Definition of the Testing Framework for the NGMN 5G TTI Interoperability

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the engine of broadband wireless innovation

next generation mobile networks

DEFINITION OF THE TESTING FRAMEWORK FOR THE NGMN 5G TTI INTEROPERABILITY

BY NGMN ALLIANCE

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25/07/2018	**V0.81**	**KEYSIGHT**	**INTEGRATION FROM JUNE 27TH WEBEX, REMOVAL OF SECTION CONTROL AND USER PLANE FROM SKT**
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List of contributing, reviewing and supporting companies

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1 Introduction

The Next Generation Mobile Networks (NGMN) Alliance was founded by leading mobile network operators in 2006. It has had a central role to define the consolidated operators' requirements, high-level functionality and performance of next generation mobile network infrastructure and had contributed significantly to the overall success of LTE.

While continuing to support LTE and its evolution, in February 2015, the NGMN Alliance published 5G White Paper elaborating 5G requirements from the global operator perspectives. Subsequently in 2016, NGMN published relevant reports addressing the requirements and architecture as well as business principles, including views of vertical industry applications.

In June 2016, NGMN started a further extension of its 5G-focused work-program with the launch of new additional work-items to facilitate the global consensus on 5G, requirements, design principles, and how various system components are introduced, inter-connect and interwork: 5G Trial & Testing Initiative (TTI), End-to-end Architecture Framework, and the V2X Task-Force.

The Trial and Testing Initiative Mission can be summarized as below:

- **Enable global collaboration of testing activities** to support an efficient, successful, and in-time 5G technology and service introduction
- **Consolidate contributions and report on industry progress** in order to ensure the development of globally aligned 5G technology and service solutions
- **Identify, test, and promote new business opportunities and use-cases** with industry stakeholders (e.g. from vertical industries)

The TTI consists of four phases summarized as follows:

- **Tests of technology building blocks** (e. g. Massive MIMO, new waveforms…) and possible pre-5G tests the member companies may be individually conducting during the pre-5G deployment period.
- **Proof of concept (PoC)** of the basic features of the radio interface, core network and 5G architectural components. The PoC may be performed using solutions which may be partially proprietary; however, this phase necessitates using the basic concepts of the 5G radio interface as specified by the Third Generation Partnership Project (3GPP).
- **Interoperability phase(IOT)** which includes testing of the network aspects and device/network interoperability.
- **Pre-commercial networks trials** with equipment close to the commercial ones. This phase focuses on the initial planning phase (including test specifications), followed by the actual trials (with pre-commercial equipment installed on sites).

This document focuses on the interoperability phase, where the main goal is to test interoperability of various equipment and interfaces in a realistic and heterogeneous environment and to provide feedback to the standardization body.

2 Scope and Timeline

This document focuses on the interoperability phase which has the following objectives:

- **Ensure that functionalities of the 5G system are implemented in a compatible way** and there is no different interpretation of the standard between solutions of 2 to 3 different providers (e.g. Radio Access solutions, Core Network solutions, Devices solutions, etc.).
- **Establish an implementation baseline** in order to reach the needed stability on interoperability. In order to be able to do this, a close examination of the standard is necessary.

This interoperability phase is split into several steps:

- **Define the common framework for interoperability** where relevant 5G components & interfaces to be tested are defined / prioritized and how the testing results can be shared. This applies to both non-standalone (5G enabled EPC) initially. The framework for standalone (5G Next-gen Core) system shall be added in accordance with the standardization timeline.
- **Perform interoperability testing of non-standalone system** (i.e., 5G gNB, 5G enabled EPC, NSA devices, etc.) first, considering the 3GPP timeline. The implementation of key interfaces of non-standalone system according the standard shall be verified.
- **Perform interoperability testing of standalone system** (i.e., 5G Next-gen Core), considering the 3GPP timeline. The implementation of key interfaces of standalone system according the standard shall be verified.

During all the above steps, it is important to provide relevant results and feedback to standardization and development.

The milestones and timelines for this phase are specified in Table 1-1: NGMN Trial Milestones and Figure 1-1.

Milestones	**. M3.1: Define interoperability testing and evaluation framework v1.0(NSA)** **. M3.2: Interoperability assessment based framework and NSA: intermediate report.** **. M3.3: Define interoperability testing and evaluation framework v2.0(SA)** **. M3.4: Interoperability assessment based framework and NSA/SA: Final Report.**

Table 1-1: NGMN Trial Milestones

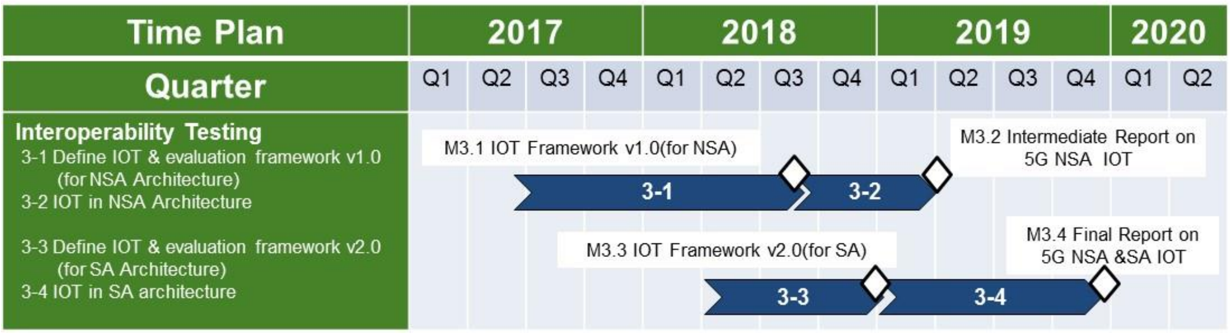


Figure 1-1 : NGMN TTI IOT Time Plan and Milestones

3 5G Architecture Review

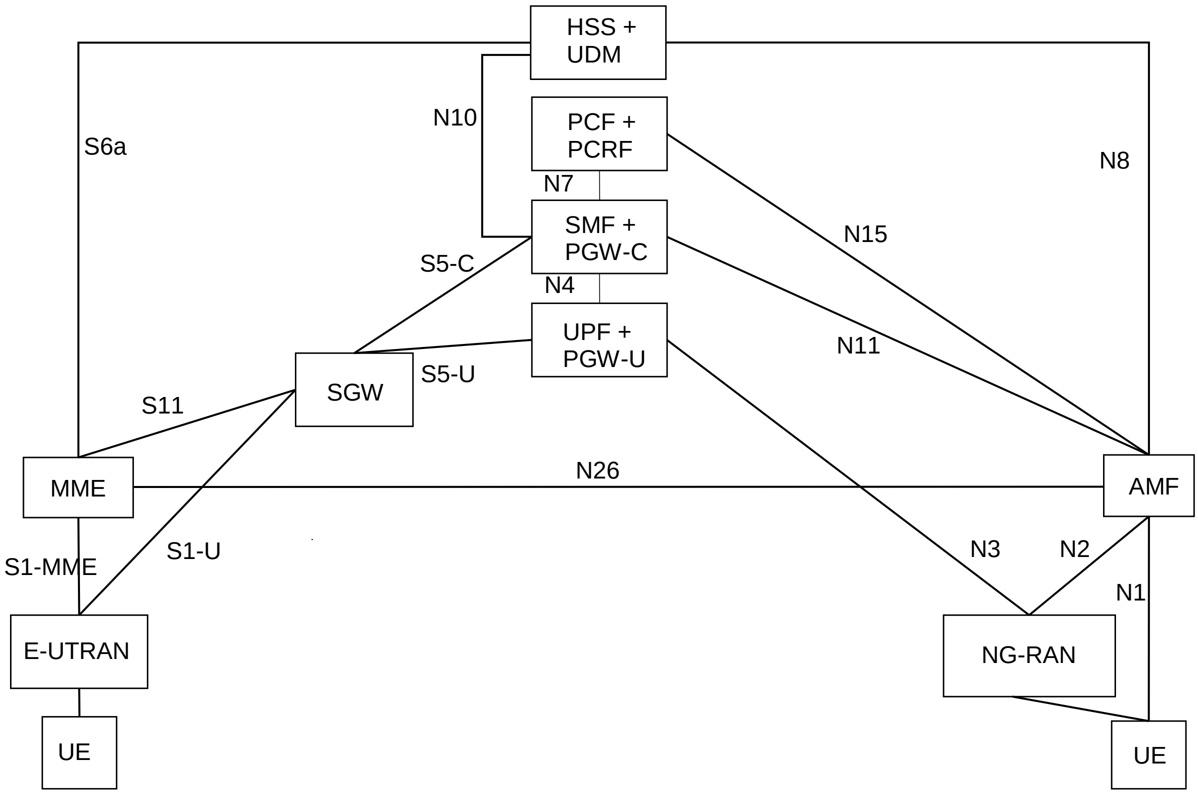
This chapter provides a high-level overview of 5G architecture and describes the full list of candidate interfaces, considered for multi-vendor interoperability testing. There are two different architectures supporting 5G NR, namely non-standalone (NSA) system where the EPC is enhanced to support 5G NR (5G enabled EPC) and standalone (SA) system where a new core network supports 5G NR independently (5G Next-gen Core). According to the current 3GPP timeline, both NSA and SA are included as part of Release-15, with the timeline of December 2017 and June 2018 respectively.

3.1 3GPP Based 5G Architecture

This section covers NSA, SA architecture and also covers SA-LTE interworking.

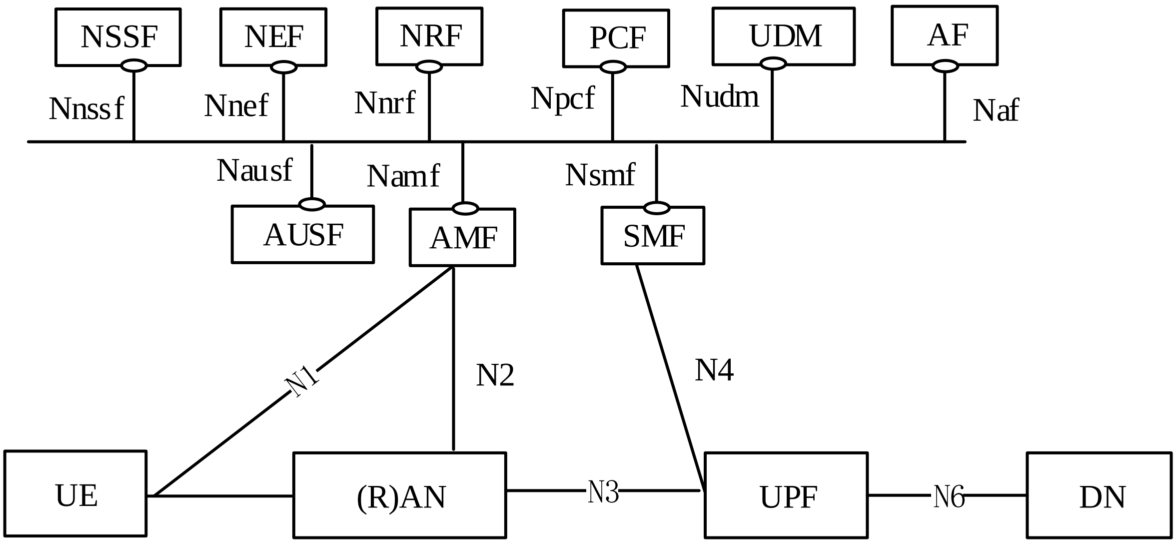
This test phase shall make sure that functionalities of the 5G system are implemented in a compatible way and there is no different interpretation of the 3GPP specification between solutions of 2 to 3 different providers (e.g. Radio Access solutions, Core Network solutions, Devices solutions…).

5G solution providers will, for the purpose of IOT testing, establish an implementation baseline in order to reach the needed stability. In order to be able to do this, a close examination of the specifications is necessary.



3GPP TS 23.501

Figure 4.3.1-1: Non-roaming architecture for interworking between 5GS and EPC/E-UTRAN



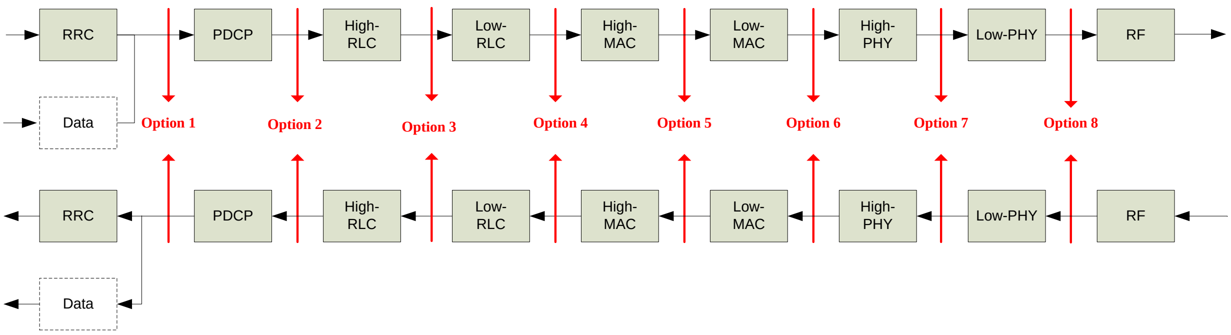
3GPP TS 23.501 v1.4.0 Figure 4.2.3-1: 5G System Architecture(SA)

3.2 RAN Architecture

This section covers RAN Architecture especially RAN functional split for 5G NR

3.2.1 RAN Functional Split Options

This section covers newly introduced interfaces by functional split in radio access network. 5G introduces diverse service requirements, including ultra-low latency and ultra-high throughput. These pose subsequent requirements on RAN to split user plane functions from the control plane functions for higher flexibility and scalability. The following figure depicts various options of splitting RAN function. From the view point of interoperability testing, these interfaces become new candidate interfaces for multi-vendor interoperability testing.



