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5G-LTE Interworking

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- Chapter has been added.

5G-LTE interworking system impact

- System impact description reorganized.

Testing 5GC000475: SgNB Addition and Release for NSA Mode 3x Operation

- Chapter has been added.

Testing 5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation

- Chapter has been added.

Testing 5GC000479: UE Inactivity Handling for NSA Mode 3x Operation

- Chapter has been added.

Testing 5GC000480: Radio Admission Control for NSA Mode 3x Operation

- Chapter has been added.

Testing 5GC000482: UE Capability Handling for NSA Mode 3x Operation

- Chapter has been added.

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- Chapter has been added.

Testing 5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)

- Chapter has been added.

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1 5G-LTE interworking requirements

Hardware, software, license, and knowledge requirements

Equipment preconditions

Table 2 Features related to 5G non-standalone deployment

Feature name	System release
LTE technology	
LTE4087: X2 Interface with NR gNB	FDD-LTE 18A / TD-LTE 18A
LTE4088: LTE-NR Dual Connectivity Option 3x	FDD-LTE 19 / TD-LTE 19
LTE4193: Dynamic Trigger for LTE-NR DC Option 3x	FDD-LTE 19 / TD-LTE 19
LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x	FDD-LTE 19 / TD-LTE 19
LTE4744: gNB Initiated EN-DC Configuration Update	FDD-LTE 19 / TD-LTE 19
5G technology	
5GC000474: X2 Management for NSA Mode 3x Operation	5G19
5GC000475: SgNB Addition and Release for NSA Mode 3x Operation	5G19
5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation	5G19
5GC000479: UE Inactivity Handling for NSA Mode 3x Operation	5G19
5GC000480: Radio Admission Control for NSA Mode 3x Operation	5G19
5GC000482: UE Capability Handling for NSA Mode 3x Operation	5G19
5GC000509: L3 Non Standalone Call with Data Transmission	5G19
5GC000543: Ciphering of U-Plane (NSA Option 3x)	5G19
5GC000570: 5G - LTE Flow Control at X2	5G19
5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)	5G19
5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6	5G19
5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)	5G19
5GC001097: Basic PCMD for NSA	5G19

Note: A UE with 5G capability is required.

Note: A UE with 5G capability is required.

Sales information

Table 3 Non-standalone 5G deployment sales information

Feature	Pricing type	License control	Activated by default
LTE4088: LTE-NR Dual Connectivity Option 3x *LTE4193: Dynamic Trigger for LTE-NR DC Option 3x* *LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x*	Application software (ASW)	SW Asset Monitoring	No
5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB) *5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)*	Application software (ASW)	5GBTS	No
5GC001097: Basic PCMD for NSA	Application software (ASW)	NetAct (pool license)	No
LTE4087: X2 Interface with NR gNB *LTE4744: gNB Initiated EN-DC Configuration Update* *5GC000474: X2 Management for NSA Mode 3x Operation* *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation* *5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation* *5GC000479: UE Inactivity Handling for NSA Mode 3x Operation* *5GC000480: Radio Admission Control for NSA Mode 3x Operation* *5GC000482: UE Capability Handling for NSA Mode 3x Operation* *5GC000509: L3 Non Standalone Call with Data Transmission* *5GC000543: Ciphering of U-Plane (NSA Option 3x)* *5GC000570: 5G - LTE Flow Control at X2* *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6*	Basic software (BSW)	-	Yes

Note: For non-standalone 5G option 3x deployment, the Nokia software introduced in LTE18A and LTE19 releases is aligned with the latest 3GPP standard evolutions:

- For LTE18A: *LTE4935: 3GPP ASN.1 R15 June 2018 for EN-DC*.
- For LTE19: *LTE5176: 3GPP R15 December 2018 for EN-DC*.

Background information

Get familiar with the following terms:

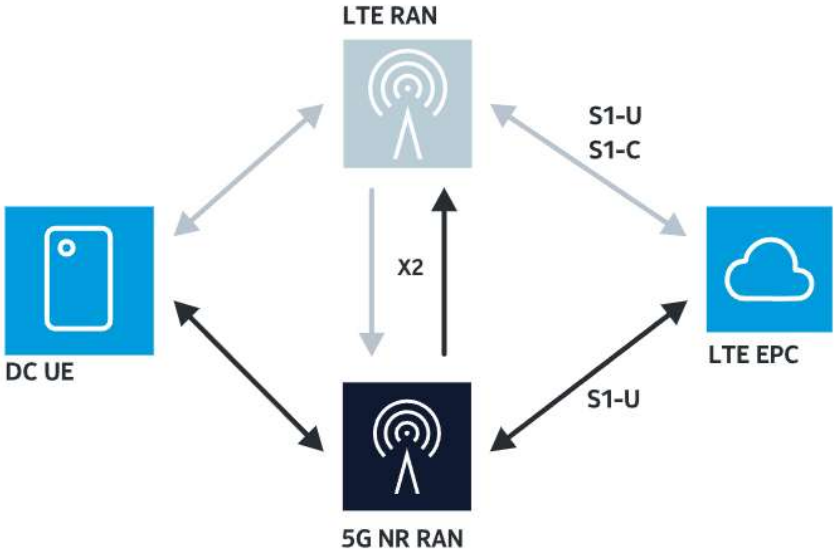
Carrier Aggregation (CA)	In radio resource management, a method of increasing the bit rate by increasing the bandwidth. It is done by scheduling the data to more than one cell (component carrier (CC)). In CA, one cell acts as a primary cell (PCell) and is changed only during a handover, while the other CCs are served by secondary cells (SCells) and can be added or removed as required.
en-gNB	A node providing NR user plane and control plane protocol terminations towards the UE, and acting as Secondary Node (SN) in EN-DC.
E-UTRA NR Dual Connectivity (EN-DC)	Functionality supported by E-UTRAN which allows for the connection of master node in LTE and secondary node in NR. EN-DC-capable UE is allowed to simultaneously transmit and receive the data from two group of cells: via Master Cell Group (MCG) and a Secondary Cell Group (SCG). A UE configured with MCG is using E-UTRA air interface, and a UE configured with SCG is using NR air interface.
gNB	In Next Generation Radio Access Network (NG-RAN) a NR NodeB. gNB provides user plane and control plane protocol terminations towards the UE.
LTE-NR Dual Connectivity (LTE-NR DC)	A technology concept that enables NR through non-standalone network structure using LTE connectivity.
Master Cell Group (MCG)	In EN-DC, a group of cells associated with the master eNB (MeNB) serving the UE. An MCG is composed of at least one serving cell working as a primary cell (PCell) and optionally one or more serving cells working as secondary cells (SCells).
Master eNB (MeNB)	A eNB in EN-DC technology. MeNB is connected with Evolved Packet Core (EPC) via S1-C interface for the control data exchange, and decides which radio (eNB or gNB) will handle user data (S1-U bearers).
Non-standalone (NSA) network architecture	In EN-DC, a structure of network in which the support for 5G technology is served by the existing LTE network elements like Evolved Packet Core (EPC) and eNB acting as a master eNB (MeNB).
NR	A 5G air interface defined by the 3GPP release 15 for support of massive device connectivity and data rates. NR supports larger than in LTE quantities of new spectrum (5G NR frequency bands), particularly in microwave (mmWave) bands.

2 Introduction to 5G-LTE interworking

Description of 5G-LTE interworking in option 3x deployment, where an eNB acts as a master node, gNB is a secondary node, and they are connected with X2 interface.

In initial 5G release, the network can be only deployed in non-standalone (NSA) architecture with LTE. 5G NSA architecture requires dual connectivity (EN-DC) operation. The gNB is connected to the EPC, with eNB acting as an anchor for the control plane (C-plane). For UE in EN-DC mode, the eNB acts as the master node (MeNB), and the gNB as the secondary node (en-gNB). They are linked by an X2 (gNB) interface to exchange signaling and data. The UE uses radio resources from both nodes, according to the respective radio interface protocol (LTE and NR respectively). 5G NSA architecture is a way for an acceleration option to deploy 5G without a dedicated 5G Core Network (5G CN) and based on the LTE infrastructure instead.

Figure 1 5G non-standalone architecture in option 3x



3.5 Support of X2 interface over IPv4/IPv6

The 5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6 feature provides the support for the non-standalone (NSA) mode 3x for S1-U, X2-U and X2-C interfaces over IPv4 or IPv6 for cloud gNB. The transport support of X2 and S1-U interfaces for classical gNB (which has no cloud-based part: gNB-CU and gNB-DU are not split) is covered by feature.

X2 interface is defined to connect Master eNB (MeNB) and en-gNB for both control plane and U-plane.

X2-C interface is used for the C-plane signalling between the MeNB and the en-gNB, for both directions. The X2-C is based on the Stream Control Transmission Protocol (SCTP).

S1-U is for user data transport between SGW and gNB. X2-U is used for user data transport between en-gNB and MeNB. Both, S1-U and X2-U are based on GTP-U over UDP/IP (3GPP TS 36.414 for S1-U and 3GPP TS 36.424 for X2-U). GTPv1-U according to 3GPP TS 29.281 is supported. User data transports for S1-U and X2-U are in both directions.

The following can be configured:

- The QoS (Layer 3) for each type of traffic: S1-U, X2-C, and X2-U
- IP addresses
  - One S1-U IPv4 or IPv6 address per UEUP VM.
  - One X2-C IPv4 or IPv6 address on CPIF VM.
  - One X2-U IPv4 or IPv6 address per UEUP VM.
  - S1-U and X2-U can share the same IP address or use different IP addresses in UEUP VM.

Note: IP address of Virtual Application is not supported.

On the Top of Rack (ToR) switch side, it is possible to configure:

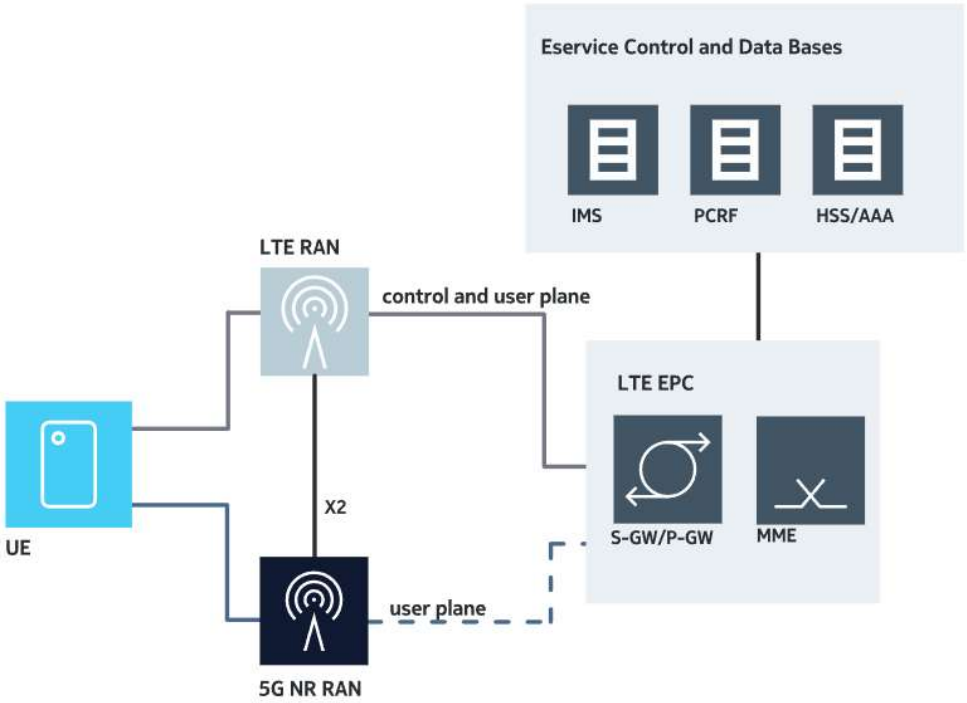
- Support of the X2 traffic in one dedicated VLAN or in a shared VLAN.
- The QoS (Layer 2) for each type of traffic: S1-U, X2-C, and X2-U.

4 LTE-NR DC option 3x

5G non-standalone (NSA) is based at existing LTE radio access and core network (EPC). Traffic is split across LTE and 5G at 5G cell. The EPC is used as an anchor for mobility management and coverage to add the 5G carrier.

