuration, synchronizes to the MN-eNB (if instructed, in case of intra-MN handover) and replies with RRC Connection Reconfiguration Complete, including a NR RRC response message, if needed.
- Upon successful completion of the reconfiguration, the success of the procedure is indicated in the SgNB Reconfiguration Complete message
- If instructed, the UE performs synchronization towards the PSCell of the SN-gNB. Otherwise, the UE may perform UL transmission after having applied the new configuration
- The MN sends the SN Status transfer, if PDCP termination point is changed for bearers using RLC AM, and when RRC full configuration is not used
- If applicable, data forwarding between MN and the SN takes place (the flow on the slide depicts the case where a bearer context is transferred from the MN-eNB to the SN-gNB).
- The SN sends the Secondary RAT Data Volume Report message to the MN and includes the data volumes delivered to the UE over the NR radio for the E-RABs to be released
- If applicable, a path update is performed.

MR-DC with EPC Operation
Secondary Node Modification Procedure - SN Initiated



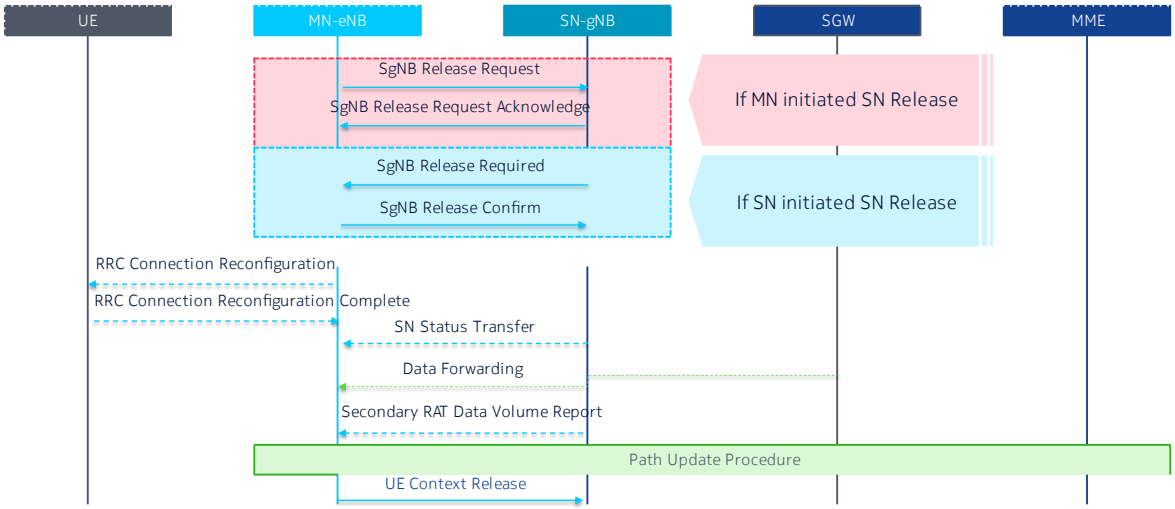
SN Modification procedure can be initiated by the SN-gNB to perform configuration changes of the SCG within the same SN, e.g. to trigger the release of SCG bearer(s) and the SCG RLC bearer of split bearer(s) (upon which the MN may release the bearer or maintain current bearer type or reconfigure it to an MCG bearer, either MN terminated or SN terminated), and to trigger PSCell change (e.g. when a new security key is required or when the MN needs to perform PDCP data recovery).

To perform the SN-gNB initiated Secondary Node Modification (with MN involvement) :

- The SN sends the SgNB Modification Required message including a NR RRC configuration message, which may contain bearer context related, other UE context related information and the new SCG radio resource configuration. For bearer release or modification, a corresponding E-RAB list is included in the SgNB Modification Required message
- For providing of forwarding addresses, sgNB Security Key: The MN initiated SN Modification procedure may be triggered by the SN Modification Required message (e.g. to provide information such as data forwarding addresses, new SN security key, measurement gap, etc...)
- The MN sends the RRC Connection Reconfiguration message including a NR RRC configuration message to the UE including the new SCG radio resource configuration
- The UE applies the new configuration and sends the RRC Connection Reconfiguration Complete message, including an encoded NR RRC response message, if needed
- Upon successful completion of the reconfiguration, the success of the procedure is indicated in the SgNB Modification Confirm message containing the encoded NR RRC response message, if received from the UE
- If instructed, the UE performs synchronization towards the PSCell of the SN as described in SN addition procedure. Otherwise, the UE may perform UL transmission after having applied the new configuration
- If PDCP termination point is changed for bearers using RLC AM, and when RRC full configuration is not used, the SN sends the MN Status transfer
- If applicable, data forwarding between MN and the SN takes place
- The SN sends the Secondary RAT Data Volume Report message to the MN and includes the data volumes delivered to the UE over the NR radio for the E-RABs to be released
- If applicable, a path update is performed.