3GPP TR 38.801 v14.0.1 Figure 11.1.1-1: Function Split between central and distributed unit

4 Interoperability in NSA

Section 4 is about interoperability testing procedures and format for elaborating the interoperability testing results of the interfaces in 5G NSA Architecture. NSA architecture is essentially a 4G network with enhancements to support 5G. As such the testing procedures focus more on interfaces and newly introduced functionalities of NSA interfaces that support 5G, rather than the 4G functionalities of NSA.

Tested Product Information/Configuration

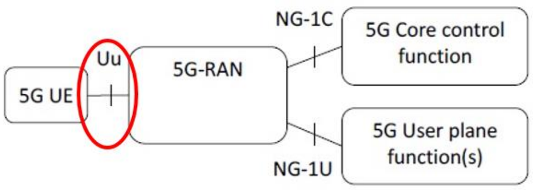
Interoperability test supervisor has to list up the information and configuration about the test setting. (Ex. Provided Vendor, Product Name, Hardware Spec/Configuration, Software Version/Configuration, etc)
This information can be optional and hidden. If the vendor's do not want to present vendor's name or some other information which are used in the test, it will be declared like this: „Vendor A", „Vendor B", etc.

As example:

NFs or Entities	Vendor	Product Name/Model No	Hardware/Infra Spec	Software version	Notes
5G-UE					
eNB					
gNB					
EPC					

In this chapter, we introduce 3 sections for addressing Interoperability testing in the following scopes:

1. **3GPP Rel.15 Uu Interface IOT Test Plan** - section 4.1, corresponding to IOT test plan from Uu (air interface) between a network vendor Vs 5G-NR UE vendors or reference design from a chipset/modem vendor

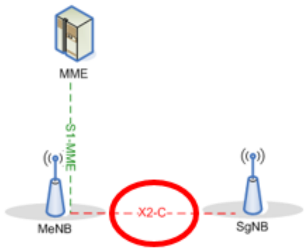


In this section, we have identified multiple test categories which are organized as following:

1. **AS(Access Stratum) Test Cases**
   i. 5G-NR System Information acquisition
   ii. 5G-NR Network Access (random access, cell selection/reselection)
   iii. 5G-NR UE capabilities and exchange with the network
   iv. NR Numerology
   v. QoS framework At Access Stratum level
   vi. RRC Connection Modes (RRC_INACTIVE / RRC_CONNECTED)
   vii. Handover at RRC level
   viii. Beam tracking
   ix. Beam management
   x. Link adaptation (reserved for later version)
   xi. Link adaptation (reserved for later version)
2. **NAS(Non- Access Stratum) Test Cases**
   i. Mobility Management in connected mode – Inter-gNB Mobility

ii. Throughput
iii. 5G-NR Carrier Aggregation
iv. EN-DC Scenarios

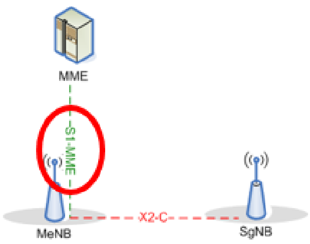
2. **3GPP Rel.15 X2 Interface IOT: E-UTRAN Vs. New Radio – Dual Connectivity (EN-DC) X2 Interface IOT Test plan** - section 4.2, corresponding to IOT test plan from X2 (air interface) between a network vendor Vs 5G-NR UE vendors or reference design from a chipset/modem vendor



In this section, we have identified multiple test categories which are organized as following:

i. EN-DC X2 Setup
ii. EN-DC Configuration Update
iii. EN-DC Cell Activation
iv. SgNB Addition
v. SgNB Modification
vi. SgNB Change

3. **3GPP Rel.15 S1 Interface IOT: EPC Vs. 5G RAN IOT Test plan** - section 4.3, EPC refers to Core Network System which is supporting NR as a secondary RAT for 5G NSA UE. eNB is also supporting equipment which has a connection to gNB for 5G NSA UE.



In this section, we have identified multiple test categories which are organized as following:

i. Registration Procedure
ii. E-RAB modification
iii. Usage Data Reporting for Secondary RAT

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4.1 3GPP Rel.15 Uu interface IOT Test Plan

This section should consider the interoperability between UE and RAN which support 5G NR. Security protocols should be implemented for testing purposes. This section mostly focuses on NSA with some SA materials. In the later documents, contents on NSA and SA will be separated.

4.1.1 General Information/Definition

This interoperability test will be done on the 3GPP specification. Based on the Definition from the 3GPP TS 23.401, Uu is the reference points between eNB and UE. This section defines how to test interoperability between one vendor's eNB and the other vendor's UE in the AS layer.

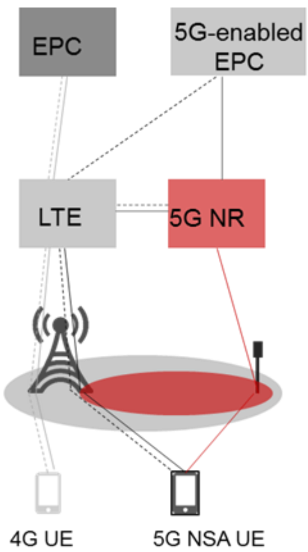
These carrier interoperability tests aim to confirm the same performance and functionality as conformance tests but in three specific ways:

1. These carrier interoperability tests are conducted on a live trial network and so confirm interoperability as well as correct function.
2. The starting parameters for the tests are specific to each carrier and therefore confirm correct operation under real operating conditions rather than the generic and predetermined conditions that apply to conformance tests.
3. Unlike conformance tests the exact protocols, timings and RF conditions are not under full control and may not be in full record capabilities, instead the success criteria is based on the correct, expected outcomes as perceived by a user or as measured passively during the process or in log post processing and analysis.

These basic tests can be repeated under a number of additional external conditions that extend the scope of coverage and increase confidence in the interoperability test results.

4.1.2 Test Setup

4.1.2.1 Environment/Architecture



4.1.2.2 Initial Access procedure and conditions

- Observe that RRC connection request message is sent by UE

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- Observe if UE is receiving RRC Connection Setup message
- Observe if UE is sending RRC Connection Setup complete message to gNB
- The gNB should send the RRC SECURITY MODE COMMAND message to the UE.
- The UE should respond with the RRC SECURITY MODE COMPLETE message
- The gNB should send RRC CONNECTION RECONFIGURATION message to the UE.
- The UE sends RRC CONNECTION RECONFIGURATION COMPLETE message to the gNB.

4.1.2.3 Logging at UE, eNB, gNB and EPC side

On UE side:

- All Packet Dump (Signal and Traffic) which is sent or received from RAN

On eNB side:

- All Packet Dump which is sent or received From UE and gNB
- S1-MME Messages

On gNB side:

- All Packet Dump which is sent or received from UE, eNB, EPC(SGW)

On EPC side:

- All Packet Dump which is sent or received from eNB and gNB
- S1-MME Messages

4.1.3 AS(Access Stratum) Test Cases

4.1.3.1 5G-NR System Information acquisition

The UE shall apply the System Information acquisition procedure upon cell selection (e.g. upon power on), cell-reselection, return from out of coverage, after reconfiguration with sync completion, after entering RAN from another RAT; whenever the UE does not have a valid version in the stored System Information.

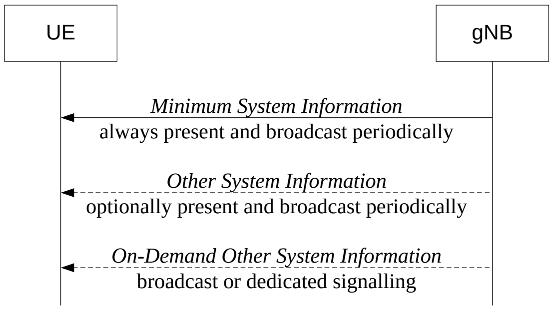
4.1.3.1.1 Success Criteria

The UE applies the System Information acquisition procedure to acquire the AS and NAS information. The procedure applies to UEs in RRC_IDLE, in RRC_INACTIVE and in RRC_CONNECTED.

The UE in RRC_IDLE and RRC_INACTIVE shall ensure having a valid version of (at least) the *MasterInformationBlock, SystemInformationBlockType1* as well as *SystemInformationBlockTypeX* through *SystemInformationBlockTypeY*.

The UE in RRC_CONNECTED shall ensure having a valid version of (at least) the *MasterInformationBlock*, *SystemInformationBlockType1* as well as *SystemInformationBlockTypeX*.

Minimum System Information should be transmitted over two different downlink channels using different messages (*MIB* and *SIB1*). If the UE cannot determine the full contents of the minimum System Information of a cell (by receiving from that cell or from valid stored System information from previous cells), the UE shall consider that cell as barred.



System Information Provisioning (3GPP TS 38.300)

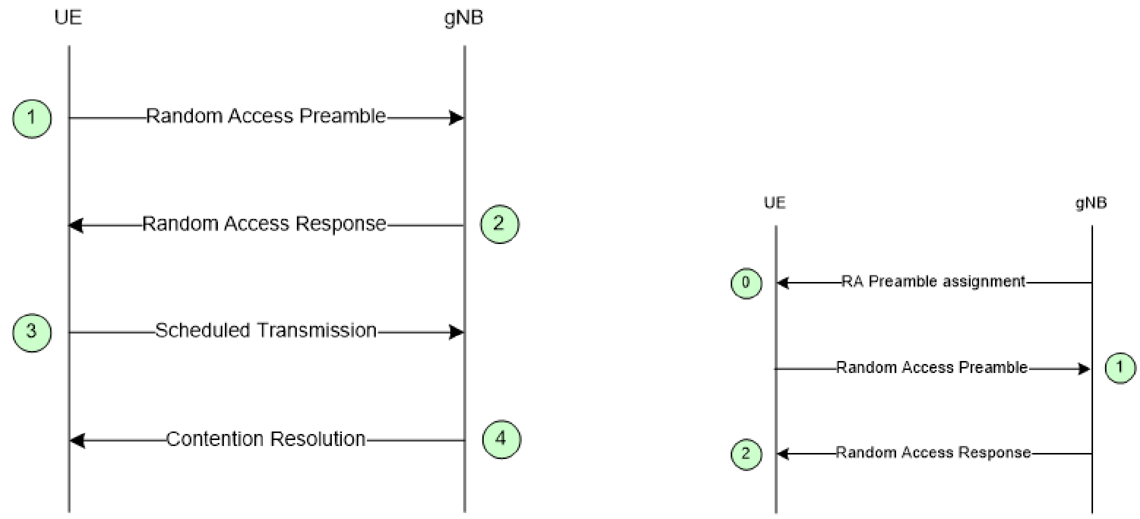
4.1.3.2 5G-NR Network Access (random access, cell selection/reselection)

4.1.3.2.1 RACH Test (Random Access channel)

Broadcast Channel (BCH); Downlink Shared Channel(s) (DL-SCH); Paging Channel (PCH); Uplink Shared Channel(s) (UL-SCH);
Paging allows the network to reach UEs in RRC_IDLE and in RRC_INACTIVE state, and to notify UEs in RRC_IDLE, RRC_INACTIVE and RRC_CONNECTED state of system information change. In RRC_INACTIVE the UE monitors paging channels for RAN-initiated paging.

4.1.3.2.1.1 Test Procedure

The random-access procedure takes two distinct forms: contention-based random access (CBRA) and contention-free random access (CFRA)



Contention – Based **Contention -Free**

Random Access Procedures (3GPP TS 38.300)

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4.1.3.2.1.2 Success Criteria

- Observe that random access preamble is sent by UE
- Observe that random access response is received by UE

4.1.3.2.2 Cell Selection - reselection

4.1.3.2.2.1 Network Selection and Initial Access

4.1.3.2.2.1.1 Test Procedure

- Ensure that there are at least 3 trial network base stations active and within reception range of the trial test UE
- Use an "Over the Air" measurement equipment* to determine the signal strength and quality of all the available signals
- Ensure the trial UE contains a SIM which is set up with the specific parameters for the trial network.
- From the same location, power up the UE and allow it to access and register with the trial network
- Record the outcome and BS used to register
- Repeat the above procedure for a number of locations in the trial network

4.1.3.2.2.1.2 Success Criteria

- The UE selects and successfully registers via the BS with the strongest/best quality signal
- If the serving cell employs beam forming for the primary synchronization and control channels, then ensure any access attempts are made during the strongest slot in the frame, as seen at the UEs physical location.

4.1.3.2.2.1.3 Test extensions

- Once powered up and registered it should be possible to move the UE to a new location which will trigger a cell reselection.
- According to the network parameters, the UE should re-register after a pre-determined time if it is left powered on and in the same location
- The UE could be "barred" by the network. In which case, no further network access should occur after the initial access.
- The UE could be equipped with a roaming SIM. Network access should then only occur if the network parameters permit it.
- While in a barred state it should still be possible to initiate an emergency call.

* An OTA measurement equipment could be a spectrum analyzer, a measuring receiver or a dedicated instrument capable of analyzing signals.