In E-UTRA NR Dual Connectivity (EN-DC), a network architecture option 3x is designed for a UE which supports EN-DC functionality. The eNB acts as a Master eNB (MeNB) and decides which bearer should be served by the LTE radio only (as Master Cell Group (MCG) bearer) or split between the LTE and NR radio (as Secondary Node (SN) split bearer). The Mobility Management Entity (MME) informs the serving gateway (S-GW) where to establish S1-U bearers towards LTE or NR, based on the instructions from the MeNB. Radio protocols are split by the en-gNB between an NR leg and an LTE leg.

Figure 2 LTE-NR dual connectivity option 3x



The LTE-NR DC option 3x functionality is based on X2 interface features. For more information, see X2 interface role in EN-DC.

4.1 Network architecture and protocol stack

A description of communication between the MeNB and the en-gNB with information on bearers, protocols, data flow control, and the required data to establish a connection.

4.1.1 SN-terminated split Data Radio Bearer establishment

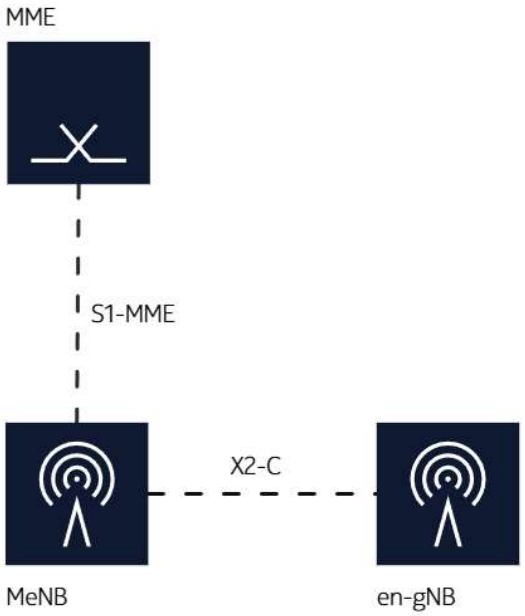
Functional overview of a dual connectivity establishment of an SCG Split data radio bearer (Split DRB). This basic functionality is introduced by LTE4088:LTE-NR Dual Connectivity Option 3x feature and 5GC000475: SgNB Addition and Release for NSA Mode 3x Operation feature.

The 5G NSA option 3x deployment is based at eNB acting as a master node (MeNB) and decides which bearer should be served by the LTE radio only (as MCG bearer) or split between the LTE and NR radio (as Secondary Node (SN) terminated split bearer). The mobility management entity (MME) informs the serving gateway (S-GW) where to establish S1-U bearers towards LTE or NR, based on the instructions from the MeNB.

Network architecture

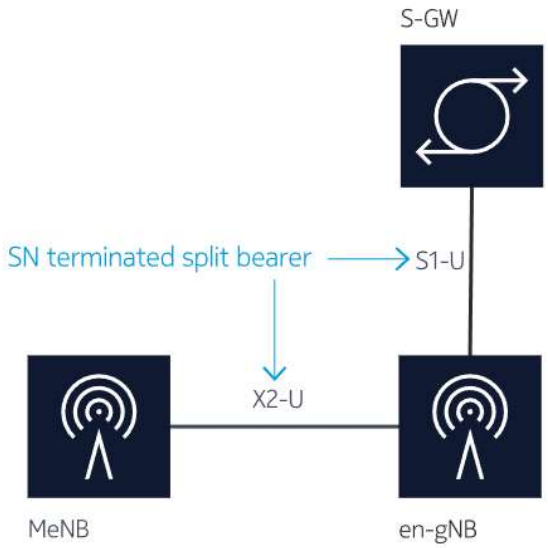
In C-plane, an en-gNB has no direct connection to the core network and whole signalling goes via MeNB and X2 interface.

Figure 3 Dual connectivity signaling with MME



In U-plane, the en-gNB has a direct connection to the core network via S1-U, and user data goes directly to the en-gNB for SN terminated split bearer. X2-U interface is used for tunneling of end-user packets between MeNB and en-gNB. Data received from S-GW is split and transmitted over LTE and/or 5G radio for SN terminated split bearer.

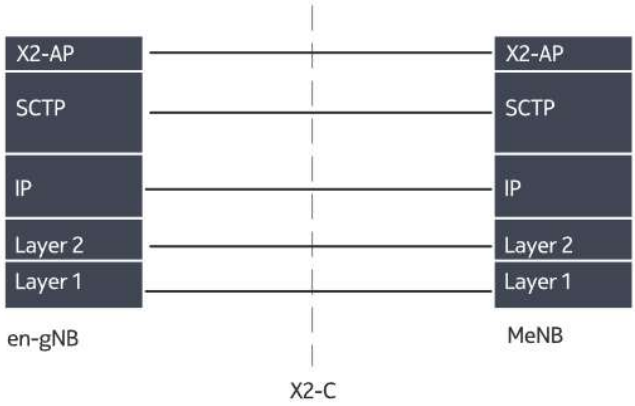
Figure 4 Dual connectivity user data transfer with S-GW



Protocol stacks (S1 and X2)

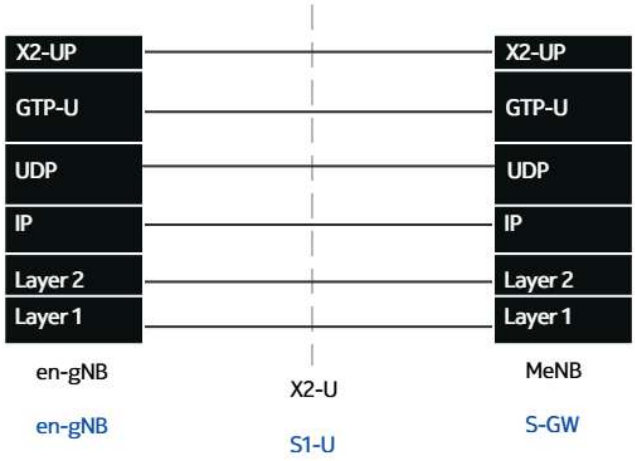
In C-plane, the en-gNB uses an X2AP protocol on top of SCTP/IP for signalling communication over X2-C interface.

Figure 5 Protocol stacks in C-Plane



In U-plane, GTP-U on top of UDP/IP is used over S1-U and X2-U interface for data transfer. An X2-UP protocol on top of GTP-U is used for communication over X2-U interface.

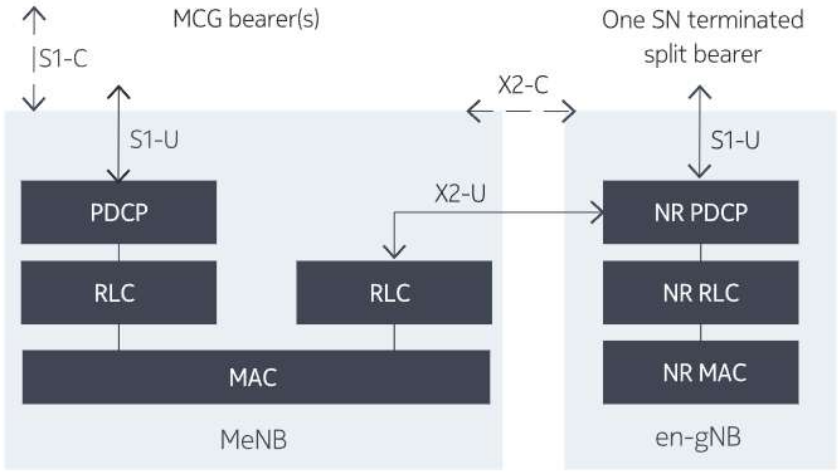
Figure 6 Protocol stacks in U-Plane



Radio protocol architecture

The DRB split according to option 3x is named SN terminated split bearer and it is split by the en-gNB, between an NR leg and an LTE leg. NR Packet Data Convergence Protocol (PDCP) splits data for an SN terminated split bearer and sends data towards MeNB via X2-U interface for transmission over LTE radio. PDCP sends data also towards NR Radio Link Control (RLC) for transmission over 5G radio.

Figure 7 Protocol split between MeNB and en-gNB in the 3x option of EN-DC



4.1.2 New Radio Packet Data Convergence Protocol

Description of Secondary Node (SN) terminated split eligible Master Cell Group (MCG) bearers with New Radio (NR) Packet Data Convergence Protocol (PDCP) in the eNB introduced by the LTE4088: LTE-NR Dual Connectivity Option 3X feature.

A radio bearer anchored in the secondary node (en-gNB) is configured with an NR version of the Packet Data Convergence Protocol (PDCP). A radio bearer anchored in the master node (MeNB) can be configured in the eNB either with the NR or with the LTE PDCP version.

To reduce the data loss and data duplication during bearer type change without affecting the other MCG bearers of the connection, the data bearer which is eligible to become an SN terminated split bearer is established in the eNB as MCG bearer with NR PDCP.

A bearer type change is executed without a handover changing both the data radio bearer identifier (DRB ID) and the logical channel identity (LCID) of the bearer. The pictures below show the affected protocol stacks when executing an MCG to SN terminated split and an SN terminated split to MCG bearer type change respectively, without a handover.

Figure 8 Protocol stacks affected by an MCG to an SN terminated split type change

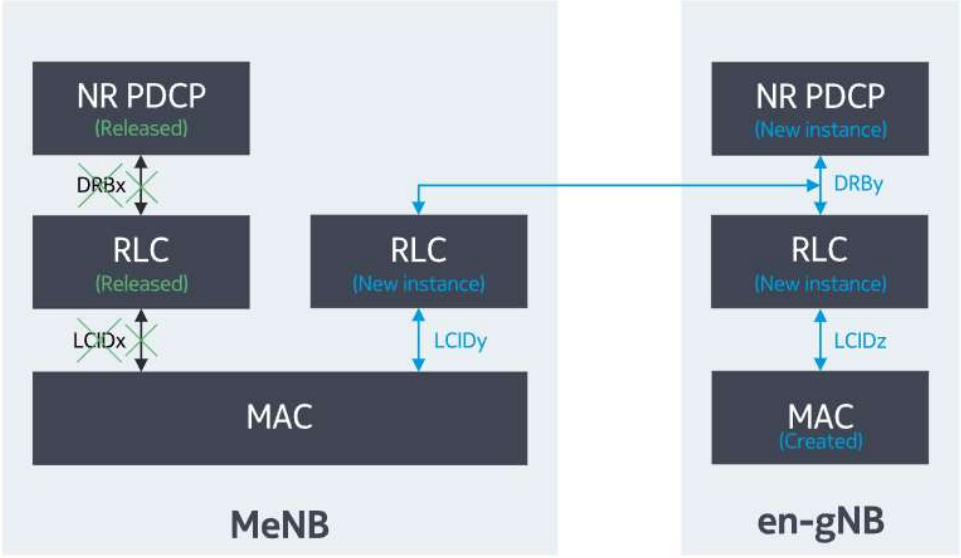
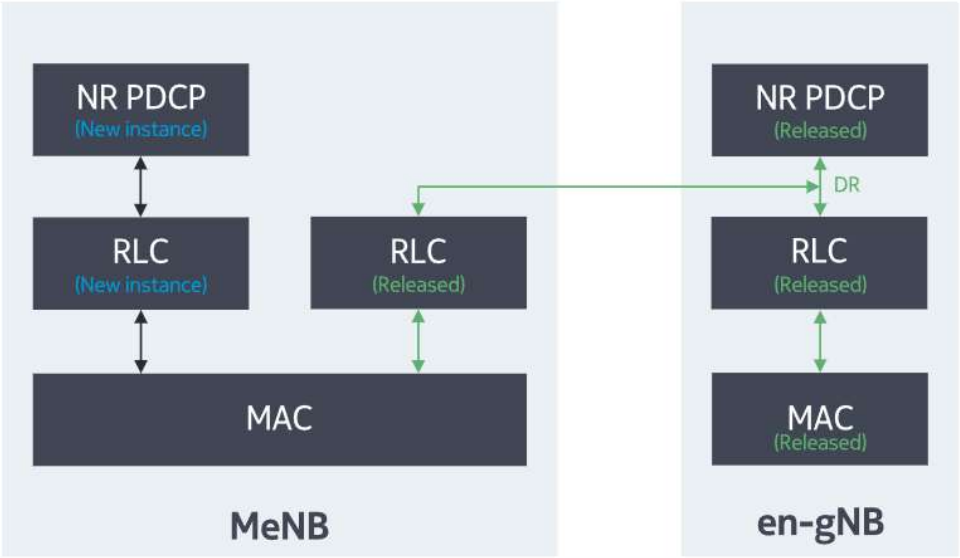


Figure 9 Protocol stacks affected by an SN terminated split to an MCG bearer type change



- active UEs operating in NSA mode 3x per 5G cell, the cell level admission limit is based on user plane (UP), control plane (CP) hardware (HW) capacity, channel state information (CSI) resource situation, PUCCH allocation
- active UEs operating in NSA mode 3x per gNB per NRCELLGRP
- non-GBR data radio bearers of active UEs operating in NSA mode 3x per NRCELLGRP

The related request is rejected if one of the above conditions is fulfilled. An all-or-nothing approach is applied by the radio admission control.