Secondary Node Release Procedure

MR-DC with EPC Operation
Secondary Node Release Procedure



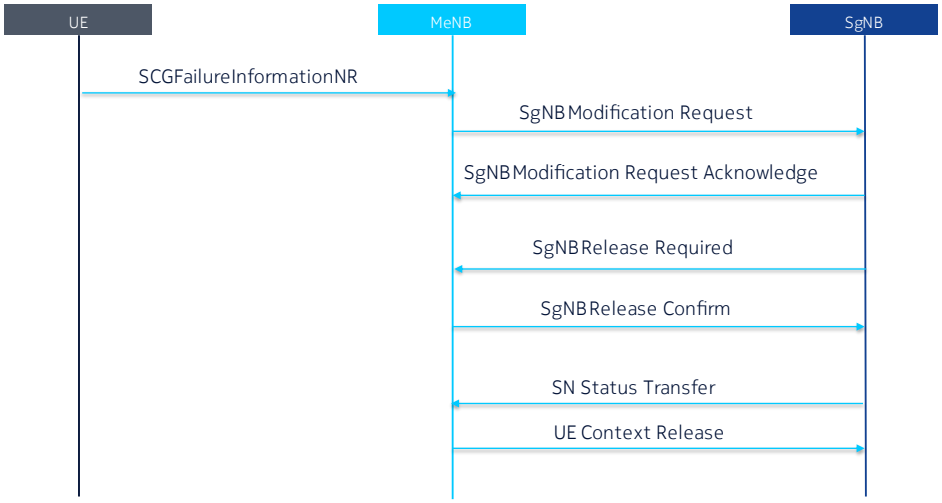
The Secondary Node Release procedure can be triggered either by the MN or by the SN and is used to initiate the release of the UE context at the SN.

For the SN release initiated by MN:

- The MNeNB initiates the procedure by sending the SgNB Release Request message. If data forwarding is requested (from SNgNB to MNeNB, for SN terminated bearers), the MNeNB provides data forwarding addresses to the SNgNB.
- The SgNB confirms the release by sending the SgNB Release Request Acknowledge message.
- If required, the MN indicates in the RRC Connection Reconfiguration message towards the UE that the UE shall release the entire SCG configuration.
- Data forwarding from the SgNB to the MeNB takes place.
- The SN sends the Secondary RAT Data Volume Report message to the MeNB and includes the data volumes delivered to the UE over the NR radio for the related E-RABs.
- If applicable, the path update procedure is initiated.
- Upon reception of the UE Context Release message, the SgNB can release radio and C-plane related resource associated to the UE context. Any ongoing data forwarding may continue.

As mentioned earlier, the Secondary Node Release procedure can be triggered by SN: The SgNB may also initiate the release with a SgNB Release Required sent to the MeNB, and the MeNB replies with SgNB Release Confirm and the same following exchanges, so that the MeNB keeps the control on the 5G addition.

MR-DC with EPC Operation
Secondary Node Release example – UE initiated RLF



3GPP 37.340 7.7 SCG/MCG failure handling

R15:

Upon SCG failure the UE suspends SCG transmissions for all radio bearers and reports the SCG Failure Information to the MN, instead of triggering re-establishment.

R16:

Upon SCG failure, if MCG transmissions of radio bearers are not suspended, the UE suspends SCG transmissions for all radio bearers and reports the *SCGFailureInformation* to the MN, instead of triggering re-establishment. If SCG failure is detected while MCG transmissions for all radio bearers are suspended, the UE initiates the RRC connection re-establishment procedure.

Wrap-up

In this module we have covered the following items

- Describe 5G NR NSA Signaling (EN-DC) with EPC Call Flow
- Describe Secondary Node Addition Procedure
- Describe Secondary Node Modification Procedure
- Describe Secondary Node Release Procedure