4.1.3.2.2.2 Cell Selection based on leveraging the stored information

4.1.3.2.2.2.1 Test procedure

- Activate E-UTRAN-Cell, power on UE.
- Verify that the UE performs the attach procedure to E-UTRAN-Cell to populate stored carrier frequency, then power off UE.
- Power up the UE.
- Verify that the UE performs the attach procedure onto E-UTRAN-Cell

4.1.3.2.2.2.2 Success Criteria

- Verify that UE will select and camp on cell based on stored information

4.1.3.2.2.3 Cell Selection with no stored information

4.1.3.2.2.3.1 Test procedure:

- Perform a UE factory reset to clear any stored cell selection information
- Activate E-UTRAN-Cell A (default band) and E-UTRAN-Cell B (alternate band)
- Power Up the UE
- Verify that the UE finds the performs attach procedure onto E-UTAN-Cell-A

4.1.3.2.2.3.2 Success Criteria

- Verify that the UE selects and camps on cell based on stored information not present

4.1.3.2.2.4 Inter-band

Inter-Band Idle Mode Cell Reselection, LTE to LTE (R15) - Priority Based
Inter-Band Idle Mode Cell Reselection, LTE (R15) to LTE - Priority Based

4.1.3.2.2.4.1 Test procedure

- Set priorities LTE to LTE (R15)
- Activate E-UTRAN-Cell A, power on UE.
- Verify that the UE performs the attach procedure to E-UTRAN-Cell A.
- Activate E-UTRAN-Cell B, release RRC Connection on Cell A.
- Verify that the UE registers to E-UTRAN-Cell B and performs a tracking area procedure
- Change priorities LTE (R15) to LTE
- Activate E-UTRAN-Cell A, power on UE.
- Verify that the UE registers to E-UTRAN-Cell A and performs a tracking area procedure

4.1.3.2.2.4.2 Success Criteria

- verifies that the UE will correctly reselect to a target cell from the idle mode when camped on a serving cell based on priorities

4.1.3.2.2.5 Same TA (Tracking Area)

Cell Reselection with Cells of Same TA, Idle Mode - LTE to LTE (R15)
Cell Reselection with Cells of Same TA, Idle Mode - LTE (R15) to LTE

4.1.3.2.2.5.1 Test procedure

- Activate E-UTRAN-Cell A, power on UE.
- Verify that the UE performs the attach procedure to E-UTRAN-Cell A.
- Activate E-UTRAN-Cell B (same freq. as Cell A, same TAC, different Cell ID as Cell A, power level the same as Cell A) release RRC Connection on Cell A.
- Modify the cell power of E-UTRAN-Cell A to trigger reselection to E-UTRAN-Cell B
- Verify that the UE performs an RRC connection after PAGING, performs a Service Request or Detach to verify Cell B reselection.
- Activate E-UTRAN-Cell A (same freq. as Cell B, same TAC, different Cell ID as Cell A, power level the same as Cell B) release RRC Connection on Cell B.

- Modify the cell power of E-UTRAN-Cell B to trigger reselection to E-UTRAN-Cell A
- Verify that the UE performs an RRC connection after PAGING, performs a Service Request or Detach to verify Cell A reselection.

4.1.3.2.2.5.2 Success Criteria

- Verifies that the UE correctly reselects an LTE cell of the same Band and Frequency during the idle mode when all the available cells are in the same Tracking Area (TA).

4.1.3.2.2.6 Different TA (Tracking Area)

Cell Reselection between Cells of Different TA, Idle Mode - LTE to LTE (R15)
Cell Reselection between Cells of Different TA, Idle Mode - LTE (R15) to LTE

4.1.3.2.2.6.1 Test procedure

- Activate E-UTRAN-Cell A, power on UE.
- Verify UE performs attach procedure to E-UTRAN-Cell A.
- Activate E-UTRAN-Cell B (same freq. as Cell A, different TAC, different Cell ID as Cell A, power level the same as Cell A) release RRC Connection on Cell A.
- Release RRC Connection on E-UTRAN-Cell A, lower cell power of Cell A
- Verify UE registers to E-UTRAN-Cell B and performs a tracking area update procedure.
- Activate E-UTRAN-Cell A (same freq. as Cell B, different TAC, different Cell ID as Cell B, power level the same as Cell B) release RRC Connection on Cell B.
- Release RRC Connection on E-UTRAN-Cell B, lower cell power of Cell B
- Verify UE registers to E-UTRAN-Cell A and performs a tracking area update procedure.

4.1.3.2.2.6.2 Success Criteria

- verify that the UE reselects an LTE cell of the same Band and Frequency during the idle mode when the target cell is in a different Tracking Area (TA).

4.1.3.3 5G-NR UE capabilities and exchange with the network

The UE capabilities in NR do not rely on UE categories. The network determines the UL and DL data rate supported by a UE from the supported band combinations and from the baseband capabilities (modulation scheme, MIMO layers, …).

4.1.3.3.1 Test procedure

- Observe that gNB is sending request to the UE to provide NR capabilities for a restricted set of band combinations.
- Observe that UE is responding. It can skip a subset of the requested band combinations when the corresponding UE capabilities are the same.

```
UE-CapabilityRAT-ContainerListUE-CapabilityRAT-ContainerList ::=SEQUENCE (SIZE (0..maxRAT-CapabilityContainers)) OF UE-CapabilityRAT-Container

UE-CapabilityRAT-Container ::= SEQUENCE {
    rat-Type                            RAT-Type,
    ue-CapabilityRAT-Container          OCTET STRING
}
```

In Multi-RAT Dual Connectivity, the capabilities of a UE supporting both E-UTRA and NR are provided to both MN and SN.

Verify that the UE-CapabilityRAT-Container as per Refer to TS 38.331 Chapter 6.3.3
The encoding is defined in the specification of each RAT:
For NR: the encoding of UE capabilities is defined in UE-NR-Capability.
For EUTRA-NR: the encoding of UE capabilities is defined in UE-MRDC-Capability

4.1.3.3.2 Success Criteria

Two possible cases: the gNB will confirm or reject the request.
When allowed by the network, a temporary capability restriction request maybe sent by the UE to signal the limited availability of some capabilities (e.g. due to hardware sharing, interference or overheating) to the gNB.

4.1.3.4 Device support of NSA-NR configuration

Check that the 5G-UE supports NSA-NR Option 3, 3a, 3x.

4.1.3.4.1.1 Test procedure:

- Activate LTE Cell, power on UE
- Verify that the UE successfully attaches to LTE Band Cell (Pcell).
- Activate a 5G-NR cell - A.
- Through RRC Connection Reconfiguration message, LTE Pcell configures NR Cell A as P cell in SCG.
- Verify that the data can be transmitted on both LTE and NR cell data paths
- Activate another 5G-NR cell - B.
- Through RRC Connection Reconfiguration message, LTE Pcell cell configures NR cell B into SCG.
- Gradually decrease 5G NR cell A power level, LTE Pcell sends TU RRC Reconfiguration to remove NR Cell A from the SCG
- Gradually increase 5G NR cell A power level, LTE Pcell adds NR Cell A back to SCG.
- Verify that the UE can receive data from all three data paths (LTE Pcell, two NR cells)

4.1.3.4.1.2 Success Criteria

Verify that the device supports NSA-NR Option 3, 3a, 3x control signaling goes through E-UTRA, DRBs can be set up on either E-UTRA or NR or both.

4.1.3.5 NR Numerology

4.1.3.5.1 Verification of different sub-carrier spacing supported by UE/gNB.

Multiple OFDM numerologies are supported as given by TS38.211 where μ and the cyclic prefix for a bandwidth part are given by the higher-layer parameters DL-BWP-mu and DL-BWP-CP for the downlink and UL-BWP-mu and UL-BWP-CP for the uplink. 38.300-Table 5.1-1: specifies supported transmission numerologies and additional info. Support may vary for FR1 and FR2 bands.

4.1.3.5.1.1 Test Procedure

- Perform the LTE Attach procedure
- Ensure MeNB performs the UE Capability Inquiry/UE Capability Information exchange with the 5G UE which shall contain supported subcarrier spacing values.
- Allow MeNB to perform SgNB Addition procedure

4.1.3.5.1.2 Success Criteria

- Verify the MIB (subCarrierSpacingCommon IE) shows subcarrier spacing for SIB1, Msg2/4 for initial access and SI-messages.
- Verify BandwidthPart-Config (subcarrierSpacing IE) shows subcarrier spacing to be used in the BWP for PDCCH, PDSCH etc.
- Verify LogicalChannelConfig (allowedSubCarrierSpacing IE) and ReferenceSignalConfig (subcarrierSpacing IE)
- Verify CSI-RS-ResourceConfig-Mobility (subcarrierSpacing IE) showing subcarrier spacing for CSI-RS.
- Verify RACH-ConfigCommon (msg2-SubcarrierSpacing and msg3-SubcarrierSpacing IEs)
- Verify ServingCellConfigCommon (subcarrierSpacingCommon and subcarrierSpacingSSB IEs)
- Verify BasebandParametersPerCC (subCarrierSpacing IE)

4.1.3.5.2 Slot format configuration for different DL/UL ratios

Where supported for TDD operation, verify the slot format patterned configuration as per the parameters defined in SIB1 in TS38.331 section 6.2.2

4.1.3.5.2.1 Test Procedure

- Perform the LTE Attach procedure
- Ensure MeNB performs the UE Capability Inquiry/UE Capability Information exchange with the 5G UE which shall contain supported subcarrier spacing values.
- Allow MeNB to perform SgNB Addition procedure

4.1.3.5.2.2 Success Criteria

- Verify within SIB1, the TD-UL-DL Pattern as shown by the dl-UL-TransmissionPeriodicity, nrofDownlinkSlots and nrofUplinkSlots IEs is as per configured DL/UL ratio provisioned.
- Verify the multiple different types of subcarrier spacing depending on the deployment scenario.
- Verify the different slot format as defined by TS 38.211.

4.1.3.6 QoS framework At Access Stratum level (refer to TS 38.300)

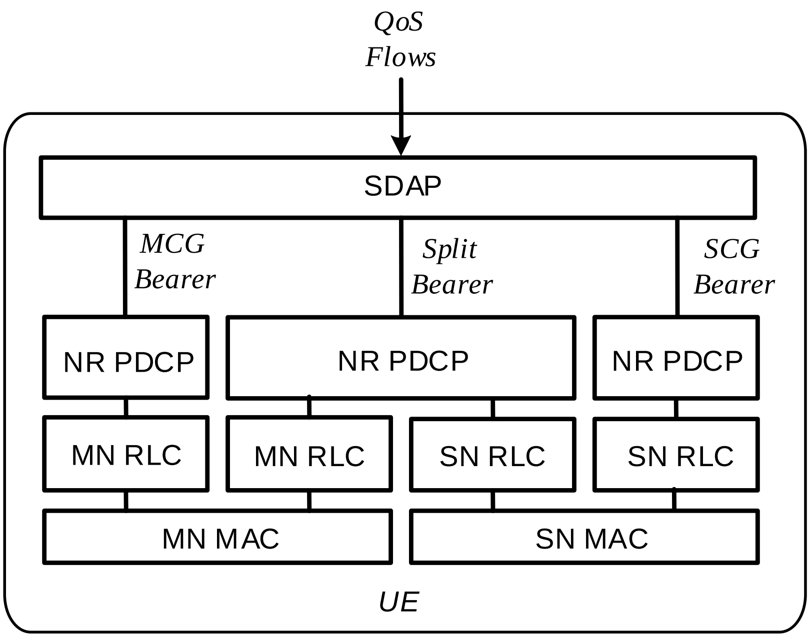
At Access Stratum level, the data radio bearer (DRB) defines the packet treatment on the Uu interface. Marking QoS flow ID (QFI) in both DL and UL packets (DL: due to reflective QoS and UL: due to new QoS framework).

The QoS flow to DRB mapping by NG-RAN is based on QFI and the associated QoS profiles (i.e. QoS parameters and QoS characteristics). Separate DRBs may be established for QoS flows requiring different packet forwarding treatment, or several QoS Flows belonging to the same PDU session can be multiplexed in the same DRB.

4.1.3.6.1 Test Procedure

For each UE, the NG-RAN establishes at least one Data Radio Bearers (DRB) together with the PDU Session and additional DRB(s) for QoS flow(s) of that PDU session can be subsequently configured.
In the uplink, the UE always applies the latest update of the mapping rules regardless of whether it is performed via reflecting mapping or explicit configuration.

When a QoS flow to DRB mapping is updated, the UE sends an end marker on the old bearer.
In the downlink, the QFI is signaled by NG-RAN over Uu for the purpose of RQoS and if neither NG-RAN, nor the NAS (as indicated by the RQA) intend to use reflective mapping for the QoS flow(s) carried in a DRB, no QFI is signaled for that DRB over Uu. In the uplink, NG-RAN can configure the UE to signal QFI over Uu.



QoS flows belonging to the same PDU session may be mapped to different bearer types (MCG, SCG and Split Bearer)

For more information and description on QoS procedures, please refer to: Annex A1 QoS Handling in RAN

4.1.3.6.2 Success Criteria

Verify within each PDU session correct mapping of multiple QoS flow to a DRB Within each PDU session, it is up to NG-RAN how to map multiple QoS flows to a DRB. The NG-RAN may map a GBR flow and a non-GBR flow, or more than one GBR flow to the same DRB.