The limitation on number of SCell allocations per cell are introduced with mobility or carrier aggregation functions.

The RAC compares the amount of NSA users, non-GBR DRBs with Operations and Maintenance (O&M) parameters.

Figure 10 Radio Admission Control – SgNB addition

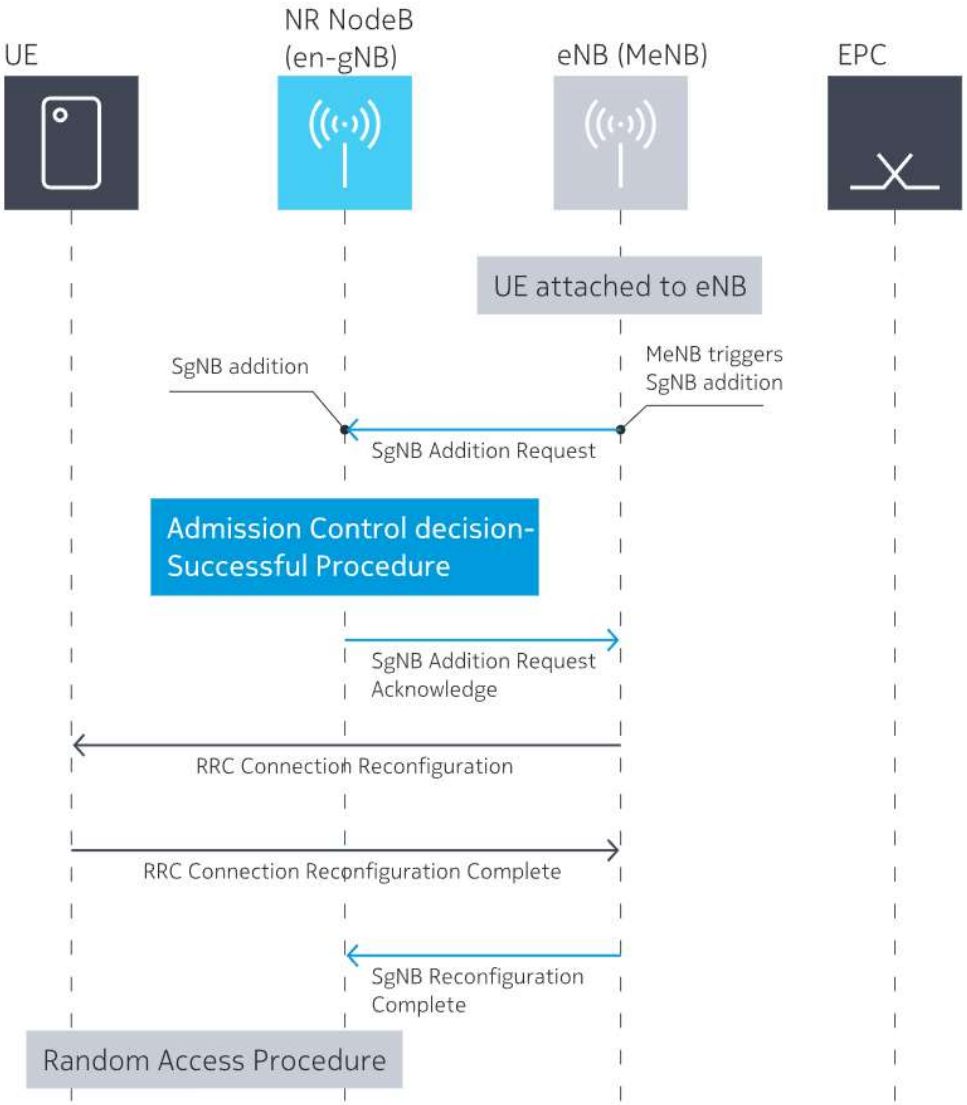
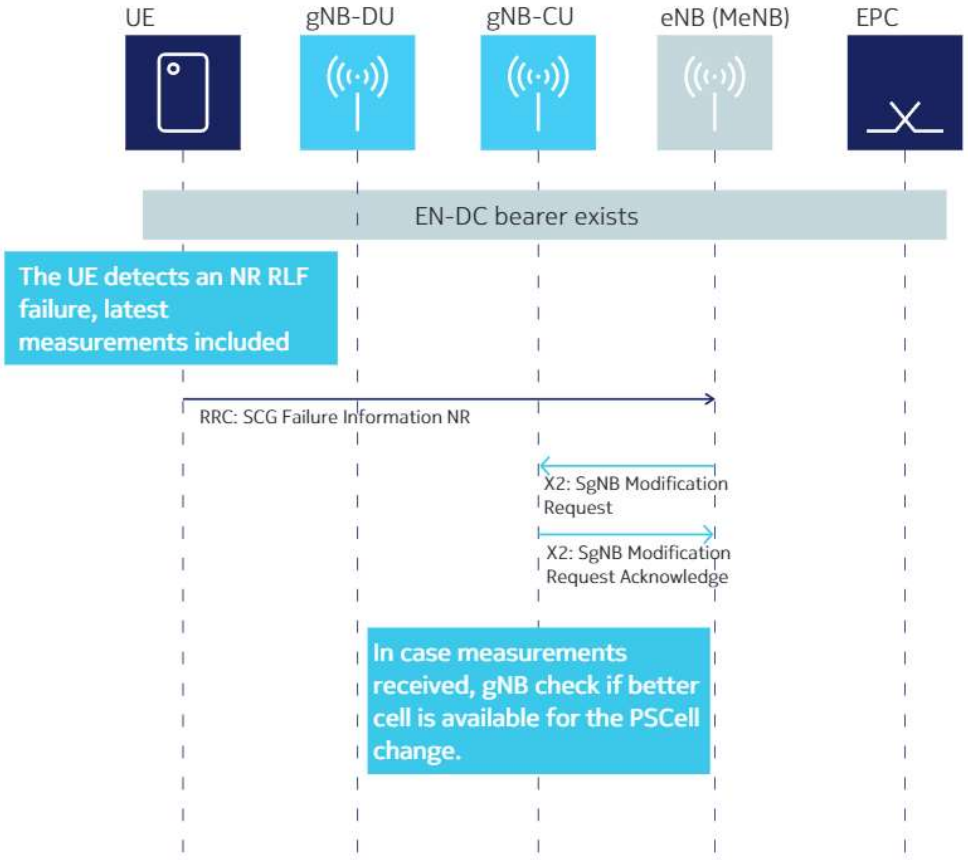


Figure 11 Scenario of UE initiating RLF detection



en-gNB-initiated RLF handling

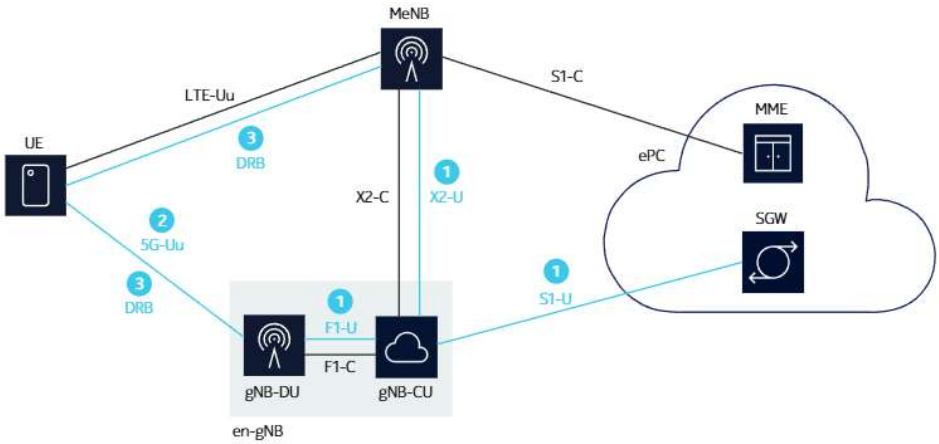
The en-gNB uses consecutive Discontinuous Transmission (DTX) detections for requested downlink HARQ feedback as well as the consecutive DTX detections for CSI reports in order to detect potential RLFs at the 5G radio link. When the en-gNB declares RLF on the PSCell, a control timer is set. During the waiting time, data can be switched to the LTE leg of the split bearer. After timer expires, if UE was not recovered, the en-gNB releases the UE context by sending an en-gNB initiated en-gNB release with the cause value (Radio Connection with UE lost) to MeNB.

4.2.3 UE Inactivity Handling

The 5GC000479: UE Inactivity Handling for NSA Mode 3x Operation feature detects UE inactivity on the 5G leg of a dual connectivity connection. When 5G inactivity is detected, gNB requests the MeNB to release its resources by using an SgNB initiated SgNB Release procedure. This provides better resources management and increases UE battery life. At the same time, with the LTE4088: LTE-NR Dual Connectivity Option 3x feature, the eNB monitors UL and DL data activity and stores this information in the UE context.

Figure 14 L3 call with data transmission

1. UE Context Setup: to setup the bearer
2. According to en-gNB configuration, contention (free or based) random access is performed to setup Uu between UE and en-gNB
3. Data Radio Bearer (DRB) establishment: UL and DL user date transfer through the en-gNB with the Serving Gateway (SGW)
4. UE Context Release: remove DRB and bearers established in steps 1-3



UE context setup and DRB establishment

This feature is applied when the MeNB and en-gNB are configured, and when UE is attached to LTE, according to prerequisite features. Especially for the gNB, this means that:

- gNB is started up, with L1 and L2 functionality, and is able to create S1-U AP and F1-U AP.
- gNB supports an active X2 link with MeNB.
- gNB-CU and gNB-DU are configured with an active F1-C connection between them.
- gNB-DU is configured with contention-free or contention-based random access parameters:
  - C-RNTI (needed for both contention-free and contention-based).
  - A set of dedicated-preamble, associated to a SS/PBCH block identifiers (only for contention-free).
- gNB-CU is configured with: non-GBR QCI profile for the DRB (MAC, RLC and PDCP), and security data.
- gNB-DU is configured with the Master Information Block (MIB) for New Radio (NR) access.
- 5G cell is configured and active.
- UE is attached to LTE.

Following the *SgNB Addition* procedure, gNB-CU receives a request from MeNB to setup the UE context with one bearer. This request leads to the following main gNB behaviors:

1. gNB-CU allocates UE F1-AP identifier.
2. gNB-CU stores the received information from MeNB, such as: TEID for UL data from gNB to SGW, TEID at MeNB for secondary node (SN) terminated split bearer, UE identifier over X2 interface, security key, and QCI.

Contention (free or based) random access

According to the section *UE context setup and DRB establishment*, the UE is ready to trigger contention-free or contention-based random access with the en-gNB where the following conditions are met:

Note:

- The PRACH configuration was already exchanged between the gNB-DU and the UE (needed for contention-based random access).
- A set of dedicated-preamble (each of the dedicated preambles being associated to a SS/PBCH block identifiers) were already exchanged between the gNB-DU and the UE (needed for contention-free random access). If no dedicated preambles are allocated, only contention-based random access can be performed.

First, the UE determines if it can trigger a contention-free random access. For that, the UE measures the SS-RSRP of all SS/PBCH blocks (periodically send by the gNB):

- If any SS/PBCH block, associated with a dedicated preamble, has a SS-RSRP higher than a threshold, the UE selects one of the SS/PBCH block to trigger a contention-free random access.
- Else, the UE fallbacks to a contention-based random access.

Contention free random access:

1. Once the UE decides to perform a contention-free random access, the UE sends a PRACH, using the dedicated preamble, to the next PRACH occasion associated with the selected SS/PBCH block identifier.
2. The gNB-DU detects the dedicated preamble, identify the UE and answer with a Random Access Response (RAR) address to RA-RNTI.
3. Once the UE received the RA-RNTI, it considers the contention-free random access procedure is successful. The UE transmits a PUSCH according to the grant received in the RAR.
4. On the first PUSCH correctly decoded, the gNB-DU releases the dedicated preamble allocated to the UE.
5. The gNB-DU switches to the UE dedicated bandwidth and restarts UL and DL schedulers for this UE.