4.1.3.7 Handover or Mobility at RRC level

3GPP, “NG-RAN; Architecture description (Release 15)” TS 38.401 which states :

- Inter-gNB-DU Mobility : when the UE moves from one gNB-DU to another gNB-DU within the same gNB-CU during NR operation.
- Intra-gNB-DU handover: when the UE moves from one cell to another cell within the same gNB-DU

The source gNB triggers the Uu handover and should send the *RRCReconfiguration* message containing Handover Command message to the UE. The Handover Command message carries the information required to access the target

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cell, which should include at least the target cell ID, the new C-RNTI, the target gNB security algorithm identifiers for the selected security algorithms, can include a set of dedicated RACH resources, the association between RACH resources and SS blocks, the association between RACH resources and UE-specific CSI-RS configuration(s), common RACH resources, and target cell SIBs, etc.

The UE synchronizes to the target cell and completes the RRC handover procedure by sending *RRCReconfigurationComplete* message to target gNB

The UE continues to use the common RACH configuration of the source cell unless it is signaled in the Handover Command Message.

4.1.3.7.1 Test Procedure

- Make sure that Xn interface is setup between source gNB and target gNB
- Based on *MeasurementReport* and RRM information source gNB decides to handover the UE.
- Verify if the source gNB sends a Handover Request message to the target gNB passing a transparent RRC container with necessary information to prepare the handover at the target side. The information should include at least the target cell ID, KgNB* (Intermediate key for signaling) , the C-RNTI of the UE in the source gNB, RRM-configuration including UE inactive time, basic AS-configuration including *antenna Info and DL Carrier Frequency*, the current QoS flow to DRB mapping applied to the UE, the minimum system information from source gNB, the UE capabilities for different RATs, PDU session related information, and can include the UE reported measurement information including beam-related information if available. The PDU session related information includes the slice information (if supported) and QoS flow level QoS profile(s).
- Verify if the target gNB sent the Handover Request Acknowledge to the source gNB. The Handover Request Acknowledge message should include a transparent container to be sent to the UE as an RRC message to perform the handover.
- Verify if the source gNB triggers the Uu handover and send the *RRCReconfiguration* message containing Handover Command message to the UE
- Verify if UE completes the RRC handover procedure by sending *RRCReconfigurationComplete* message to target gNB

4.1.3.7.2 Success Criteria

- Verify that the UE correctly handovers to target gNB.

4.1.3.8 Beam tracking

If a BS employs beam forming and beam tracking, it should be possible to demonstrate that the BS is pointing the beam at the UE in question. The beam direction and shape are factors that carriers will find useful to optimize their networks.

4.1.3.8.1 Test Procedure

- All traffic on the BS under test is either terminated or moved onto other cells.
- A continuous data link is established between a UE and the BS under test.
- Using a measuring antenna and a spectrum analyzer or other OTA test equipment, measure the relative received signal strength at points along an arc, in-line with the UE and at locations either side, ensuring the distance from the BS does not change.
- If the OTA test equipment can discriminate between the broadcast control/sync channels and the data traffic resource elements, then a more accurate result can be obtained.

* The test should be repeated for a number of points within the antennas field, ensuring the full range arc is tested.
* The test points must all be in the far field and well away from tall reflecting structures.

4.1.3.8.2 Test Extensions

* In situations where the BS is located on a tall building or mast, the dip angle could also be measured. This would be good practice at mmWave frequencies where beams will tend to be narrower (by angle) and the coverage area is smaller, hence the elevation is more significant
* Providing measurements are made along the arc formed by a constant distance from the BS, the side lobe energy and front to back ratio of the antenna can also be determined.

4.1.3.8.3 Success Criteria

The peak signal direction should be in-line with the UE. Actual performance is a matter for the carrier to determine, however it is generally agreed that the target receiver (UE) should be within the -3dB points of the beam.

4.1.3.9 Beam Management

References:

3GPP, "NR and NG-RAN Overall Description - Rel. 15," TS 38.300, 2018.
3GPP, "NR - Physical channels and modulation - Release 15," TS 38.211, V15.0.0, 2018.
3GPP, "NR - Physical layer procedures for control - Release 15," TS 38.213, 2018.
3GPP, "NR - Physical layer measurements - Rel. 15," TS 38.215, 2017
3GPP, "NR - Radio Resource Control (RRC) protocol specification Release 15," TS 38.331, 2017.

Large part is also based on the following research publication:

M. Giordani, M. Polese, A. Roy, D. Castor, and M. Zorzi, "A Tutorial on Beam Management for 3GPP NR at mmWave Frequencies," submitted to IEEE Communications Surveys & Tutorials, 2018. https://arxiv.org/abs/1804.01908
Keysight Application Note: Testing 5G: Data Throughput, section 8 Beam Forming - Keysight 2018

The intent in this section is to verify how the Users and base stations align their beams during both initial access and data transmissions (idle and connected modes), to ensure that the right behavior of beamforming system management and the maximum performance is reach between the 5G-UE and gNB:

* The accuracy: Beam selection and directional scanning, the Beam determination and the Beam reporting
* The delay in updating the beam pair or performing initial access
* Impact on end-to-end performance and the quality of service / User's experience

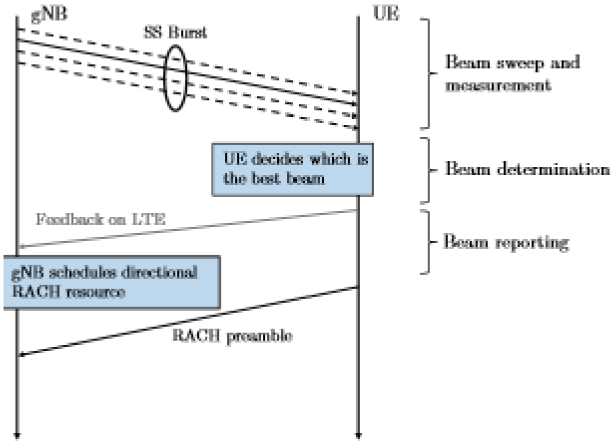
This is based on 3GPP beam management procedures included in the 5G-NR specifications and focusing on Non-Standalone (NSA) interworking with sub 6 GHz and LTE anchor and supposed to increase robustness and faster system acquisition while the Standalone (SA) will be treated in a second phase as part of the Standalone (SA) section of this document.

The actual 3GPP standard is still subject to discussion including multiple 3GPP T-docs looking after this and providing recommendations and multiple test results to the standard group.

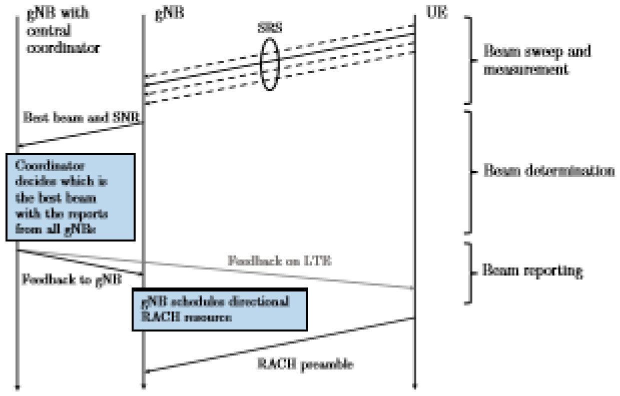
the 3GPP 5G-NR specifications include a set of beam-related procedures for the control of multiple beams at frequencies above 6 GHz and the related terminologies, which are based on the reference signals

The different operations are categorized under the term "beam management" composed of 4 different operations:

- **Beam sweeping:** covering a spatial area with a set of beams transmitted and received according to pre-specified intervals and directions.
- **Beam measurement:** the evaluation of the quality of the received signal at the gNB or at the UE
- **Beam determination:** the selection of the suitable beam or beams either at the gNB or at the UE, according to the measurements obtained with the beam measurement procedure
- **Beam reporting:** the procedure used by the UE to send beam quality and beam decision information to the Radio Access Network (RAN).



Signals and messages exchanged during the NSA-DL beam management procedure



Signals and messages exchanged during the NSA-UL beam management procedure

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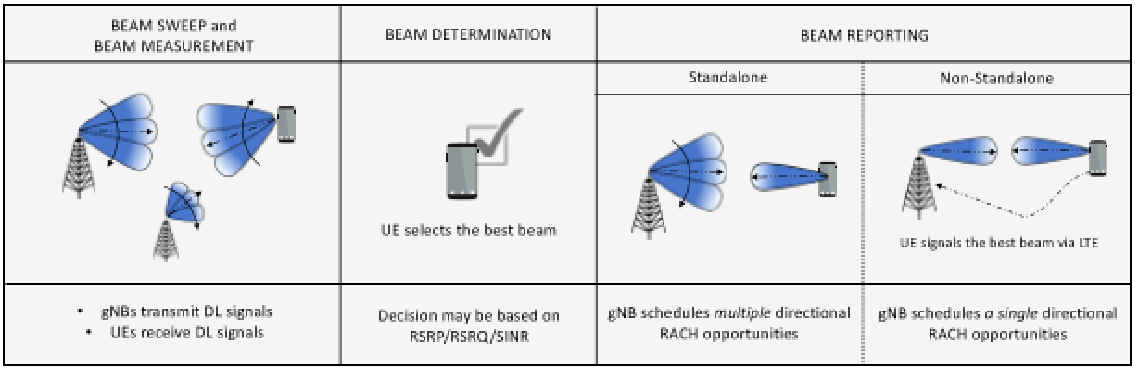
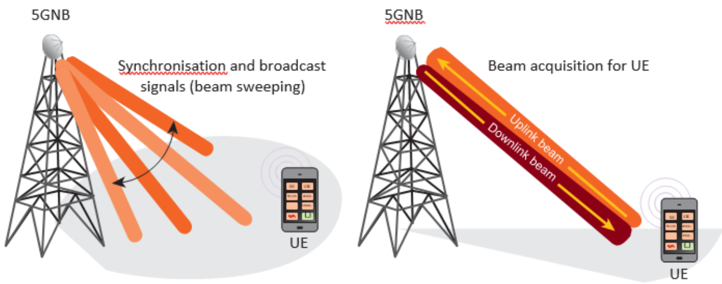


Graphical representation of the beam management procedures SA and NSA architectures



Graphical representation of the beam management procedures

4.1.3.9.1 **Test Procedure**

We can resume this section by the following:

- Verify that the UE selects the best sub-array or beam on which to receive and transmit
- Verify that the selected sub-array or beam uses beam-tracking and beam-steering to track and maintain the associated beam from eNB
- Verify robust mobile broadband communications even under NLOS RF channel conditions and or 5G-NR UE mobility conditions
- Verify the effect of hand blocking and antenna system diversity performance

4.1.3.9.2 **Success Criteria**

The beam management challenge for the feasibility of 5G cellular systems operating at mmWave is the rapid channel dynamics that affect a high-frequency environment and the need to maintain alignment between the communication endpoints.

In this regard, the design and configuration of efficient initial access and tracking procedures able to periodically identify the optimal beam pair with which a base station and a mobile terminal communicate is of extreme importance.

Please also note that the that the duration of beam management procedure is not in fix since it depends on the actual configuration of the network parameters and mainly on the numerology used for the corresponding configuration.
It also depends on beam forming technologies used on both 5G-NR UE and gNB like analog or digital beamforming or both.

The most important metrics to be considered are detection accuracy, reactiveness, overhead, robustness and hand blocking:

- **The accuracy:** represents the capability of the beam management system to identify and correctly measure the beams
- **The reactiveness:** represents how quickly the beam management system is able to detect an updated channel condition
- **The overhead:** is the ratio between the number of time and frequency resources that should be allocated to beam management operations (instead of data transmission) and all the available resources.
- **The robustness:** is the broadband communications performance under LOS and NLOS RF channel conditions and/or 5G-NR UE mobility conditions, RLF recovery time
- **The hand blocking:** effect of hand blocking and antenna system diversity performance

Beam Forming System Design Considerations:

The beamforming architectures and the number of antennas at the gNBs and the UEs (i.e., MgNB and MUE, respectively) are key parameters in the design of directional initial access and tracking.

From Fig. Below, we observe that a larger number of antennas enables narrower beams which, in turn, guarantee better accuracy (thanks to the higher gains achieved by beamforming). On the other hand, highly directional communications lead to worse performance in terms of reactiveness and overhead (due to the increased number of directions that need to be scanned before the optimal beam configuration is selected). A digital beamforming architecture (which allows the processing of the received signals in the digital domain, enabling the transceiver to generate beams in multiple directions at the same time) has the potential to improve the reactiveness of the measurement scheme and decrease the overhead, without penalizing the accuracy. However, it suffers from increased power consumption with respect to an analog strategy.

For completeness, it should be mentioned that the 5G equipment manufacturers are also considering a hybrid beamforming solution, which uses KBF radio-frequency chains and enables the transceiver to transmit/receive in KBF directions simultaneously. Nevertheless, when hybrid beamforming is used for transmission, the power available at each transmitting beam is the total node power constraint divided by KBF, thus potentially reducing the received power.

The setup of the maximum number of SS blocks in a burst and the SS block periodicity, have also a significant impact on reactiveness and overhead. The higher number of SS blocks per burst, although increasing the overhead linearly, increases the probability of completing the sweep in a single burst and thus reduces the time it takes to perform IA. In these circumstances, a higher T_{SS} would guarantee more reactive tracking operations and reduce the overhead of the SS blocks, as shown by the "IA overhead" axis in Fig.b.

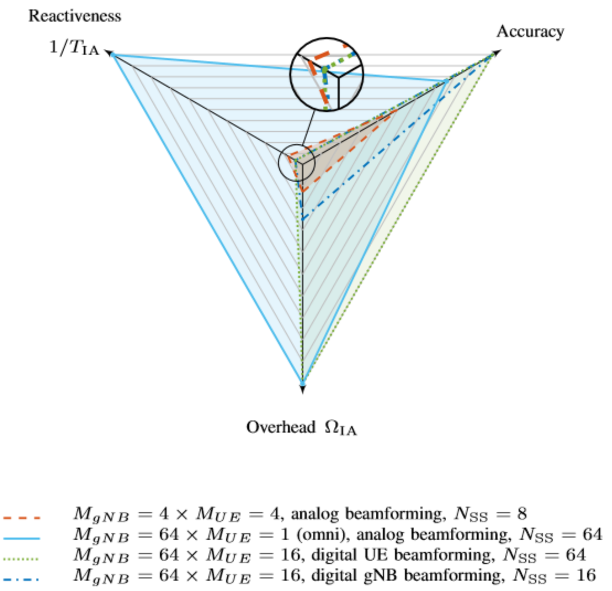


Fig.(a) Performance of different directional IA schemes with different antenna configurations, i.e., number of antennas at the gNB MgNB and at the UE MUE, beamforming architecture and number of SS blocks per burst N_{SS}. The periodicity of the SS burst T_{SS} = 20 ms is fixed.

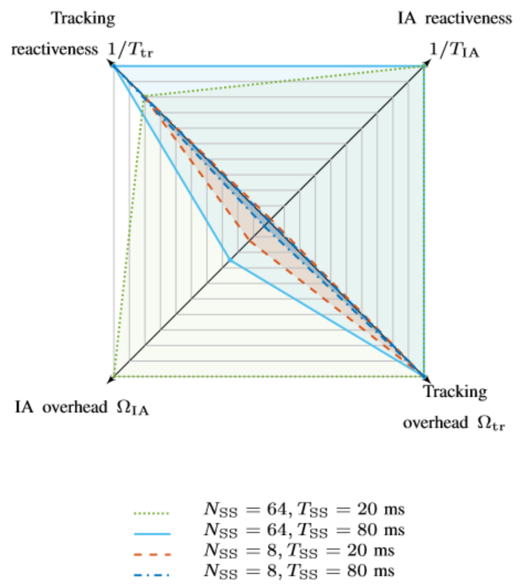
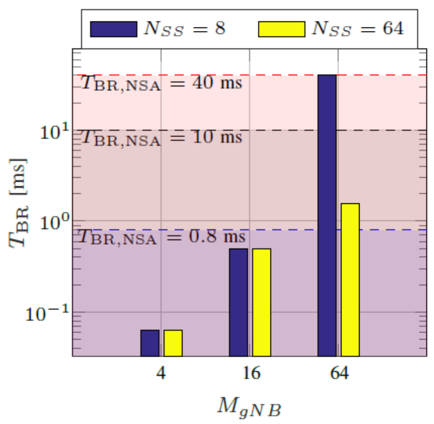


Fig.(b) Performance of different directional IA schemes with different number of SS blocks per burst N_{SS} and SS burst periodicities T_{SS}. The antenna configuration is fixed, with digital beamforming at the gNB and analog at the UE, with 64 and 16 antenna elements respectively.

From the picture above, describe the performance of beam management frameworks for the IA and the tracking as a function of different parameters. The metrics considered represent:

- The accuracy of the framework (which is inversely proportional to the misdetection probability),
- The reactiveness (which is inversely proportional to TIA and Ttr)
- The overhead.



(a) Reactiveness. $T_{SS} = 20$ ms, $\Delta_f = 120$ KHz.

Example of reactiveness at the gNB Vs number of TX Antennas

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M_{gNB}	Standalone				Non Standalone	
	$\Omega_{BR} \cdot 10^{-3}$		P_C [W]		$\Omega_{BR} \cdot 10^{-3}$	P_C [W]
	Analog	Digital	Analog	Digital		
4	0.0894	0.0894	16.2847	64.359	0.0894	16.2847
16	0.7149	0.0894	135.8934	257.433	0.0894	16.9867
64	2.2341	0.0894	494.8670	1030.74	0.0894	19.7947

Example of Overhead and power consumption measurement.

In the following example we have Beam reporting performance considering an SA or NSA architecture.
Analog or digital beamforming is implemented at the gNB side, for different gNB antenna array structures and SS block configurations. The UE is already steering through its selected direction, therefore beam sweeping is not required.

Antenna		$T_{RLF,SA}$ [ms]		
M_{gNB}	M_{UE}	$N_{SS} = 8$, $T_{SS} = 20$ gNB ABF, UE ABF	$N_{SS} = 64$, $T_{SS} = 40$ gNB DBF, UE ABF	$N_{SS} = 64$, $T_{SS} = 80$ gNB DBF, UE ABF
4	4	30.2322	20.3572	40.3572
64	1	130.1072	20.0535	40.0535
64	16	5250	22.6072	42.6072
$T_{RLF,NSA} \in \{10, 4, 0.8\}$ ms.				

RLF recovery delay considering the SA or the NSA measurement frameworks, for different values of NSS, TSS and for different beamforming configurations. _f = 120 kHz. ABF stands for Analog Beamforming, and DBF for Digital.

And so, based on the above design considerations, it is very important to clearly state the results according to the overall system configuration on both side network and devices.

4.1.3.10 Radio Link adaptation

Not considered today in release 1.0 of the IOT Official document – left for next version

4.1.3.11 MIMO RI & PMI

Not considered today in release 1.0 of the IOT Official document – left for next version

4.1.4 End to End NAS(Non-Access Stratum) Test Cases

4.1.4.1 Throughput

4.1.4.1.1 Test Procedure

- Once the UE has camped on to a cell it should be possible to initiate a data link. This could take the form of a file download/upload or a continuous stream of data.
- If the data transfer employs re-transmission protocol then the file should eventually be transferred error free. In this case it is necessary to record the time taken for the transfer.
- If the data transfer does not employ any error correction, other than that afforded by the protocol itself, the error rate can be determined.
- End-to-end data analyzers could be used to measure the error rate as a continuous measurement.
- Alternatively, the received data stream could be saved and analyzed post transmission.
- The expected/maximum data transfer rate will be determined by the bandwidth available to the UE and the network, and the type of link requested

4.1.4.1.2 Test extensions

The above tests could be repeated under any or all the following stress conditions scenario

- Ensure the acceptable targets are maintained during an intercell handover
- Ensure the acceptable rates are maintained at the cell edges (where handover is prevented or not possible)
- The network could be loaded with high levels of traffic
- Co-channel interference could be applied, either from a special generator or from adjacent cells. In the latter case it will be necessary to measure it
- Using data analyzers, it should be possible to measure the end-to-end latency
- Looped back data could be used to determine the round-trip delay.

4.1.4.1.3 Success Criteria

- The successful, error free reception of a file within an acceptable period. Under clear signal conditions this should be close to the theoretical minimum time. Actual targets should be determined by the service the carrier aims to supply
- The successful, streaming of data with acceptable error rates, transfer rates and latency. Under clear signal conditions this should be close to the theoretical maximum transfer rates and acceptable error rates. Actual targets should be determined by the service the carrier aims to supply

4.1.4.2 5G-NR Carrier Aggregation

4.1.4.2.1.1 Intra-Band CA, SCC Configuration

Similar to EUTRAN procedure, the 5G-NR carrier aggregation function aggregates multiple contiguous or non-contiguous carriers for the data transmission of one UE, thereby improving spectral efficiency and providing better user experience. This test case verifies Intra-band CA with SCC Configuration.

4.1.4.2.1.1.1 Test Procedure

- Perform the LTE Attach procedure
- Allow MeNB to perform SgNB Addition procedure
- SgNB cells under test (ie PCC and SCC(s)) are configured and are available with RRC/Handover established.
- SCC(s) are configured via blind or event based measurement
- Trigger SCC activation via throughput test
- Repeat as per supported combos for 2CC and greater for both UL and DL

4.1.4.2.1.1.2 Success Criteria

- Verify that the IE BandCombinationList contains a list of NR CA and/or MR-DC band combinations (also including DL only or UL only band) which includes combo in test.
- Verify for the intra-band CA scenario, that the gNB sends an RRCConnectionReconfiguration message to configure the NR SCells for the UE.

4.1.4.2.1.2 Inter-Band CA, SCC Configuration

Similar to EUTRAN procedure, the 5G-NR carrier aggregation function aggregates multiple contiguous or non-contiguous carriers for the data transmission of one UE, thereby improving spectral efficiency and providing better user experience. This test case verifies Inter-band CA with SCC Configuration.

4.1.4.2.1.2.1 Test Procedure

- Perform the LTE Attach procedure
- Allow MeNB to perform SgNB Addition procedure
- SgNB cells under test (ie PCC and SCC(s)) are configured and are available with RRC/Handover established.
- SCC(s) are configured via blind or event based measurement
- Trigger SCC activation via throughput test
- Repeat as per supported combos for 2CC and greater for both UL and DL

4.1.4.2.1.2.2 Success Criteria

- Verify that the IE BandCombinationList contains a list of NR CA and/or MR-DC band combinations (also including DL only or UL only band) which includes combo in test.
- Verify for the inter-band CA scenario, that the gNB sends an RRCConnectionReconfiguration message to configure the NR SCells for the UE.

4.1.4.2.1.3 SCell Change via A6 HO event Measurement Report

Similar to EUTRAN procedure, the 5G-NR A6 procedure occurs when the neighbor offset becomes better than SCell. This test case verifies the event A6 HO occurs when this offset is achieved.

4.1.4.2.1.3.1 Test Procedure

- Perform the LTE Attach procedure
- Allow MeNB to perform SgNB Addition procedure
- SgNB cells under test (ie PCC and SCC(s)) are configured and are available with RRC/Handover established.
- SCC(s) are configured via blind or event based measurement
- Create a neighbor offset such that the target SCell becomes better that the source while maintaining coverage on the PCell.
- Event A6 report received
- Check that a change occurs in the SCell while keeping the PCell unchanged.

4.1.4.2.1.3.2 Success Criteria

- The IE ue-CapabilityRAT-Container in the UE Capability information message declares support for Event A6.
- Verify event A6 report received (detection of another cell whose single being stronger than current SCell) with the change of SCell while keeping the PCell unchanged
- SCC Release and SCC Add will happen within the same RRC Connection Reconfiguration MSG

4.1.4.2.1.4 SCell Removal via event A2 event Measurement Report

Similar to EUTRAN procedure, the 5G-NR SCells may be removed via event A2 in the event SCell(s) signal quality is poor. This test case aims to verify the removal of SCell(s)

4.1.4.2.1.4.1 Test Procedure

- Perform the LTE Attach procedure
- Allow MeNB to perform SgNB Addition procedure
- SgNB cells under test (ie PCC and SCC(s)) are configured and are available with RRC/Handover established.
- SCC(s) are configured via blind or event based measurement
- Create a condition such that the SCells' signal quality is poor, meeting the triggering condition of event A2.
- Check that the PCell is still configured in normal operation

4.1.4.2.1.4.2 Success Criteria

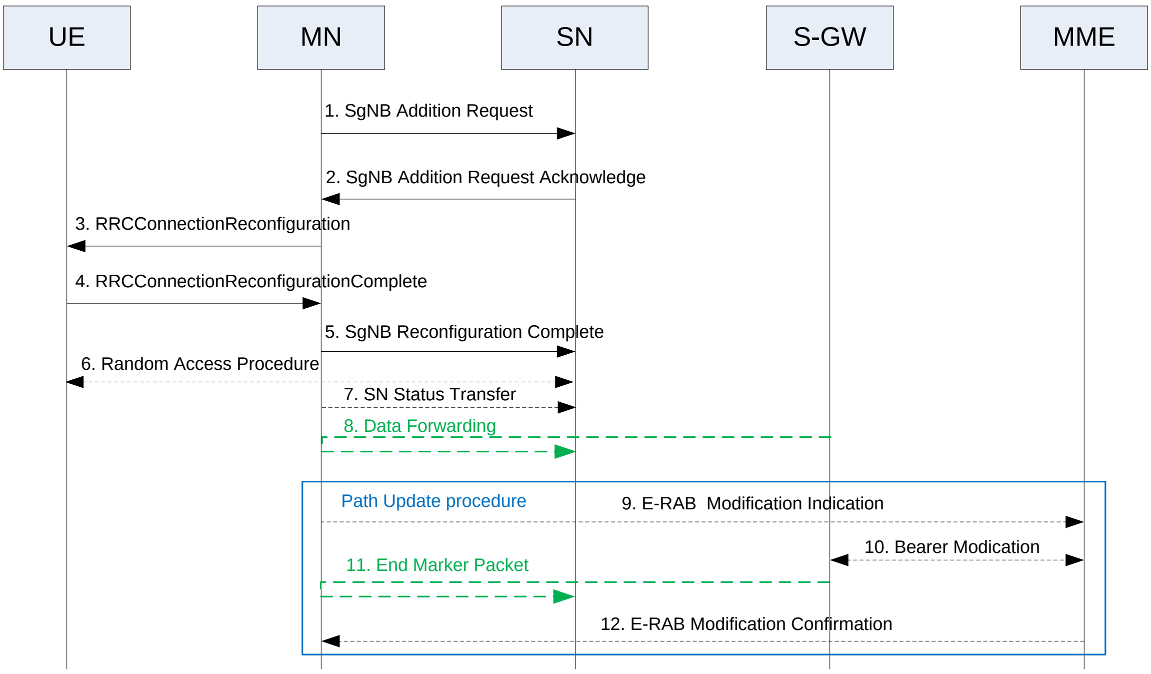
- UE properly triggers event A2 measurement report when SCell coverage is reduced
- Verify when the SCells' signal quality is poor, meeting the triggering condition of event A2, it can remove the SCell.
- UE is still in normal EN-DC operation with PCell still configured