Contention based random access:

1. The process starts when the UE determines the RACH occasion opportunity, and selects a PRACH preamble in random access preambles group A. On the next RACH occasion opportunity, the UE transmits the PRACH preamble. A timer is started to monitor the reception of the response message.
2. The gNB-DU detects the PRACH preamble (including the timing information) and acknowledges it with PDCCH, with a temporary C-RNTI.
3. The UE detects the PDCCH and decodes the PDSCH, and if it finds its transmitted preamble, it stops its timer.
4. Then the UE sends a message to the gNB with the UE C-RNTI, and encodes it, using the temporary C-RNTI. Then the UE starts another timer.
5. The gNB receives it, identifies the UE with the UE C-RNTI, and schedules a Contention Resolution Grant (UL grant) address to the UE C-RNTI. The temporary C-RNTI is released.

6. Upon reception of a uplink address (with the UE C-RNTI), the UE considers the contention is resolved, so its timer is stopped, and the contention-based random access procedure is terminated. The UE sends a PUSCH.

Note: If PUSCH is incorrect, the gNB schedules hybrid automatic repeat request (HARQ) retransmission using the temporary C-RNTI until the maximum number of HARQ retransmissions is reached. The UE restarts its timer for each HARQ retransmission.

For both contention-free and contention-based random access:

- In case of failure, the gNB-CU triggers *SgNB initiated Release* procedure with the appropriate cause value, then performs the *UE Context Release*.
- The en-gNB can also try change of the serving PSCell according to the *5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation* feature.

User data transfer through the en-gNB

Once the gNB has setup UE context and established DRB, and the contention-free or based random access process is complete, UL and DL user data transfer over the established DRB can occur through the en-gNB.

For downlink user data transfer over DRB, the gNB behavior is:

1. The gNB-CU receives the GTP PDU from S-GW.
2. The gNB-CU processes the GTP header and extract: Version, payload type (PT), Message type, sequence number flag (S), extension header flag (E), Length and TEID fields.
3. In case of error, the gNB-CU sends error indication to S-GW, and stops further processing.
4. The gNB-CU extracts the GTP payload based on the Length.
5. The gNB-CU provides the GTP payload (PDCP SDUs) and TEID to complete the PDCP.
6. The gNB-CU prepares the PDCP PDU from the received PDCP SDUs, so the downlink user data can be sent to the UE thanks to the *5GC000630: F1-U Interface* feature.

For uplink user data transfer over DRB, the gNB behavior is:

1. The gNB-CU receives PDCP SDUs over the F1-U interface (uplink) from the UE, thanks to the *5GC000630: F1-U Interface* feature.
2. The gNB-CU adds the GTP header and prepares the GTP PDU.
3. The gNB-CU completes the GTP PDU with source IP address, S-GW IP address, and DSCP value.
4. The gNB-CU uses the S-GW IP address to send the GTP PDU to the S-GW.

Note: Both for uplink and downlink, the ciphering is covered by the *5GC000543: Ciphering of U-Plane (NSA Option 3x)* feature.

This feature also introduces the gNB behavior in case of failures.

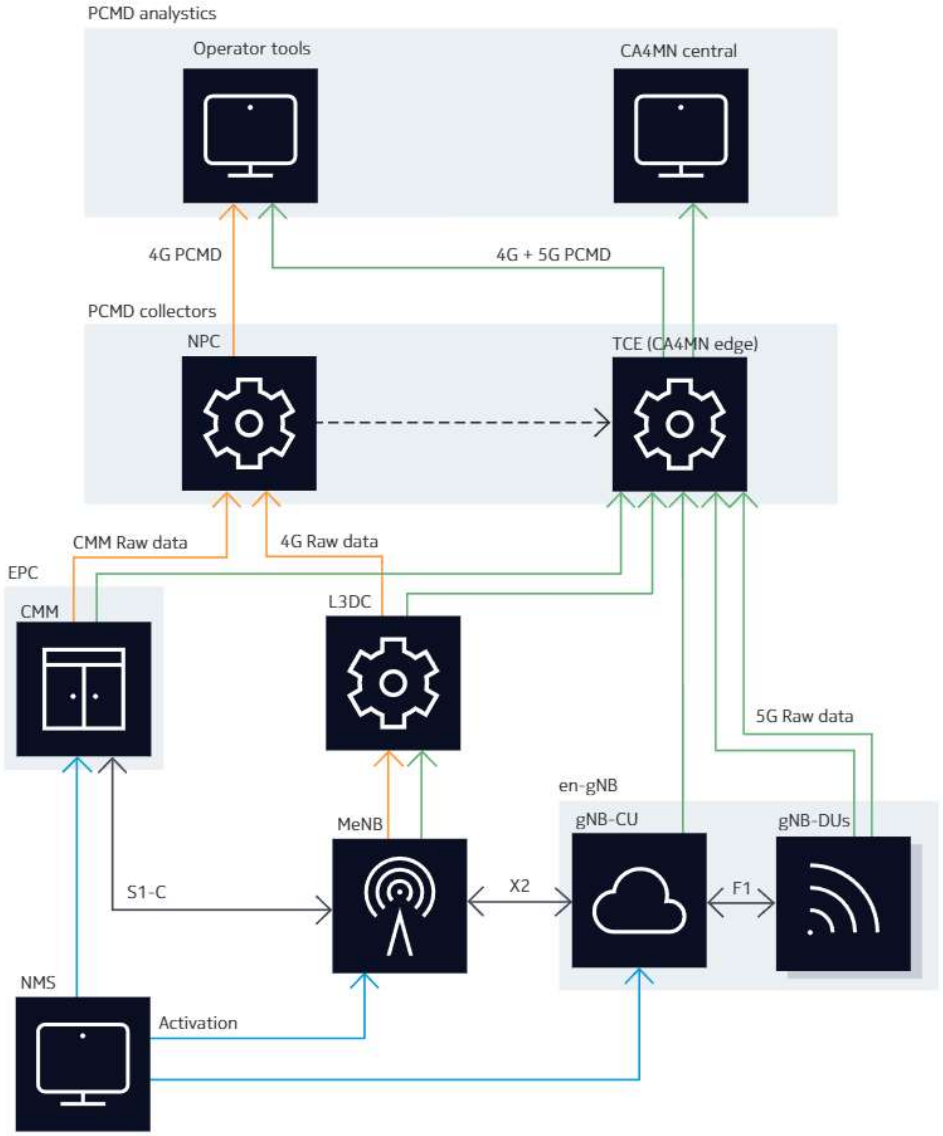
Following failures can occurs:

The PCMD is a summary of each call, gathering information from all software layers.

Nokia LTE networks already support 4G PCMD feature, where data is collected from Nokia eNodeB and Nokia Mobility Management Entity (MME), and aggregated by the Nokia Network PCMD Correlation (NPC) entity. The resulting 4G PCMD record is analysed by the Nokia 9959 Network Performance Optimizer (NPO) or by operator specific tools.

In Nokia 5G networks with NSA architecture, the 5G call is managed by more Nokia entities: MeNB, en-gNB (gNB-CU and gNB-DUs) and MME (supported by Nokia Cloud Mobility Manager (CMM)). The collection and aggregation of raw PCMD data from these entities are performed by the TCE. This includes correlation of data from gNB-CU and gNB-DUs, and with 4G PCMD data and MME data, for the call of the same UE. The TCE supported by Nokia is the CA4MN Edge.

Figure 15 PCMD data collection in 5G networks with NSA architecture



Like the eNodeB in Nokia LTE network, the gNB provides PCMD data using similar interface, extended to 5G, based on ASN.1 encoder on top of TCP format. There is one TCP link to the TCE per gNB-CU, and another per gNB-DU.

The CA4MN Edge provides the final PCMD record, one per call for easy analysis. It includes data from the MeNB, en-gNB, and MME. IMSI and IMEI, and other MME information are added by the CA4MN Edge. Analytics of these final PCMD records are done by the CA4MN Central or by operator-specific tools.

The operator can activate the PCMD feature at gNB-CU and gNB-DUs level from a single operation initiated at NMS. Activation on gNB-CU and gNB-DUs should be done together to get complete PCMD result, but this is not mandatory.

When PCMD is activated, and at least one cell is up, the gNB setups TCP connections to the TCE (an alarm is raised if the TCE is not reachable). Then the gNB starts to collect and send PCMD-related information for all users visiting the cell (up to the parameter: maximum number of UE connections traced per cell).

Using similar process, the operator can deactivate the PCMD feature on a gNB, leading to stop ongoing PCMD tracing on gNB and to terminate the sessions with the TCE.

The gNB does not wait until the UE leaves a cell for sending raw PCMD data towards the TCE. The C-plane events are sent as they occur. The U-place data is sent at approximatively every 4096 ms (the reporting interval must be the same as set in LTE side). So a single call is broken in multiple pieces.

The CA4MN starts or stops PCMD collection for a UE according to the following triggers:

- The start trigger: anytime when a new gNB or PSCell (gNB addition) is established.
- The end trigger: anytime when the gNB or PSCell is released.

At the end of the LTE call (end trigger) the CA4MN aggregates data received from eNB and gNB for a call summary.

CA4MN performs the correlation of data from gNB-CU and gNB-DU for the en-gNB based on F1AP ID, which is unique to an UE in whole gNB.

PCMD data provided by en-gNB and MeNB are combined by CA4MN using: SgNB UE X2AP ID and eNodeB UE X2AP ID.

The list of measurements and values that are collected by the gNB includes, for example:

- Control Plane data, such as PhysicalCellID, CellID
- Fields required for correlation, such as UE F1AP ID, MeNB UE X2AP ID, SgNB UE X2AP ID
- Data on such procedures, such as SgNB addition (SgNB addition request time and SgNB addition request reject reason)

Note: LTE PCMD feature is still available (and running if activated) for MeNB working with en-gNB for LTE only UEs.

CA4MN can correlate en-gNB and MeNB data only if PCMD feature is activated on the MeNB. CA4MN can correlate with MME data only if PCMD feature is activated on the CMM. Refer to LTE eNB and CMM documentation for PCMD activations on these products.

4.3 Mobility management

A description of supported handover procedures assuring service continuity in case of a moving UE

4.3.1 Intra-frequency intra en-gNB mobility

The 5GC000572: Intra-Frequency Intra en-gNB Mobility (NSA Option 3x) feature supports an intra-frequency change of the serving primary cell supported by two gNB Distributed Units (gNB-DU) of the same secondary gNB (en-gNB), triggered by this en-gNB, for 3GPP non-standalone (NSA) architecture option 3x. The feature allows reliable NR service continuity (lossless) for User Equipment (UE) during intra en-gNB inter-cell inter-gNB-DU handover.

This inter-gNB-DU PSCell change procedure is:

- possible if more than one gNB-DU is supported by this gNB-CU.
- supported for NSA calls with at least one established secondary node (SN) terminated split data radio bearer (DRB).

Figure 16 Intra-frequency inter-DUs en-gNB mobility (NSA option 3x)

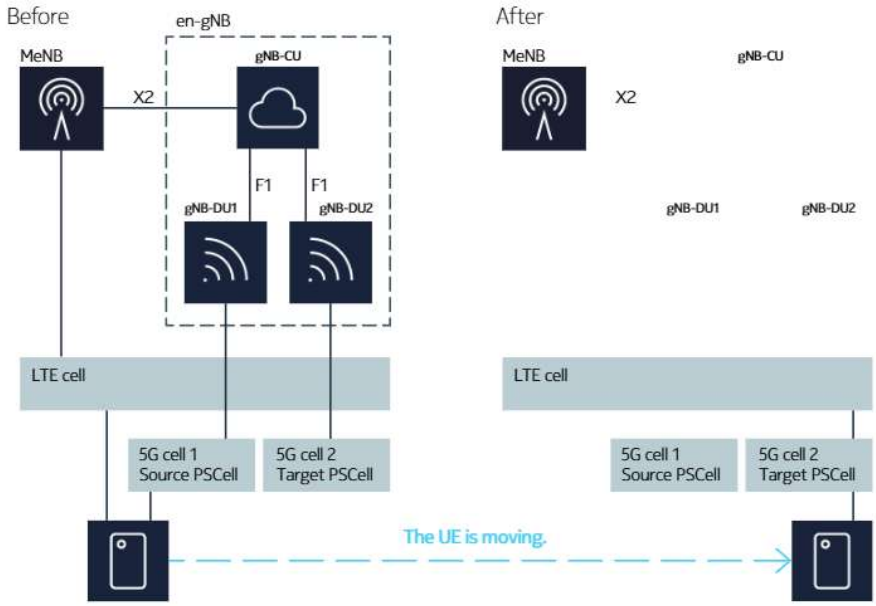
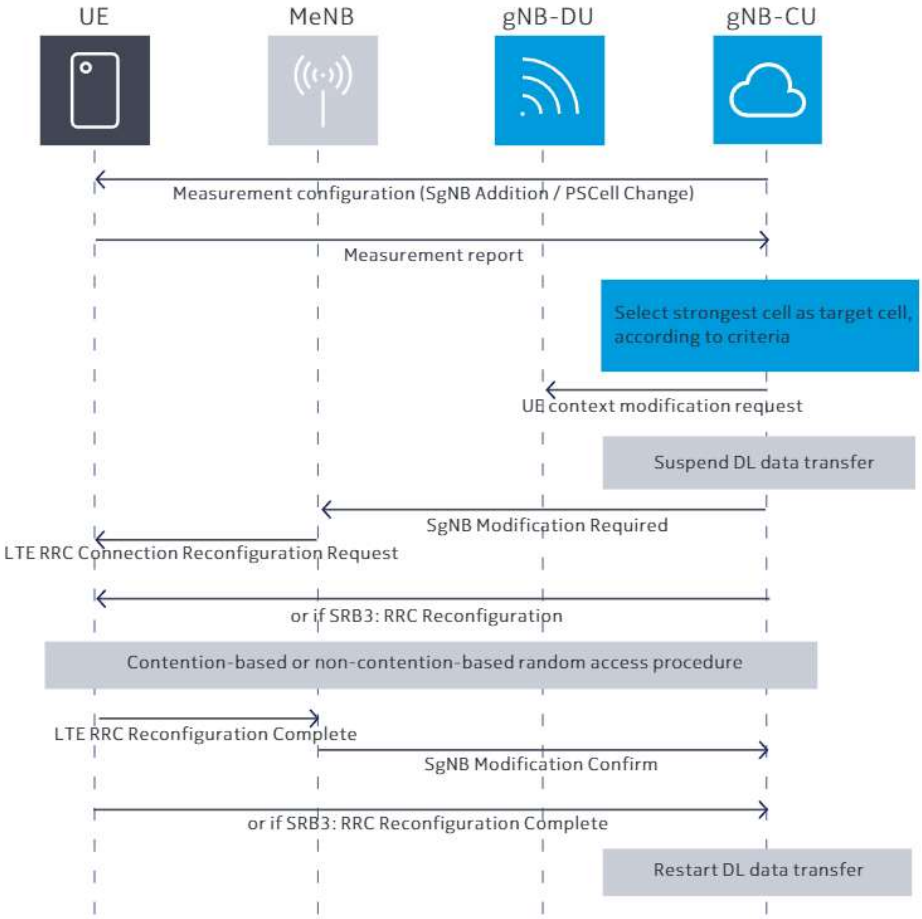


Figure 19 Messages flow for intra-frequency intra-DU en-gNB mobility



Intra-gNB-DU PSCell change preparation

UE sends Measurement Report when measurement criteria are fulfilled. a measurement report does not include the cells which are contained in the operator-configured blacklist used during the measurement configuration. That message is delivered to en-gNB via MeNB through the X2 interface or directly via air interface if SRB3 is available.

Based on the measurement reports from the UE, the en-gNB selects the strongest reported target cell that also meets a certain amount of criteria (not temporally blacklisted, Public Land Mobile Network (PLMN) is allowed in the Handover Restriction List (HRL)). If the target cell belongs to the same gNB-DU, the en-gNB triggers to the UE a network-controlled intra-gNB-DU PSCell change.

The gNB-CU performs bearer context modification, sends UE context modification request to the gNB-DU, and suspend downlink data transfer to the gNB-DU. But data transfer is not suspended toward MeNB.

If 5G Carrier Aggregation (CA) feature is active in the en-gNB, new SSCells are assigned to the UE during PSCell change. The SSCells are implicitly activated when SSCells are configured. Any SSCells currently active at the source are released during 5G bearer release.

Also, measurement configuration for target PSCell is defined during PSCell change.

Furthermore, the *Dynamic Trigger* functionality brings the functionality for the eNB to support PDCP status report during the incoming handover with EN-DC QCI eligible bearer. The PDCP status report indicates which PDCP Service Data Units (SDUs) are missing and which are not following PDCP re-establishment. When PDCP entity receives a PDCP status report, it forwards the PDCP SDUs to lower layers which have been set to zero in the corresponding bitmap.

Note: With the *Dynamic Trigger* functionality, the PDCP sequence number size is 18 bit.

4.4.1.1 Dynamic Trigger for the EN-DC procedure

The Dynamic Trigger functionality introduced by the LTE4193: Dynamic Trigger for LTE-NR DC Option 3x feature supports eNB capability to trigger EN-DC setup based on NR coverage.

The *Dynamic Trigger* functionality uses as a prerequisite the *X2 Interface with NR gNB* functionality introduced by the *LTE4087* feature, which provide the support by an eNB of X2 links to an NR NodeB. The *LTE-NR Dual Connectivity Option 3x* functionality introduced by the *LTE4088* feature provides the EN-DC with 3GPP option 3X for the *Dynamic Trigger* operation. With the *Blind CA with LTE-NR DC Option 3x* feature activated there is a CA supported for EN-DC capable UE.

The basic *LTE-NR Dual Connectivity Option 3x* functionality, allows only for immediate EN-DC setup triggered blindly after *Initial Context Setup* procedure signaling. With the *Dynamic Trigger* functionality, it allows a UE to select neighbor NR cell to establish the LTE-NR Dual Connectivity (DC). This functionality is based on the UE measurements of the NR cell strength and multiple NR Packet Data Convergence Protocol (PDCP) bearer support.

For NR coverage detection, the eNB uses B1 measurements on NR frequencies. The UE triggers measurement report for B1 event when strength of a candidate cell is above a specified threshold. When NR coverage conditions are met, EN-DC procedure to perform Secondary Node (SN) terminated split bearer is triggered. The NR cell used for secondary gNB (en-gNB) addition is chosen as the strongest cell from B1-NR measurement report from the UE. The NR PDCP bearer chosen for SN terminated split bearer creation is based on allocation and retention priority (ARP) level of the bearer as in the basic *LTE-NR Dual Connectivity Option 3x* functionality.

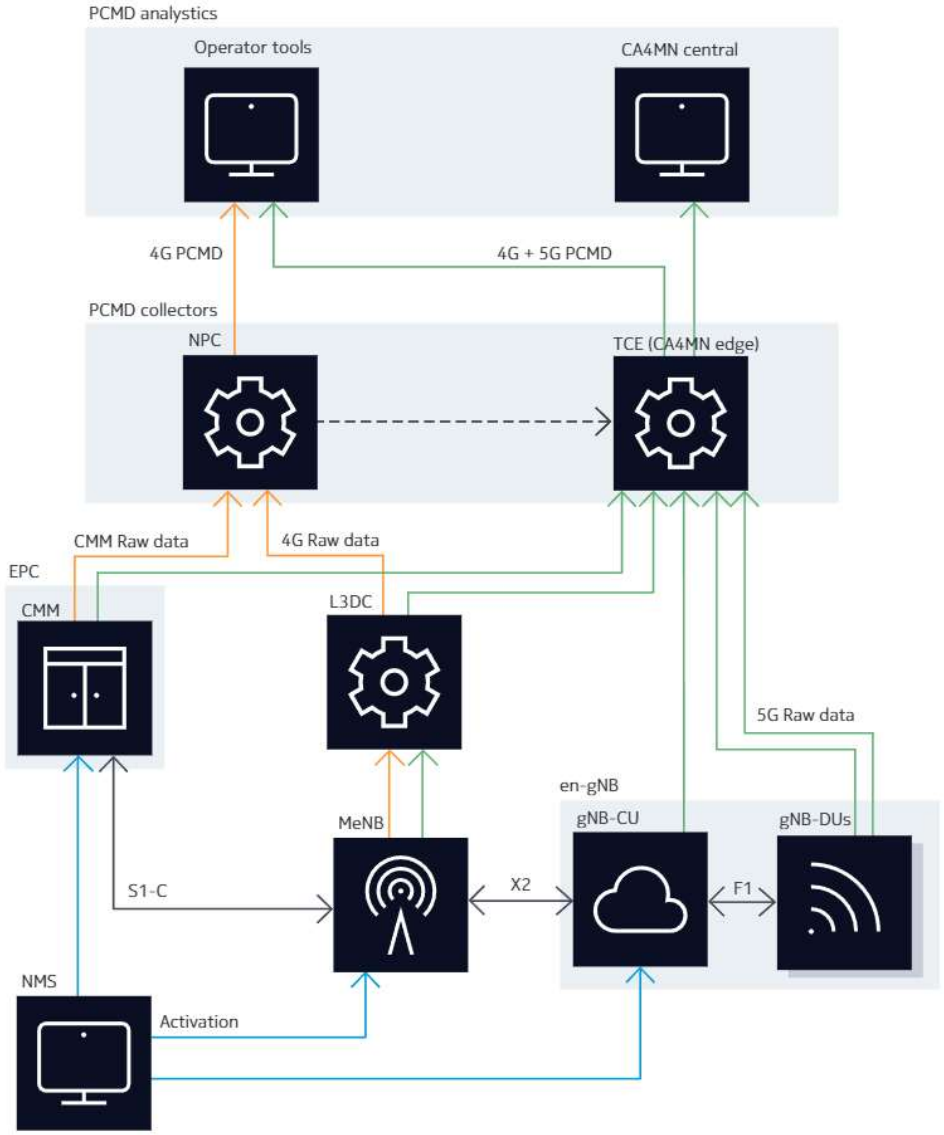
If *SgNB addition* procedure fails for the selected en-gNB, MeNB re-tries *SgNB addition* procedure for the next en-gNB based on the next strongest B1-NR measurement result until there are no more NR cells in B1-NR measurement report. MeNB sends all reported NR cells corresponding to the selected en-gNB in the *SgNB addition* procedure.

Note: In case of the blind *SgNB addition* procedure, only the default or prioritized NR cell is attempted and there is no retry of other NR cells in case of failure.

As mentioned above, this functionality supports selecting the strongest neighbor NR cell candidate based on B1 measurements. To support multiple NR neighbor cells that would be eligible for EN-DC, the number of instances of neighbor NR relation configuration (**LNRELGNBCELL**) is extended.

Measurement gap for B1-NR measurements

Figure 20 PCMD data collection in 5G networks with NSA architecture



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The operator can activate the PCMD feature at gNB-CU and gNB-DUs level from a single operation initiated at NMS. Activation on gNB-CU and gNB-DUs should be done together to get complete PCMD result, but this is not mandatory.

When PCMD is activated, and at least one cell is up, the gNB setups TCP connections to the TCE (an alarm is raised if the TCE is not reachable). Then the gNB starts to collect and send PCMD-related information for all users visiting the cell (up to the parameter: maximum number of UE connections traced per cell).

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PCMD data provided by en-gNB and MeNB are combined by CA4MN using: SgNB UE X2AP ID and eNodeB UE X2AP ID.

The list of measurements and values that are collected by the gNB includes, for example:

- Control Plane data, such as PhysicalCellID, CellID
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- Data on such procedures, such as SgNB addition (SgNB addition request time and SgNB addition request reject reason)

Note: LTE PCMD feature is still available (and running if activated) for MeNB working with en-gNB for LTE only UEs.

CA4MN can correlate en-gNB and MeNB data only if PCMD feature is activated on the MeNB. CA4MN can correlate with MME data only if PCMD feature is activated on the CMM. Refer to LTE eNB and CMM documentation for PCMD activations on these products.

4.5 Security

The 5G-LTE security is a technology that provides the confidentiality of user data and prevents hacker attacks to the interworking networks and network elements. Also, by means of security, the 5G and LTE networks can assure data integrity protection, access control for the system, and users authentication.