4.1.4.3 EN-DC Scenarios

4.1.4.3.1 SgNB Addition verification

Reference Call Flow &Test Scope

This section covers 3GPP 37.340 section 10.2. The signaling procedures are shown below:



4.1.4.3.1.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up

- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Start downloading data or perform a speed test
- Configure MeNB such that it triggers SgNB addition (always or when more capacity needed)
- Observe the messaging sequence in "Reference Call Flow &Test Scope" section

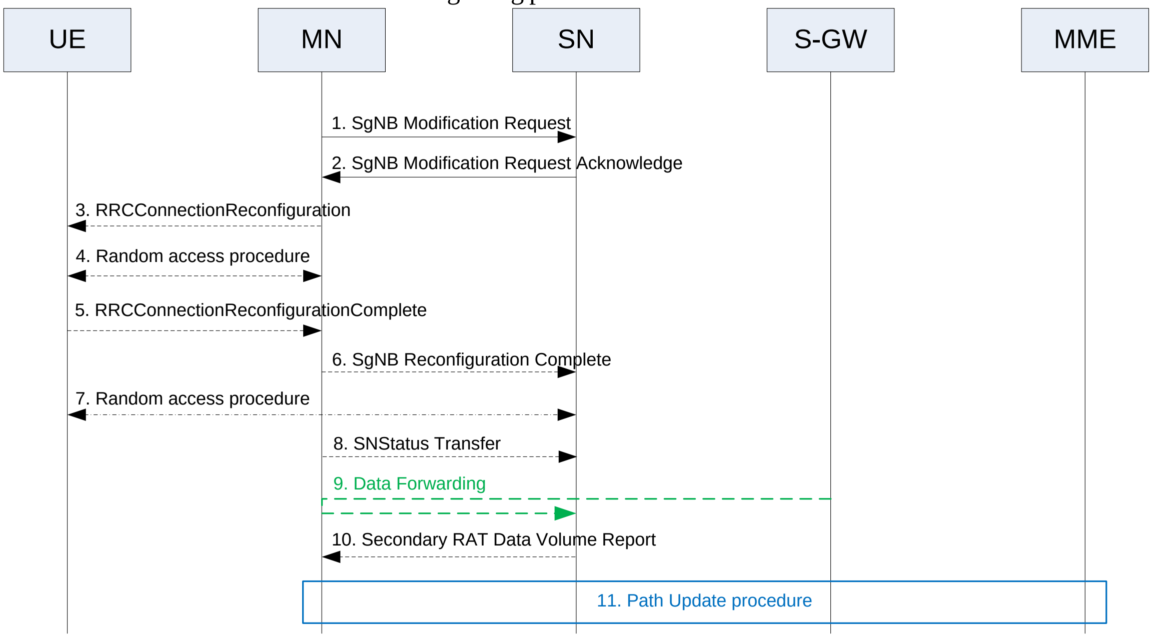
4.1.4.3.1.2 Success Criteria

- Verify the SgNB addition procedures via "SgNB Addition Request/SgNB Addition Request ACK/SgNB Reconfiguration Complete "(including SCG-ConfigInfo) messages are present.

4.1.4.3.2 SgNb Modification Verification

Reference Call Flow &Test Scope

This section covers 3GPP 37.340 section 10.2. The signaling procedures are shown below:



4.1.4.3.2.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Modify, establish or release bearer contexts, to transfer bearer contexts to and from the SN or to modify other properties of the UE context within the same SN.
- Observe the messaging sequence in "Reference Call Flow &Test Scope" section

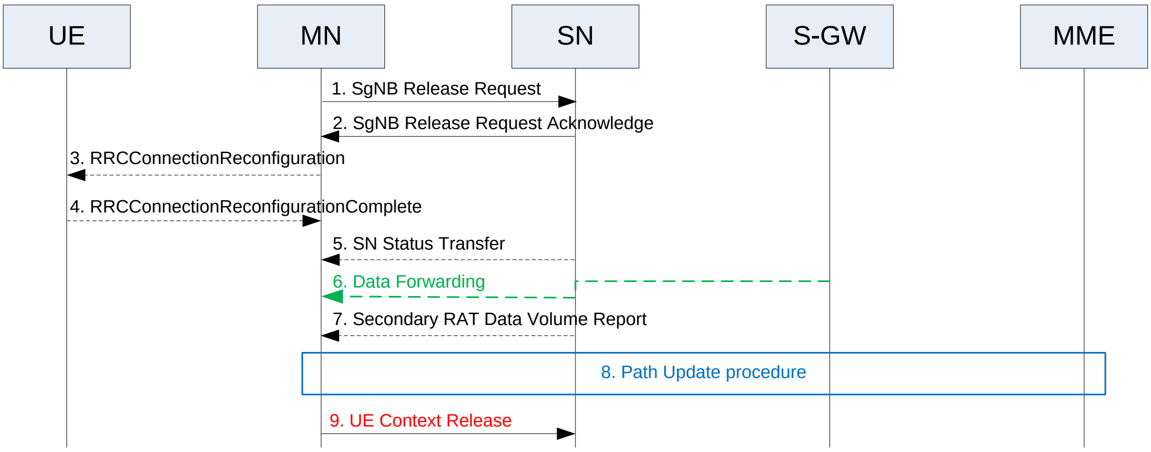
4.1.4.3.2.2 Success Criteria

- The SgNB sends an RRC message to the MeNB and then to the UE to trigger an SgNB Modification procedure.

4.1.4.3.3 SgNB Release Verification

Reference Call Flow &Test Scope

This section covers 3GPP 37.340 section 10.2. The signaling procedures are shown below:



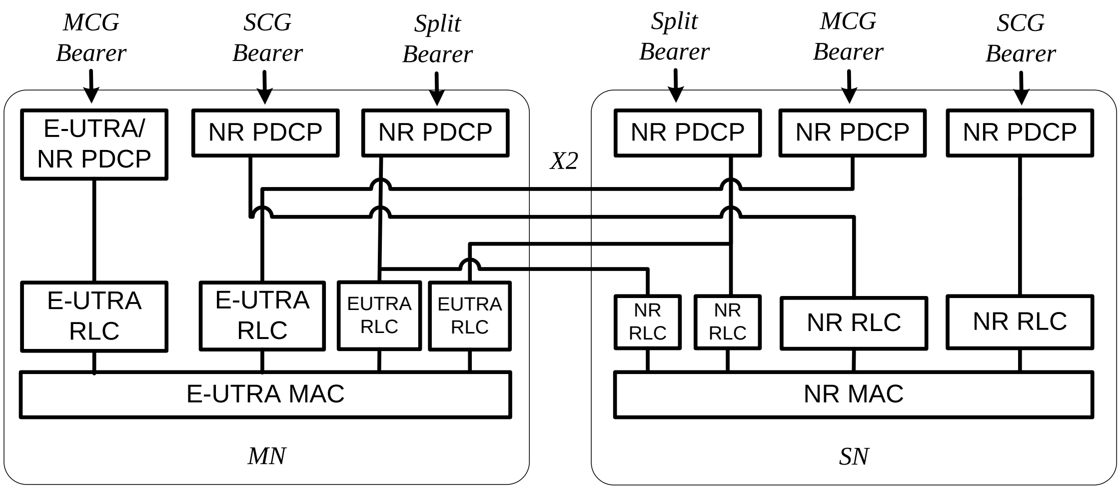
4.1.4.3.3.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Trigger a condition such that the MeNB receives an SCG Failure Report.
- Observe the messaging sequence in "Reference Call Flow &Test Scope" section

4.1.4.3.3.2 Success Criteria

- Checking SgNB Release Request sending on MN SgNB Release Required sending on SN
- Data forwarding from the SN to the MN takes place.

4.1.4.3.4 Data split on MCG, SCG or MCG+SCG for both DL and UL -



4.1.4.3.4.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Based on policy, specify whether data split is performed at the LTE PDCP layer or NR PDCP layer.

- Start downloading data or perform a speed test

4.1.4.3.4.2 Success Criteria

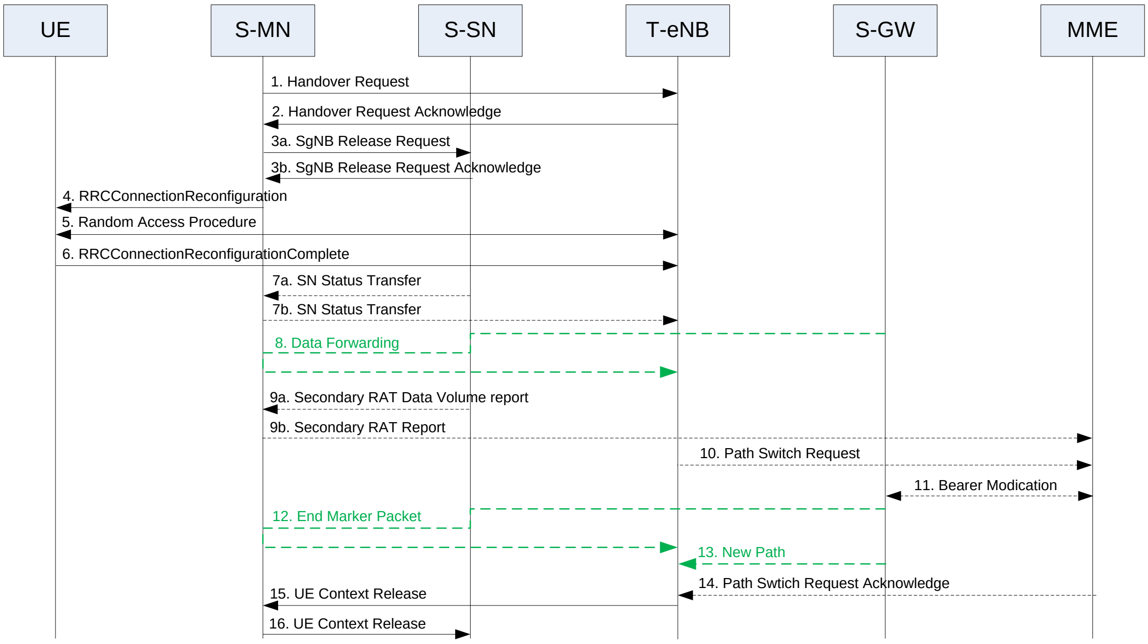
- Verify that the data split functionality performed at the LTE PDCP layer and NR PDCP layer based on policy settings available for configurations for NR and E-UTRAN for both DL and UL.
- Packets are sent in turn based on the ratio of the RLC perceived rates.

4.1.4.3.4.3 PCC Handover when MeNB does not support EN-DC

Verify that when the target MeNB does not support NSA DC, the SgNB needs to be released during the handover.

Reference Call Flow &Test Scope

This section covers 3GPP 37.340 section 10.2. The signaling procedures are shown below:



4.1.4.3.4.3.1 Test Procedure

- Make sure that X2 is setup between S-MeNB and 5G S-SN. T-eNB shall have connectivity to S-MeNB through X2 or S1 without EN-DC configured.
- Make sure that LTE and 5G NR cells are up with active data transfer.
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Trigger a handover from the S-MeNB to the T-eNB
- Verify the UE is in a normal operation mode on the the T-eNB in a non EN-DC mode.

4.1.4.3.4.3.2 Success Criteria

- The S-MeNB initiates the release of the source SN resources towards the source SN including a Cause indicating MCG mobility.
- The MeNB triggers the UE to apply the new configuration. Upon receiving the new configuration, the UE releases the entire SCG configuration.

- UE operates in LTE only mode without EN-DC.
- NR SCG change (same and different site configurations) - SCG change test based on intra-freq handover in the same site (co-located) and different site (non-colocated sites with different BBU). The SgNB receives an event A3.
- PCC Handover (same and different site configurations) - PCC handover (Both inter-frequency and intra-frequency) where LTE cells are in the same site and EN-DC is configured.
- NR RRC_Inactive verification - Verify in the RRC_Inactive state that the UE is still RM_Registered and CM_Connected state still.
- Dual RRC State verification (LTE + NR RRC states) - Verify the various UE RRC state combinations for LTE and NR (LTE RRC Idle, Connected plus NR RRC Idle, Inactive, Connected)

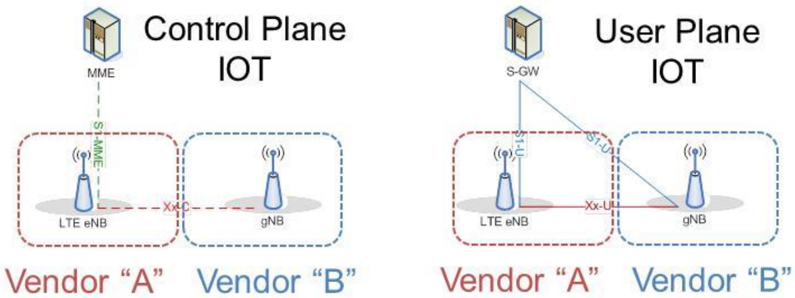
4.2 3GPP Rel.15 X2 interface IOT E-UTRAN Vs. New Radio – Dual Connectivity (EN-DC) X2 interface IOT Test plan

4.2.1 General Information/Definition

This interoperability test will be done based on the 3GPP Rel.15 specifications based on the definition from the 3GPP TS 36.423 & TS 37.340. X2 is the interface between eNB and gNB. This section defines how to test interoperability between one vendor's eNB and the other vendor's gNB. The procedures or functions which are described on the 3GPP TS 36.423 & TS 37.340 with emphasis on gNB support will be tested.