5 5G-LTE interworking system impact

The 5G-LTE interworking features system impact and impact on other features for X2 link and option 3x related features

Table 6 Division of 5G-LTE interworking features to X2 link and option 3x related features

Feature name	Feature division
LTE4087: X2 Interface with NR gNB	X2 link
LTE4744: gNB Initiated EN-DC Configuration Update	X2 link
5GC000474: X2 Management for NSA Mode 3x Operation	X2 link
5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6	X2 link
LTE4088: LTE-NR Dual Connectivity Option 3x	option 3x / X2 link
5GC000475: SgNB Addition and Release for NSA Mode 3x Operation	option 3x / X2 link
LTE4193: Dynamic Trigger for LTE-NR DC Option 3x	option 3x
LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x	option 3x
5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation	option 3x
5GC000479: UE Inactivity Handling for NSA Mode 3x Operation	option 3x
5GC000480: Radio Admission Control for NSA Mode 3x Operation	option 3x
5GC000482: UE Capability Handling for NSA Mode 3x Operation	option 3x
5GC000509: L3 Non Standalone Call with Data Transmission	option 3x
5GC000543: Ciphering of U-Plane (NSA Option 3x)	option 3x
5GC000570: 5G - LTE Flow Control at X2	option 3x
5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)	option 3x
5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)	option 3x
5GC001097: Basic PCMD for NSA	option 3x

5.1 X2 link features system impact

The 5GC000474: X2 Management for NSA Mode 3x Operation, LTE4087: X2 interface with NR gNB, LTE4088: LTE-NR Dual Connectivity Option 3x, LTE4744: gNB Initiated EN-DC Configuration Update features impact the following aspects of the system: interfaces, system performance and capacity.

Impact on interfaces by X2 features

The *5GC000474: X2 Management for NSA Mode 3x Operation*, *LTE4087: X2 Interface with NR gNB*, *LTE4088: LTE-NR Dual Connectivity Option 3x*, *LTE4744: gNB Initiated EN-DC Configuration Update* features impact X2 interface with the introduction of EN-DC dedicated X2 management procedures for eNB and gNB interworking (for more, see Table 4: X2-C interface procedures).

Impact on system performance and capacity by X2 features

The *5GC000474: X2 Management for NSA Mode 3x Operation*, *LTE4087: X2 Interface with NR gNB*, *LTE4088: LTE-NR Dual Connectivity Option 3x*, *LTE4744: gNB Initiated EN-DC Configuration Update* features impact system performance and capacity as follows:

- The procedures over X2 (gNB) interface and the triggered ones over the Uu interface consume the part of C-plane capacity budget (bounded to 1500 events per second in total).
- Additional fields for monitoring gNBs are included in the per call measurement data (PCMD) records generated eNBs, in DC to monitor network key performance indicators (KPIs) for 4G and 5G networks, and for efficient issues troubleshooting. The following information is included in the PCMD records:
  - SgNB UE X2AP ID
  - eNB UE X2AP ID
  - TEID
  - whether UE is EN-DC capable

Impact on network management tools by X2 features

The X2 related features have no impact on network management tools.

5.1.1 5G X2 link features impact on other 5G features

List of correlations between 5G X2 features and other 5G features

5GC000474: X2 Management for NSA Mode 3x Operation

The following features are prerequisites for the *5GC000474: X2 Management for NSA Mode 3x Operation* feature:

- *5GC000167: Fault Management General Flow and Mechanism*
- *5GC000236: gNB Object Model*
- *5GC000481: F1 Link Management*
- *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6*
- *5GC000645: 5G Cloud OAM Restart Improvement*
- *5GC000718: F1 Cell Management*

5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6

The following features are a prerequisite for the *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6* feature:

- *5GC000167: Fault Management General Flow and Mechanism*
- *5GC000236: gNB Object Model*
- *5GC000718: F1 Cell Management*

5GC000475: SgNB Addition and Release for NSA Mode 3x Operation

Note: The *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation* feature introduces X2 procedures but it main functionality is related to option 3x, so the *5GC000475* feature impact on other 5G features is presented in the 5G option 3x features impact on other 5G features section.

5.1.2 LTE X2 link features impact on other LTE features

List of correlations between LTE X2 link related features and other LTE features

LTE4087: X2 Interface with NR gNB

The following feature is a prerequisite before using the *LTE4087: X2 Interface with NR gNB* feature:

- *LTE3: S1, X2 and RRC common signaling*

The *LTE4087: X2 Interface with NR gNB* feature is impacted by the following features:

- *LTE433: Cell Trace*
  The *LTE433: Cell Trace* feature must be enabled to trace the new X2 messages.
- *LTE529: Dynamic X2 & S1 Firewall Configuration*
  If the *LTE529: Dynamic X2 & S1 Firewall Configuration* feature is enabled, the eNB will process *LTE529* specific actions before triggering X2 (gNB) establishment attempts for an X2 (gNB) link.
- *LTE644: Configurable Cell Trace Content*
  New X2 messages are selectable or de-selectable for interface tracing.
- *LTE1014: X2 eNB Configuration Update*
  The configuration update procedure introduced by the *LTE1014* feature is not triggered on X2 links to the en-gNB.
- *LTE1048: X2 Mesh Connectivity with IPsec*
  The *LTE1048: X2 Mesh Connectivity with IPsec* feature does not apply for the X2 (gNB) links.

LTE4744: gNB Initiated EN-DC Configuration Update

The *LTE4744: gNB Initiated EN-DC Configuration Update* feature has no impact on other LTE features.

LTE4088: LTE-NR Dual Connectivity Option 3x

Note: The *LTE4088: LTE-NR Dual Connectivity Option 3x* feature introduces X2 procedures but it main functionality is option 3x, so the *LTE4088* feature impact on other LTE features is presented in LTE option 3x features impact on LTE features.

LTE4193: Dynamic Trigger for LTE-NR DC Option 3x feature has no impact on interfaces.

LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x feature has no impact on interfaces.

5GC000475: SgNB Addition and Release for NSA Mode 3x Operation

The *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation* feature impacts X2-C (X2AP) interface with the introduction of X2 messages supporting EN-DC.

The *5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation* feature introduces X2 interfaces. The UE reports failure information to the eNB via LTE SRBx. Radio link failure in the 5G leg is forwarded to en-gNB via X2 interface.

The *5GC000543: Ciphering of U-Plane (NSA Option 3x)* feature impacts the Uu interface. With this feature, the protocol data units (PDUs) sent over the air interface (Uu) are ciphered.

The *5GC000570: 5G - LTE Flow Control at X2* feature impacts the X2 interface. It introduces flow control over X2.

5GC001097: Basic PCMD for NSA

Nokia proprietary interface is introduced for sending PCMD vendor records from the gNB (from gNB-CU and gNB-DU) to the TCE. The gNB sends Nokia proprietary messages over this interface to a given IP address. This interface uses ASN.1 encoding over Transmission Control Protocol (TCP) stream.

The following features have no impact on interfaces:

- **5GC000479: UE Inactivity Handling for NSA Mode 3x Operation**
- **5GC000480: Radio Admission Control for NSA Mode 3x Operation**
- **5GC000482: UE Capability Handling for NSA Mode 3x Operation**
- **5GC000509: L3 Non Standalone Call with Data Transmission**
- **5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)**
- **5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6**
- **5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)**

Impact on system performance and capacity by option 3x features

LTE4088: LTE-NR Dual Connectivity Option 3x

The *LTE4088: LTE-NR Dual Connectivity Option 3x* feature impacts system performance as follows:

- The procedures over X2 (gNB) interface and the triggered ones over the Uu interface consume part of the control plane (C-Plane) capacity budget (bounded to 1500 events per second in total).
- eNB handles additional X2 links and X2 (gNB) links towards the neighbor gNBs, and additional neighbor relations towards the neighbor NR cells what cause capacity budget is diminished.

LTE4193: Dynamic Trigger for LTE-NR DC Option 3x

The *LTE4193: Dynamic Trigger for LTE-NR DC Option 3x* feature impacts system performance as follows:

- Handling of the additional EN-DC triggers including incoming handover and additional E-RAB setup with EN-DC QCI eligible bearer. Those additional EN-DC triggers consumes part of the control plane (C-Plane) capacity.
- The *LTE4193* feature impacts C-Plane capacity due to the handling of the B1 measurements with UE for NR coverage detection over the Uu interface.

LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x

The *LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x* feature increases eNB load and UE throughput while comparing to EN-DC without Carrier Aggregation (CA).

The option 3x-related 5G features have no impact on system performance and capacity.

Impact on network management tools by option 3x features

The option 3x related features have no impact on network management tools.

5.2.1 5G option 3x features impact on other 5G features

List of correlations between 5G option 3x features and other 5G features

5GC000475: SgNB Addition and Release for NSA Mode 3x Operation

The following features are a prerequisite for the *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation* feature:

- *5GC000425: TDD Lower Layer Support - 100 MHz Cell Bandwidth*
- *5GC000474: X2 Management for NSA Mode 3x Operation*
- *5GC000481: F1 Link Management*
- *5GC000509: L3 Non Standalone Call with Data Transmission*
- *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6*
- *5GC000630: F1-U Interface*

5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation

The following features are a prerequisite for the *5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation* feature:

- *5GC000165: Performance Management Generic Mechanism*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000509: L3 Non Standalone Call with Data Transmission*
- *5GC000523: TDD Scheduler for Multi-UE Support*
- *5GC000570: 5G - LTE Flow Control at X2*
- *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*

5GC000479: UE Inactivity Handling for NSA Mode 3x Operation

The following features are a prerequisite for the *5GC000479: UE Inactivity Handling for NSA Mode 3x Operation* feature:

- *5GC000165: Performance Management Generic Mechanism*
- *5GC000474: X2 Management for NSA Mode 3x Operation*

- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000480: Radio Admission Control for NSA Mode 3x Operation*
- *5GC000509: L3 Non Standalone Call with Data Transmission*

There are no correlations between the **5GC000480: Radio Admission Control for NSA Mode 3x Operation** feature and any other feature.

5GC000482: UE Capability Handling for NSA Mode 3x Operation

The following features are a prerequisite for the *5GC000482: UE Capability Handling for NSA Mode 3x Operation* feature:

- *5GC000474: X2 Management for NSA Mode 3x Operation*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*

The *5GC000482: UE Capability Handling for NSA Mode 3x Operation* feature impacts the following features:

- *5GC000527: Intra-band CA TDD FR2 up to 2 CCs*
- *5GC000605: DL SU Adaptive 4x4 MIMO (open loop)*

5GC000509: L3 Non Standalone Call with Data Transmission

The following features are a prerequisite for the *5GC000509: L3 Non Standalone Call with Data Transmission* feature:

- *5GC000165: Performance Management Generic Mechanism*
- *5GC000167: Fault Management General Flow and Mechanism*
- *5GC000309: Support of F1 Interface over IPv4 or IPv6*
- *5GC000425: TDD Lower Layer Support - 100 MHz Cell Bandwidth*
- *5GC000474: X2 Management for NSA Mode 3x Operation*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000481: F1 Link Management*
- *5GC000511: PRACH Control*
- *5GC000521: Master Information Block*
- *5GC000543: Ciphering of U-Plane (NSA Option 3x)*
- *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*
- *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6*
- *5GC000630: F1-U Interface*
- *5GC000718: F1 Cell Management*

5GC000543: Ciphering of U-Plane (NSA Option 3x)

The following features must be activated before activating the *5GC000543: Ciphering of U-Plane (NSA Option 3x)* feature:

- *5GC000425: TDD Lower Layer Support - 100 MHz Cell Bandwidth*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000718: F1 Cell Management*

5GC000570: 5G - LTE Flow Control at X2

The following features are a prerequisite for the *5GC000570: 5G - LTE Flow Control at X2* feature:

- *5GC000165: Performance Management Generic Mechanism*
- *5GC000509: L3 Non Standalone Call with Data Transmission*
- *5GC000510: Uplink Open Loop Power Control*
- *5GC000577: TRS Support of NSA Interfaces (X2 and S1-U) over IPv4 / IPv6*
- *5GC000630: F1-U Interface*

5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)

The following features are a prerequisite for the *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)* feature:

- *5GC000474: X2 Management for NSA Mode 3x Operation*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000480: Radio Admission Control for NSA Mode 3x Operation*
- *5GC000481: F1 Link Management*
- *5GC000482: UE Capability Handling for NSA Mode 3x Operation*
- *5GC000509: L3 Non Standalone Call with Data Transmission*
- *5GC000543: Ciphering of U-Plane (NSA Option 3x)*

The *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)* feature impacts the following features:

- *5GC000533: Digital Beamforming for CPRI Based RUs*
- *5GC000535: Analog Beamforming*

5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)

The following features are a prerequisite for the *5GC001094: Intra-Frequency Intra-DU en-gNB Mobility (NSA Option 3x)* feature:

- *5GC000414: 5G DU Configurations: mmWave-CPRI*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000480: Radio Admission Control for NSA Mode 3x Operation*
- *5GC000482: UE Capability Handling for NSA Mode 3x Operation*
- *5GC000496: Classical BTS Introduction*
- *5GC000543: Ciphering of U-Plane (NSA Option 3x)*
- *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*

5GC001097: Basic PCMD for NSA

The following features are a prerequisite for the *5GC001097: Basic PCMD for NSA* feature:

- *5GC000414: 5G DU Configurations: mmWave-CPRI*
- *5GC000425: TDD Lower Layer Support - 100 MHz Cell Bandwidth*
- *5GC000474: X2 Management for NSA Mode 3x Operation*
- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *5GC000478: Radio Link Failure Handling for NSA Mode 3x Operation*
- *5GC000496: Classical BTS Introduction*
- *5GC000509: L3 Non Standalone Call with Data Transmission*
- *5GC000570: 5G - LTE Flow Control at X2*
- *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*

When the *LTE1771* feature is active, no load sharing over the S1-U interface for SN terminated split bearers can be guaranteed, as the S1-U interface is relocated to the en-gNB.