4.2.2 Test Setup

Control plane and user plane configuration is shown in figure below:

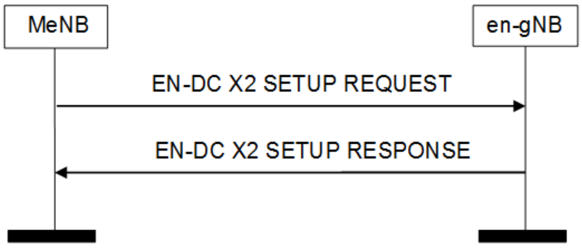


4.2.3 Testing Scenario and Expected Result

4.2.3.1 EN-DC X2 Setup

Reference Call Flow &Test Scope

This section covers 3GPP TS 36.423 section 8.7.1. The signaling procedure is shown below:



4.2.3.1.1 Test Procedure

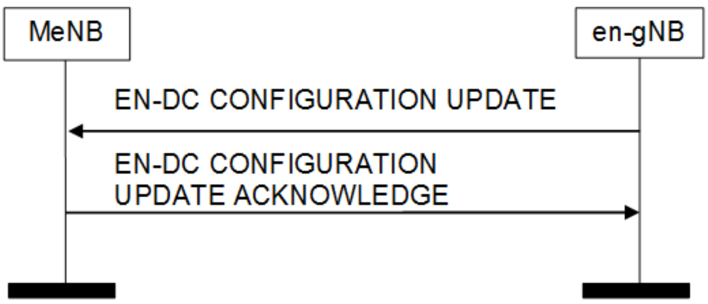
- Setup a Master eNodeB from Vendor A
- Setup a Seconday 5G NR gNB from Vendor B
- Make sure that IP connectivity exist between MeNB and 5G NR gNB
- Setup SCTP link between them
- Configure X2 link between two nodes
- Observe that EN-DC X2 SETUP REQUEST message is sent
- Observe that EN-DC X2 SETUP RESPONSE message is received
- Observe that X2 states are up on both nodes

4.2.3.1.2 Success Criteria

Observe that X2 is successfully setup on both nodes.
Check the message flow on X2 interface.Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.
If the message are delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

4.2.3.2 EN-DC Configuration Update

Reference Call Flow &Test Scope
This section covers 3GPP TS 36.423 section 8.7.2. The signaling procedure is shown below:



4.2.3.2.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Deactivate a 5G NR cell (by manually or for power saving reasons)
- Observe that EN-DC CONFIGURATION UPDATE message with Deactivation Indication IE which is contained in the *Served NR Cells to Modify* IE, is sent from gNB.

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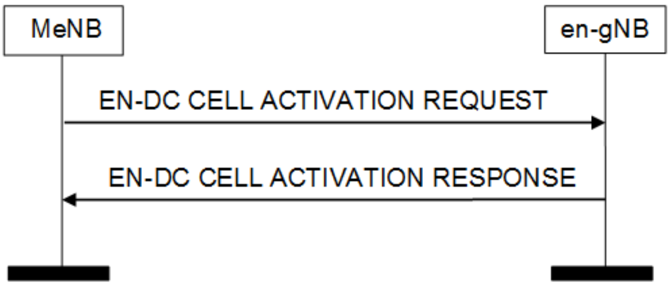
- Observe that EN-DC CONFIGURATION UPDATE ACKNOWLEDGE message is received.

4.2.3.2.2 Success Criteria

Observe that MeNB modified the info about the 5G NR cell indicated in EN-DC CONFIGURATION UPDATE message.
Check the message flow on X2 interface.Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.
If the message are delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

4.2.3.3 EN-DC Cell Activation

Reference Call Flow &Test Scope
This section covers 3GPP TS 36.423 section 8.7.3. The signaling procedure is shown below:



4.2.3.3.1 Test Procedure

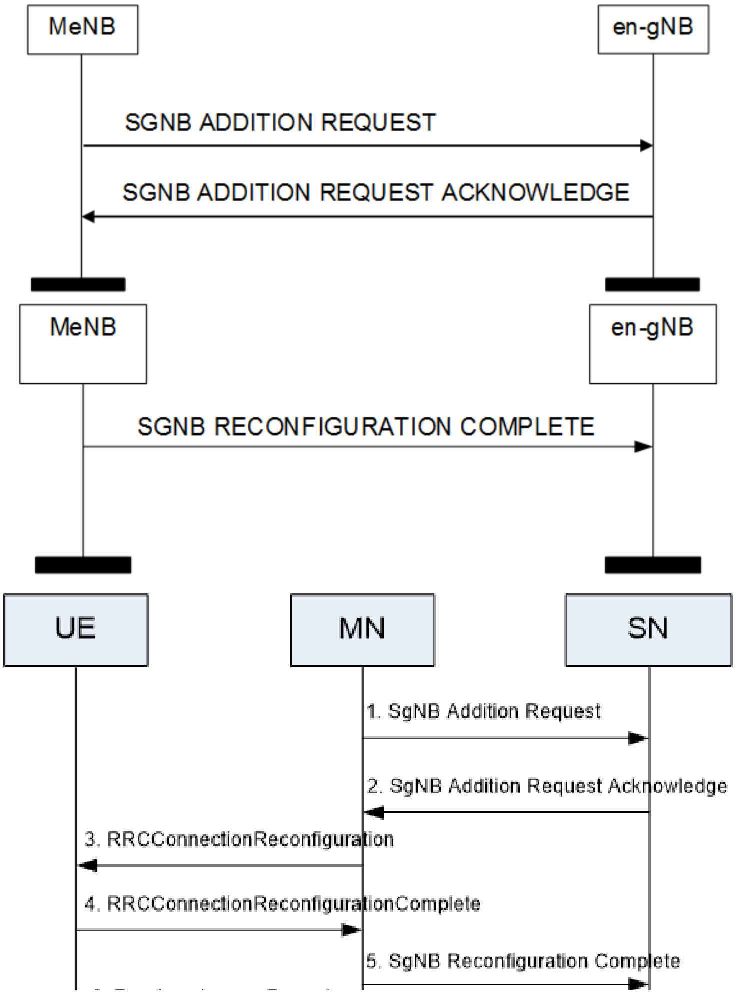
- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Deactivate a 5G NR cell (by manually or for power saving reasons)
- Configure eNB such that it requests deactivated 5G NR cells to be activated via EN-DC CELL ACTIVATION REQUEST
- Observe that 5G NR gNB responds with EN-DC CELL ACTIVATION RESPONSE
- Observe that 5G NR cells are activated

4.2.3.3.2 Success Criteria

Observe that en-gNB has activated the cell(s) indicated in the EN-DC CELL ACTIVATION REQUEST message
Check the message flow on X2 interface.Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.
If the message are delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

4.2.3.4 SgNB Addition

Reference Call Flow &Test Scope
This section covers 3GPP TS 36.423 section 8.7.4 and 8.7.5. and 3GPP 37.340 section 10.2. The signaling procedures are shown below:



MN refers to Master eNB and SN refers to en-gNB in the above figure.

4.2.3.4.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Start downloading data or perform a speed test
- Configure MeNB such that it triggers SgNB addition (always or when more capacity needed)
- Observe the messaging sequence in “Reference Call Flow &Test Scope” section
- Observe that UE performs data download from 5G NR cell.

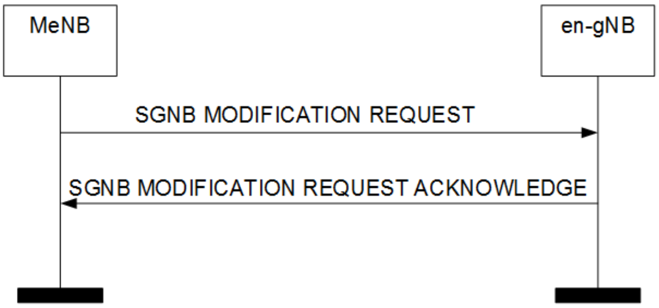
4.2.3.4.2 Success Criteria

Observe that 5G NR capable UE is getting service from 5G NR and performing data download from 5G NR cell. Check the message flow on X2 interface.Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.
If the message are delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

4.2.3.5 SgNB Modification

Reference Call Flow &Test Scope

This section covers 3GPP TS 36.423 section 8.7.6. The signaling procedure is shown below:



4.2.3.5.1 Test Procedure

- Make sure that X2 is setup between MeNB and 5G NR gNB.
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage
- Start downloading data or perform a speed test
- Configure MeNB such that it triggers SgNB addition (always or when more capacity needed)
- Observe that UE performs data download from 5G NR cell.
- With the help of PCRF, modify eRAB properties e.g. APN AMBR
- Observe that SGNB MODIFICATION REQUEST message is sent from MeNB.
- Observe that SGNB MODIFICATION REQUEST ACKNOWLEDGE message is received.

4.2.3.5.2 Success Criteria

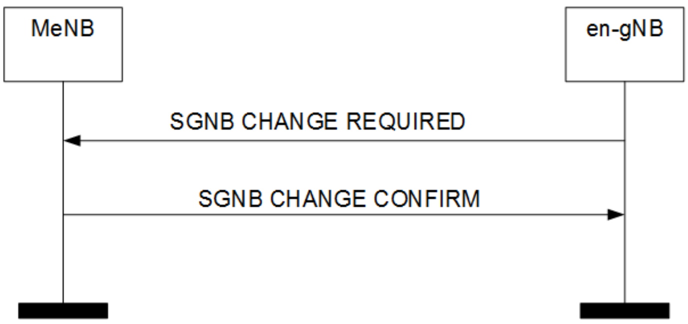
Check the message flow on X2 interface.Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.

If the message are delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

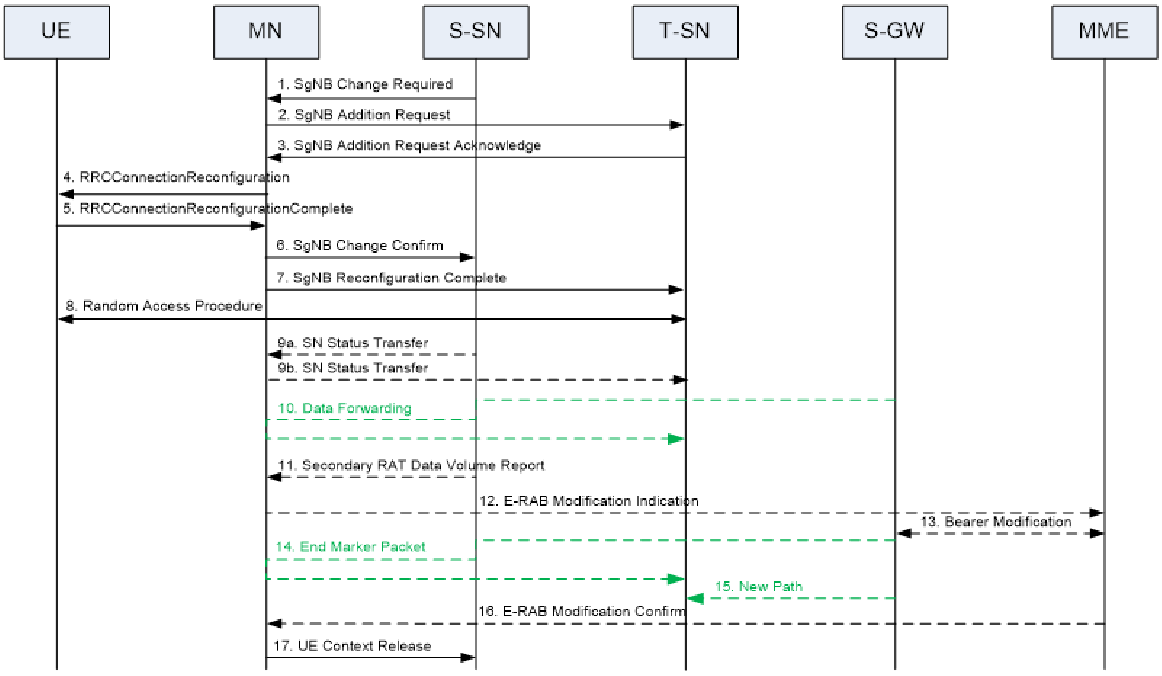
4.2.3.6 SgNB Change

Reference Call Flow &Test Scope

This section covers 3GPP TS 36.423 section 8.7.8 and 3GPP TS 37.340 section 10.5. The signaling procedures are shown below:



SN initiated SN Change



4.2.3.6.1 **Test Procedure**

- Setup one MeNB and 2 gNB (source and target) from different vendors.
- Make sure that X2 is setup between MeNB and Source 5G NR gNB and also between MeNB and target 5G NR gNB
- Make sure that LTE and 5G NR cells are up
- Place a 5G NR capable UE under both LTE and 5G NR coverage (source gNB cells)
- Start downloading data
- Configure MeNB such that it triggers SgNB addition (always or when more capacity needed)
- Observe that UE performs data download from 5G NR cell.
- Move 5G NR capable UE from source gNB 5G NR cell coverage to target gNB 5G NR cell coverage.
- Observe that the source SN initiates the SN change procedure by sending SgNB Change Required message which contains target SN ID information and may include the SCG configuration (to support delta configuration) and measurement results related to the target SN.
- Observe that the MeNB requests the target SN to allocate resources for the UE by means of the SgNB Addition procedure, including the measurement results related to the target SN received from the source SN.
- Observe that the MeNB triggers the UE to apply the new configuration. The MeNB indicates the new configuration to the UE in the *RRCConnectionReconfiguration* message including the NR RRC configuration message generated by the target SN. The UE applies the new configuration and sends the *RRCConnectionReconfigurationComplete* message, including the encoded NR RRC response message for the target SN, if needed.
- Observe that MeNB sends SGNB CHANGE CONFIRM message.
- Make sure that UE is continuing data download from target 5G NR gNB cells.