- *LTE1240: User Layer TCP MSS Clamping*
  When the *LTE1240* feature is active, the Maximum Segment Size (MSS) value correction algorithm calculation will not consider the GPRS Tunnelling Protocol (GTP) header size increase due to SN terminated split bearers over X2(gNB) interface as this would impact the end user MSS for all bearers (both S1 and X2). This means, the *LTE1240* feature MSS benefit is not applicable for SN terminated split bearer traffic.

LTE4193: Dynamic Trigger for LTE-NR DC Option 3X

The following features must be activated before activating the *LTE4193: Dynamic Trigger for LTE-NR DC Option 3X* feature:

- *LTE1130: Dynamic PUCCH allocation*
  The *LTE4193* introduces B1-NR measurement which requires measurement gaps that are aligned with SSB timing and duration on 5G NR side. This requires dynamic PUCCH (re)allocation that would favor such measurement gaps. The *LTE1130* allows dynamic PUCCH re-allocation for example after RRC Connection Setup, during RRCConnectionReconfiguration for ICS. Without dynamic PUCCH allocation measurement gap allocation for B1-NR measurement would fail.

The following features must be deactivated before activating the *LTE4193: Dynamic Trigger for LTE-NR DC Option 3X* feature:

- *LTE1068: S1/X2 satellite connection*
  If the transport delay over the X2 (gNB) interface exceeds 20 ms one way, EN-DC does not work properly and service impact might occur due to signaling delay and throughput degradation. For this reason, usage of satellite links is not allowed in the eNB when the *LTE4088* feature is active.
- The *LTE4193: Dynamic Trigger for LTE-NR DC Option 3X* feature impacts the following features:
  - *LTE13: Rate capping*
    There is no coordination between the MeNB and the en-gNB for capping the DL/UL UE Aggregate Maximum Bit Rate (AMBR) when there is an SN terminated split bearer. UL/DL AMBR is controlled by the MeNB as if all UE's bearers were MCG ones and by the en-gNB as if the SN terminated split bearer was the only bearer of the UE connection.
  - *LTE1047: Control plane overload handling*
    When C-plane overloaded, EN-DC attempt will be suppressed.
  - *LTE1089: Downlink carrier aggregation - 20 MHz*
    With the *LTE4193* Carrier Aggregation could be supported on UE with NR-PDCP MCG bearers.
  - *LTE1558: TDD Downlink carrier aggregation*
    With the *LTE4193* Carrier Aggregation could be supported on UE with NR-PDCP MCG bearers.
  - *LTE2275: PCell swap*
    The *LTE2275* trigger shall be buffered if EN-DC setup procedure is ongoing. If EN-DC setup succeeds, PCell swap will not be initiated.
  - *LTE3105: RLF triggered HO enhancements*

The *LTE3105* feature supports full-configuration of RCC reestablishment.

- *LTE3590: CA and MFBI interworking extensions*
  The *LTE3590* feature is supported for step-wise CA, so blind EN-DC setup trigger time point is different from LTE3590 intra-cell HO trigger time point.

LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3X

The DL Carrier Aggregation (CA) feature must be activated before activating the *LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x* feature:

- In FDD technology, for example, the *LTE1089: Downlink Carrier Aggregation - 20 MHz* feature
- In TDD technology, for example, the *LTE1558: TDD Downlink Carrier Aggregation* feature

The *LTE2612: ProSe Direct Communications for Public Safety* feature must be deactivated before activating the *LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x* feature.

The *LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x* feature impacts the following features:

- *LTE1092: Uplink Carrier Aggregation - 2 CC* and *LTE2105: TDD Uplink intra band Carrier Aggregation - 2CC*
  The *LTE4575* feature does not support UL CA for an EN-DC-capable UE.
- *LTE2105: TDD Uplink intra band carrier aggregation - 2CC*
  The *LTE2105* feature can be activated together with *LTE4575* feature but *LTE2105* feature will not work for EN-DC capable UE.
- *LTE2275: PCell swap*
  When the *LTE4575* feature is in operation, the primary cell (PCell) swap trigger should be buffered if EN-DC setup procedure is ongoing. If EN-DC setup is completed, the PCell swap trigger is discarded. For UE in EN-DC mode, PCell swap cannot be initiated.
- *LTE3590: CA and MFBI Interworking Extensions*
  When the *LTE4575* feature is in operation, the handover trigger should be buffered if EN-DC setup procedure is ongoing. If EN-DC setup is completed, the Carrier Aggregation (CA) driven intra-cell handover trigger is discarded. For UE in EN-DC mode, CA-driven intra-cell handover cannot be initiated.

5.2.3 Option 3x feature impact on Carrier Aggregation

The LTE4575: Blind Carrier Aggregation with LTE-NR DC Option 3x feature improves Carrier Aggregation (CA) technology with the support of 5G carriers in combination with LTE carriers.

5.2.4 Option 3x features changes to the system

List of changes to the system caused by the option 3x related features

6 5G deployment details and procedures

Detailed aspects of LTE-NR DC option 3x functionality configuration and related activation, deactivation and verification procedures

6.1 Activating and deactivating LTE-NR DC Option 3x functionalities

Instructions to activate or deactivate the features in the network

6.1.1 General information on managing 5G features with 5G BTS Element Manager

General information and instructions on how to activate and deactivate 5G features by managing parameters in 5G BTS Element Manager.

Parameters tab allows a user to:

- Edit/delete existing parameters
- Add non-existing parameters

It is possible to find the parameter that needs to be updated using the filters on the top of the parameter window. If the specified parameter is not found, it should be added manually.

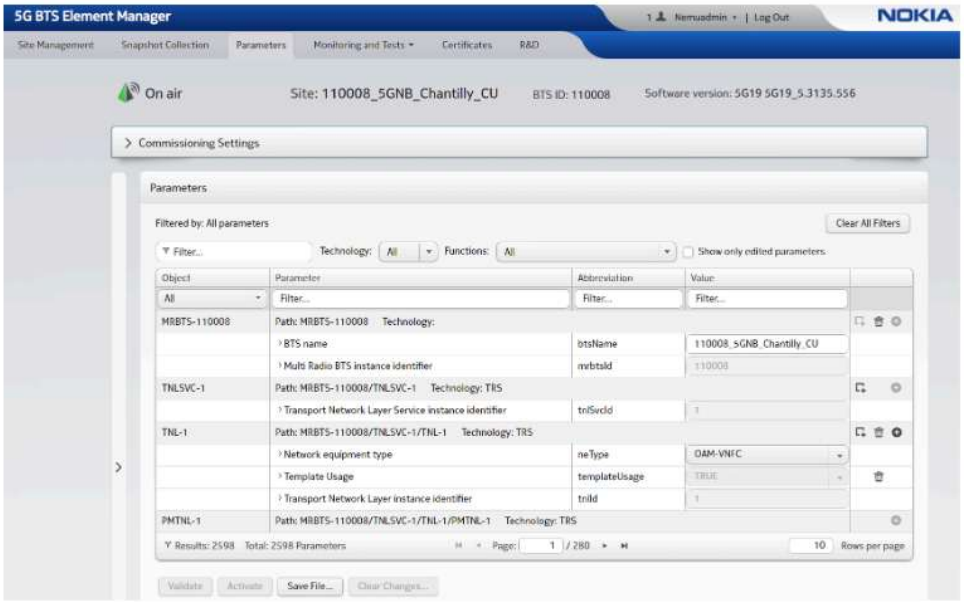
Parameters can be sorted by clicking on the column names and filtered by using <Filter> fields.

Parameters are divided into mandatory and optional. Mandatory ones are marked with the * icon.

Note: In 5G, only numeric identifiers for Managed Objects (MOs) are allowed, for example TNL-1 is allowed, while TNL-1-1 is not.

For information on appropriate values and MO path for parameters, see the *5G BTS Parameters* document in the 5G Operating Documentation.

Figure 21 5G BTS Element Manager parameter view



Any changes done are applied to current gNB configuration after *Validating* and *Activating* the configuration plan.

Parameter modification types

BTS checks the **modification type** of all parameters when a configuration is changed. There are following modifications types:

- **BTS restart needed**
  gNB restart is required to use the modified value. A reset is performed automatically by OAM.
- **Conditional BTS restart**
  A modification of the value will likely require a gNB restart dependent on the comparison of the current and the new requested configuration. gNB SW decides dynamically if a gNB restart or a configuration update with a minor impact on service is possible.
- **Cell locking**
  A modification of such parameters requires locking a cell or a set of cells. The system automatically restarts the affected cells.
- **Not modifiable**
  The value for parameters cannot be modified after creating an object. A change is only possible via object instance deletion and recreation of a new object instance. Typical examples are naming attributes (object Ids), or key parameters like cell global identifiers.
  All parameters defined as 'value set by system' are defined as **not modifiable**.
- **Online**
  Parameters which can be modified instantly without any restarts, deletion or locking.

Note: If more than one parameter is changed in one plan, the modification type of the plan is chosen always for the strongest condition of the individual parameter.

Note: **Not modifiable** is not chosen by gNB SW as the strongest modification type. **BTS restart needed** is considered as the strongest one.

Note: The term gNB refers to gNB-CU with all connected gNB-DUs.

Adding, editing and deleting parameters

There are available three actions that can be performed on the parameters:

- Adding a parameter
  Click the button. The Select parameter drop-down list appears with available parameters under the specific MO.

  Note: It may happen, that some parameter is not present in the **Parameter** list. In that case, first add its MO.

- Changing a parameter value
  Enter the new value in the **Value** column or select from a drop-down list if available.
- Deleting a parameter
  Click the button, next to the parameter name, to delete that parameter.

If any alarms or faults occur after plan activation, proceed as described in the *5G BTS Alarms and Faults* document in the 5G Operating Documentation.

Adding and deleting managed objects

To add a new MO, click the button, select specific MO from the **Add object** pop-up window and click the **Save** button.

Note: During the process of adding a new MO, it may be necessary to set values for mandatory parameters.

Figure 22 Adding a new managed object

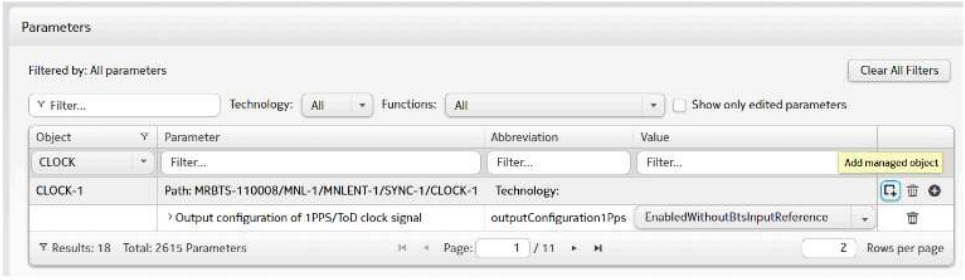
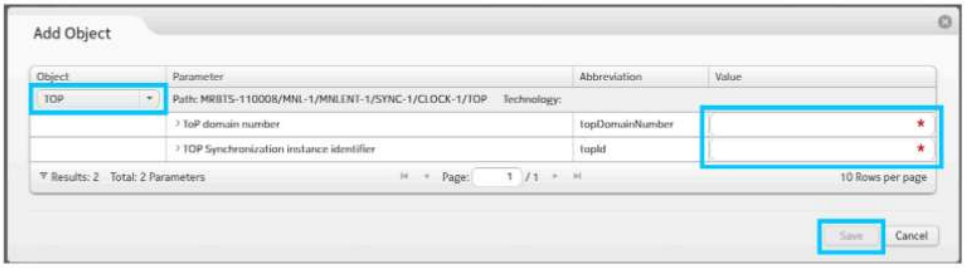


Figure 23 New managed object and mandatory parameters to be set



6.2 Verifying LTE-NR DC option 3x functionalities

Instructions to verify features in the network

6.2.1 Testing *5GC000474: X2 Management for NSA Mode 3x Operation*

Examples of the 5GC000474: X2 Management for NSA Mode 3x Operation feature verification. Do not use it for the feature as such in live network. The configuration and parameter settings described are only examples and they can vary in different networks.

6.2.1.1 5GC000474 verifying X2 link activation initiated by eNB

How to verify X2 link activation initiated by eNB.

Purpose

The purpose of this test is to verify the procedure of a successful EN-DC X2 setup.

Equipment preconditions

You need the following:

- gNB (cloud or classical) working in 5G Non-standalone (NSA) option 3x network
- eNB
- Evolved Packet Core (EPC)
- 5G capable UE
- 5G BTS Element Manager
- Test PC
- UE Air interface tracing tool, for example, Wireshark

Before you start

- Operational gNB
- gNB cell setup corresponding to the eNB
- SCTP association with eNB
- IP connectivity available between eNB and gNB

Procedure

1 Start BTS and connect it to 5G network.

2 Collect the trace on X2 link with Wireshark.

3 Check if X2 link is created and cell is in **On air** state in WebUI.

- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *LTE4088 LTE-NR Dual Connectivity Option 3X*

Procedure

1 Attach EN-DC UE to gNB cell.

2 Start IP packet capture on gNB control plane using preferred IP tracing tool.

3 Start tracing RRC messages on attached EN-DC UE.

Result

Expected outcome:

- EN-DC UE is successfully attached
- IP packets capturing started correctly
- RRC messages tracing started correctly

6.2.3.3 5GC000478 verifying RLF initialization

Purpose

The purpose of this test is to attach UE and prepare logs gathering.

Before you start

Equipment preconditions:

- LTE eNB
- en-gNB
- EPC or EPC simulator
- IP tracing tool, for example Wireshark LTE + pcap or tcpdump
- RRC messages tracing tool-Emil or UE specific tracing tool (such as QXDM)
- EN-DC UE or EN-DC UE simulator

Following features need to be enabled:

- *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation*
- *LTE4088 LTE-NR Dual Connectivity Option 3X*

Procedure

1 Initiate RLF with programmable attenuator.

Signal should be slowly faded to full attenuation.

Result

Expected outcome:

Verifying if the UE context setup is successful with the contention (free or based) random access procedure followed by UL and DL data transfer for Sub-6 GHz.

Equipment preconditions

You need the following:

- 5G BTS Element Manager (WebUI)
- Interface analysis tools: tcpdump, Wireshark
- 4G eNB as MeNB in NSA radio network
- 5G gNB as en-gNB in NSA radio network
- Qualcomm UE with QXMD and QCAT licenses
- Evolved Packet Core (EPC)

Before you start

- En-gNB, UE, EPC are commissioned and configured with the required software build
- RLC AM and Sub-6 GHz are used
- One carrier frequency with at least one 5G cell in **On air** state
- One 4G cell with the coverage overlapping with 5G cell
- Qualcomm UE is functioning (APN is configured)
- gNB start-up on ASIK/ABIL
- gNB and UE are synchronized with respect to SFN and slot boundaries using GPS signal
- Available X2 link between eNB and gNB
- Available F1 connection between gNB-CU and gNB-DU
- Required logs capturing is enabled. In LTE, the www interface starts **IP Traffic Capturing**.
- UE is successfully attached to MeNB
- gNB-DU has allocated a CRNTI and a set of dedicated-preamble. Each of the dedicated preambles is associated to a SS/PBCH block ID. Those resources are provided to the MAC layer.
- 5G UE has received the same CRNTI, with the same set of dedicated-preamble. Each of the dedicated preambles is associated to a SS/PBCH block ID.
- Contention-free random access configuration is supported
- The following features are enabled:
  - *5GC000425: TDD Lower Layer Support - 100 MHz Cell Bandwidth*
  - *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*

Procedure

1 Reset the site with the Web UI.

2 Ping the OAM VM.

3 When pinging the OAM VM works, log into it.

4 Check if the X2 link is available from LTE BTS LNADJGNB object.

5 Make a PS call with 5G UE.

6 Verify the UL and DL data with ping.

Result

- Data tunnels are established over the F1, X2, and S1 interfaces.
- UE is configured with the random access parameters and ready to trigger the contention-free random access procedure.
- End-to-end data transfer (UL and DL) is ready between UE, en-gNB, and SGW.

6.2.8 Testing 5GC000543: Ciphering for NSA mode 3x operation

This is an example of the verification. Do not use it for the feature as such in live network. The configuration and parameter settings described are only examples and they can vary in different networks.

6.2.8.1 5GC000543 Simultaneous UL and DL data traffic using NEA0 algorithm

Purpose

The purpose of this test case is to check that en-gNB successfully handles simultaneous uplink and downlink data transmission using Null Ciphering Algorithm (NEA0) ciphering algorithm.

Equipment preconditions

You need the following:

The feature is tested using 1 gNB-CU + 1 gNB-DU equipped with

- 2 x AirFrame (All-in-one config with redundancy)
- 1 ToR switch
- 1x AirScale AMIA Subrack
- 1 x ASIK board
- 1x ABIL board
- 1 Radio unit without an antenna (wired IF) for tests executed with external UE simulator like Prisma or Qualcomm UE

The feature requires that the gNB operates in Non-standalone (NSA) mode 3x environment (using X2 connection to 4G eNB or LTE Simulator for UE Attach and RRC signaling (SRB on 4G stack))

Before you start

- NR NodeB is up and running

Equipment preconditions

You need the following:

The feature is tested using 1 gNB-CU + 1 gNB-DU equipped with

- 2 x AirFrame (All-in-one config with redundancy)
- 1 ToR switch
- 1x AirScale AMIA Subrack
- 1 x ASIK board
- 1x ABIL board
- 1 Radio unit without an antenna (wired IF) for tests executed with external UE simulator like Prisma or Qualcomm UE

The feature requires that the gNB operates in Non-standalone (NSA) mode 3x environment (using X2 connection to 4G eNB or LTE Simulator for UE Attach and RRC signaling (SRB on 4G stack))

Before you start

- NR NodeB is up and running
- AES Ciphering Algorithm (128-NEA2) is configured with higher priority in gNB SCF of webUI.
- UE simulator is including AES (128-NEA2) algorithm in its UE Security Capabilities

Note: When AES is used for ciphering:

- In UL:
  - UE ciphers the data and sends it to gNB.
  - gNB-DU forwards the ciphered PDUs to PDCP over F1-U (data cannot be verified here as the data part is ciphered)
  - gNB-CU de-ciphers the packet and sends it over S1-U (data can be verified at this point as the data is de-ciphered)
- In DL:
  - Data arriving at PDCP over S1-U is ciphered and forwarded to DU over F1-U (data on F1-U cannot be verified).
  - Once the data is received at UE, the data is de-ciphered. Data can be verified at this point by comparing with the data received at PDCP from S1-U before ciphering

Procedure

1 Under 4G + 5G cells coverage, UE attaches to MeNB.

2 MeNB triggers blind SgNB Addition procedure via X2 interface (Refer to *5GC000509: L3 Non Standalone Call with Data Transmission* and *5GC000475: SgNB Addition and Release for NSA Mode 3x Operation* for details on NSA 3x call setup).

3 Start UL and DL data transmission between UE and S-GW (S1 Simulator or Real CN) via en-gNB radio stack.

4 UE detaches from MeNB.

5 MeNB triggers SgNB Release via X2 interface.

Result

1. UE is attached and DRB configured in en-gNB .
2. AES ciphering algorithm (128-NEA2). shall be selected by gNB during SgNB Addition.
3. Successful transmission of UL data from UE to the S-GW via en-gNB using AES (128-NEA2) ciphering algorithm:
   - Check that received UL data content on S-GW side (S1 interface) is the same as the one sent from UE.
   - Check that the data content is also the same on gNB internal interface due to AES ciphering.
4. Successful transmission of DL data from S-GW to the UE via en-gNB using AES (128-NEA2) ciphering algorithm:
   - Check that received DL data content on UE side (Deciphered at PDCP level by UE simulator) is the same as the one sent from S-GW (S1 interface).
   - Check that the data content is also the same on gNB internal interface due to AES ciphering.
5. Upon reception of the SgNB Release message from MeNB, the SgNB shall delete the DRB and related security context (S-KgNB key and KSgNB-UP-enc keys).

6.2.9 Testing *5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB)*

Examples of the 5GC000572: Intra-Frequency Inter-DU en-gNB mobility (NSA option 3x, Cloud gNB) verification. Do not use it for the feature as such in live network. The configuration and parameter settings described are only examples and they can vary in different networks.

Equipment preconditions

You need the following:

- Non-standalone (NSA) mode 3x operation
- gNB: one gNB-CU with two gNB-DUs
- eNB
- Evolved Packet Core (EPC)
- Test PC for data transfer
- 5G BTS Element Manager (WebUI)

Result

The LTE-NR Dual Connectivity Option 3x is configured and ready for activation the Dynamic Trigger functionality. For more information, see Activating LTE4193.

7.3 Activating and deactivating LTE-NR DC Option 3x functionalities

Instructions to activate or deactivate the features in the network

7.3.1 Activating and deactivating LTE4088

Instructions to activate or deactivate the feature in the network

Before you start

See *Configuring features with Web Element Manager* for general management tool instructions.

7.3.1.1 Activating LTE4088

Instructions to activate the feature using Web Element Manager

Before you start

- Follow the "Configuring LTE4088" prerequisite procedure. For more information, see Configuring LTE4088.

Procedure

1 Go to the **Commissioning Wizard**

Path: **Configuration ► Configuration Management ► Commissioning Wizard**

2 Go to the **Parameter Editor**.

Select from the available options

- **Configuration ► Configuration Management ► Navigation Panel ► Steps ► Radio Network Configuration ► Parameter Editor**
- **Configuration ► Configuration Management ► Parameter Editor**

3 Go to the **LNBTS** object.

Object path: **MRBTS ► LNBTS**

Figure 30 RRC Connection Reconfiguration message with ‘B1 Measurement Report for NR’

```
value DL-DCCH-Message ::=
{
  message c1 : rrcConnectionReconfiguration :
  {
    rrc-TransactionIdentifier 1,
    criticalExtensions c1 : rrcConnectionReconfiguration-r8 :
    {
      measConfig
      {
        measObjectToAddModList
        {
          {
            measObjectId 1,
            measObject measObjectEUTRA :
            {
              carrierFreq 1400,
              allowedMeasBandwidth mbw25,
              presenceAntennaPort1 TRUE,
              neighCellConfig '00'B
            }
          },
          {
            measObjectId 2,
            measObject measObjectNR-r15 :
            {
              carrierFreq-r15 524000,
              rs-ConfigSSB-r15
              {
                measTimingConfig-r15
                {
                  periodicityAndOffset-r15 sf5-r15 : 0,
                  ssb-Duration-r15 sf1
                },
                subcarrierSpacingSSB-r15 kHz15
              },
              quantityConfigSet-r15 1
            }
          }
        },
        reportConfigToAddModList
        {
          {
            reportConfigId 1,
            reportConfig reportConfigEUTRA :
            {
              triggerType event :
              {
                eventId eventA3 :
                {
                  a3-Offset 2,
                  reportOnLeave FALSE
                },
                hysteresis 0,
                timeToTrigger ms320
              },
              triggerQuantity rsrp,
              reportQuantity both,
              maxReportCells 8,
              reportInterval ms640,
              reportAmount infinity
            }
          },
          {
            reportConfigId 2,
            reportConfig reportConfigEUTRA :
            {
              triggerType event :
              {
                eventId eventA5 :
                {
                  a5-Threshold1 threshold-RSRP : 24,
                  a5-Threshold2 threshold-RSRP : 26
                },
                hysteresis 0,
                timeToTrigger ms320
              },
              triggerQuantity rsrp,
              reportQuantity both,
              maxReportCells 8,
              reportInterval ms640,
              reportAmount infinity
            }
          },
          {
            reportConfigId 3,
            reportConfig reportConfigEUTRA :
            {
              triggerType event :
              {
                eventId eventA2 :
                {
                  a2-Threshold threshold-RSRP : 18
                },
                hysteresis 0,
                timeToTrigger ms256
              },
              triggerQuantity rsrp,
              reportQuantity sameAsTriggerQuantity,
              maxReportCells 8,
              reportInterval min60,
              reportAmount r1
```