4.2.3.6.2 **Success Criteria**

Observe that handover is successfully performed to target 5G NR cell and UE is continuing data download from target 5G NR gNB cell.
Check the message flow on X2 interface. Make sure that message sequence is coherent with the "Reference Call Flow &Test Scope" section.
If the message is delivered and all the necessary information elements are set on the message according to the 3GPP reference document, the test is successful.

4.3 3GPP Rel.15 - S1 Interface IOT - EPC Vs. 5G-NR IOT test plan

In this section, EPC refers to Core Network System which is supporting NR as a secondary RAT for 5G NSA UE. eNB is also supporting equipment which has a connection to gNB for 5G NSA UE.

4.3.1 General Information/Definition

This interoperability test will be done on the 3GPP specification. Based on the Definition from the 3GPP TS 23.401, S1-MME and S1-U are reference points between eNB/gNB and EPC. This section is about how to test interoperability between one vendor's eNB/gNB and the other vendor's EPC. And the Procedures or Functions which are described on the 3GPP TS 23.401 and related with NR supporting will be tested.

- Case #1) Registration Procedure
- Case #2) E-RAB modification procedure
- Case #3) Usage Data Reporting for Secondary RAT

4.3.2 Test Setup

4.3.2.1 Environment/Architecture

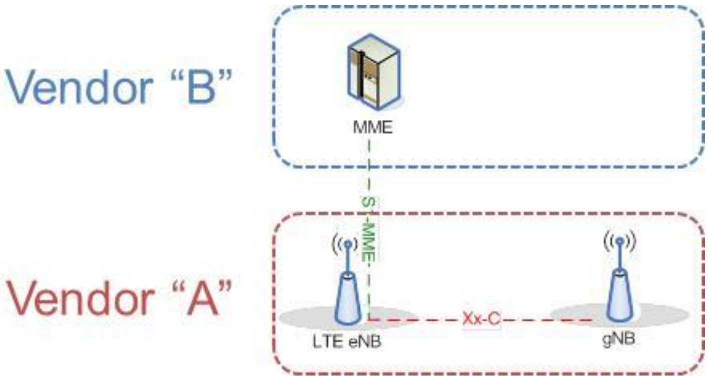


Figure 5.3.3.1 : S1 Interoperability Test for NSA
(Vendor A's eNB – Vendor B's EPC)

4.3.2.2 Reference Document

Interoperability test supervisor has to list up major related reference standard document. These documents will be a baseline for interpreting and discussing about the test result.

As Example:

Document No	Subject	Version	Notes

Commercial Address:

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3GPP TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access	V15.4.0(2018-06)	
3GPP TS 36.300	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description;	V15.2.0(2018-06)	
3GPP TS 36.413	S1 Application Protocol (S1AP)	V15.2.0(2018-06)	

4.3.3 Testing Scenario and Expected Result

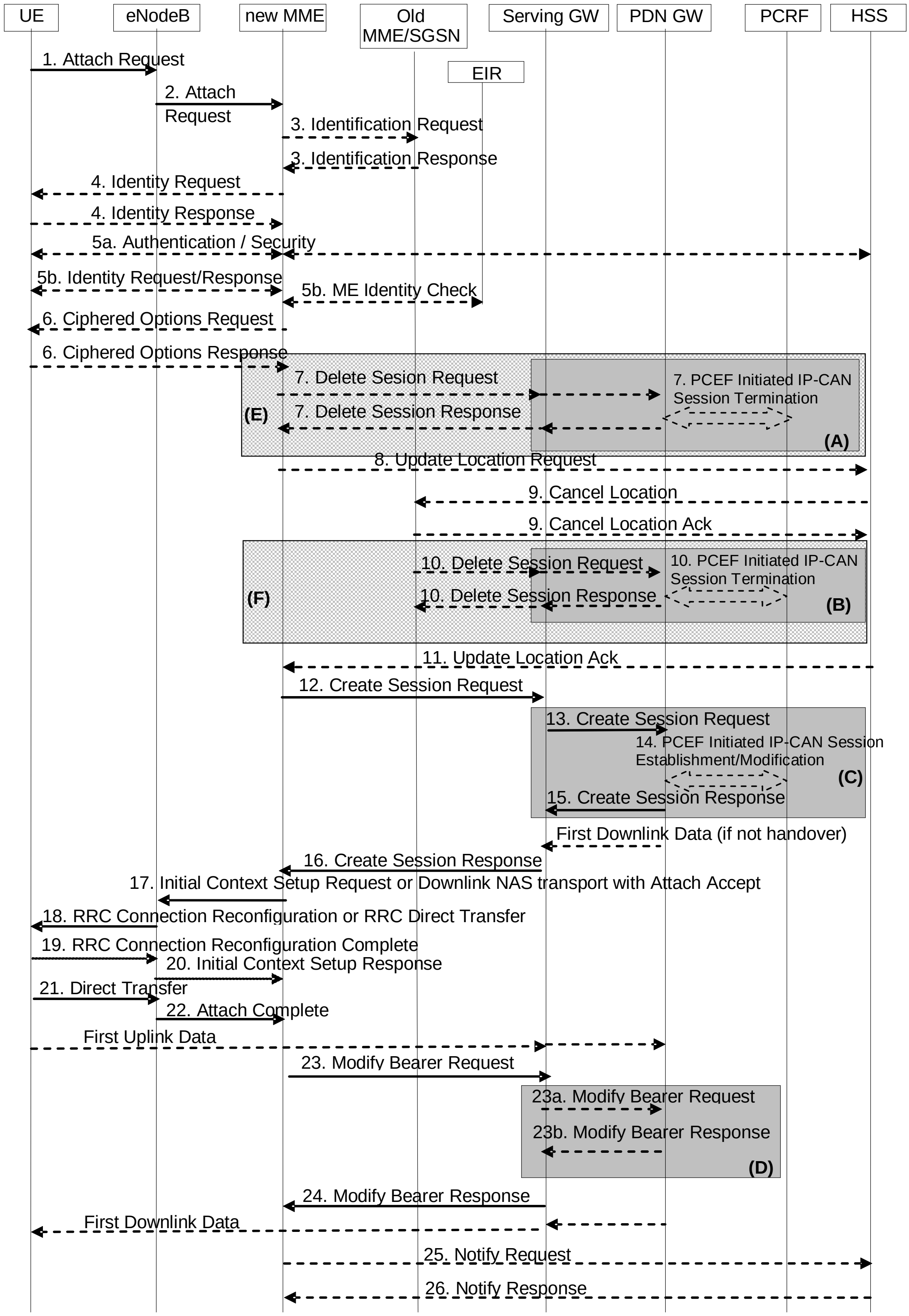
4.3.3.1 General

3GPP Specification Documents provide information flows for NSA system. Test Supervisors will collect the message log from the eNB side and EPC side.

4.3.3.2 Case #1) Registration Procedure

Reference Call Flow &Test Scope

General Registration Call Flow is described under below. Test Supervisors will collect the message log from the UE, eNB and EPC side.



3GPP TS 23.401 Figure 5.3.2.1-1: Attach procedure

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4.3.3.2.1 Test Procedure

Testing Supervisor fulfills these steps and collects log at each side

- Prepare UE, eNB, gNB, EPC which are support 5G NR
- Do Registration and Default EPS Bearer Setup and Release
- Verify UE capability reporting for 5G (Check-UE CAPABILITY INFO INDICATION: Dual connectivity with NR (DCNR) Bit)

4.3.3.2.2 Logging at UE side and EPC side

On UE side:

- NAS Messages

On eNB side:

- NAS Messages from/to UE Side
- S1-MME Messages from/to MME

On EPC side:

- NAS/GTP-C Messages for testing UE

4.3.3.2.3 Success Criteria

Check the "UE capability information" between UE- eNB and EPC.
5G NR supported UE has to set 5G DCNR Bit: 1 and EPC has to interpret this IE and support 5G UE.

4.3.3.2.4 Test Result Report

Test supervisor has to make a simple report which are described under below and should attach the log files, whether success or fail. (And if the test is fail, he/she may request to analyze the log files to the vendors and suggest how to improve the interoperability between eNB and EPC in the Test Result Report)

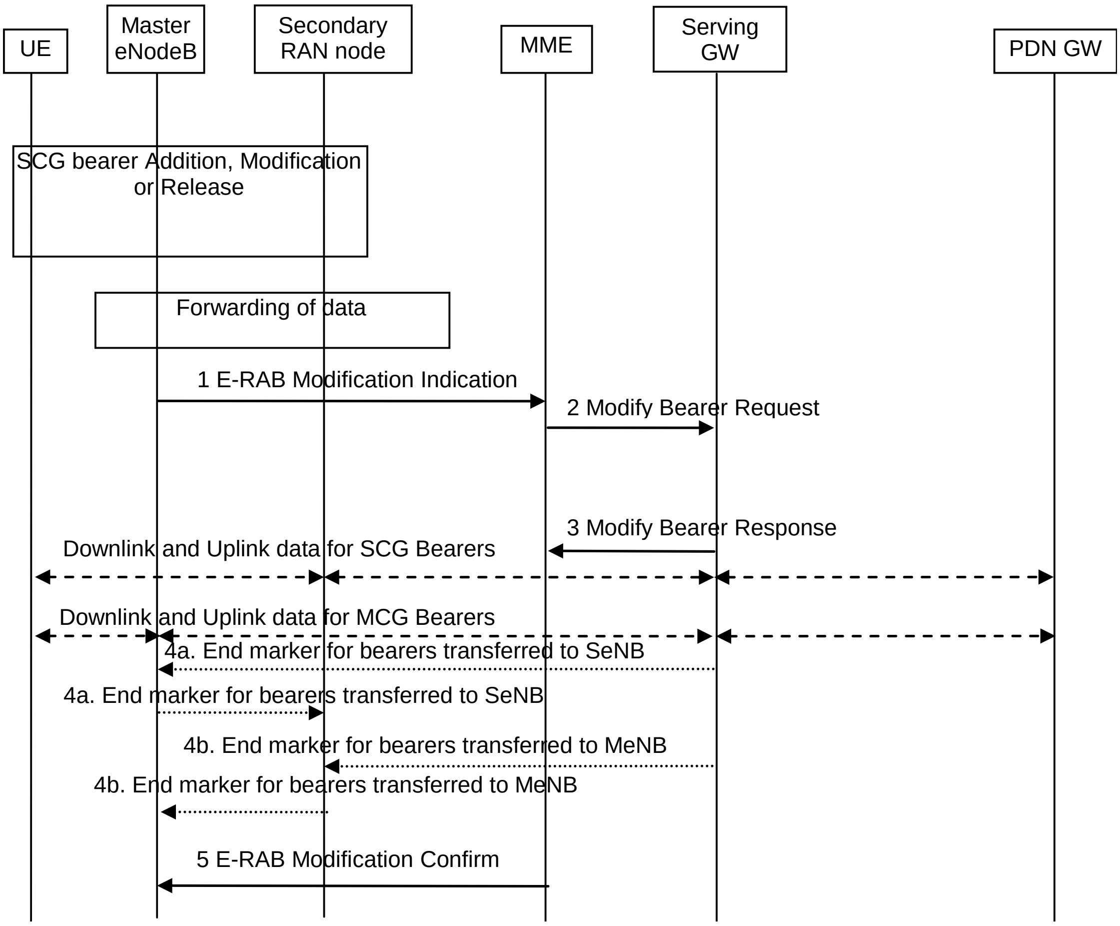
As example:

Testing Subject	Test Result	UE	eNB	EPC	Notes
Successful EPS Attach procedure. -Verify UE capability reporting for 5G	Success/Fail	*Describe UE's behavior & attach UE's log*	*Describe eNB's behavior & attach eNB's log*	*Describe EPC's behavior & attach EPC's log*	

4.3.3.3 Case #2) E-RAB modification

Reference Call Flow &Test Scope

The details of the E-RAB modification procedure is defined in TS.23.401 § 5.4.7.



3GPP TS 23.401 Figure 5.4.7-1: E-UTRAN initiated E-RAB modification procedure

4.3.3.3.1 **Test Procedure**

Testing Supervisor fulfills these steps and collects log at each side

- The UE is connected is registered in EPC. The UE is authorized to access NR.
- Test of the eNB initiating the activation of the NR bearer
    - test eNB sends the eRAB modification indication to MME
    - test MME sends eRAB modification confirm to eNB
- Test the UE sends and receive data on the LTE and NR bearer

4.3.3.3.2 **Success Criteria**

Check the messages between eNB and EPC, and if data are sent on the gNB-EPC interface. If the message are delivered and the all parameters which are described on the reference document be set on the message, the test is success.

4.3.3.3.3 **Test Result Report**

Test supervisor has to make a simple report which are described under below and should attach the log files, whether success or fail. (And if the test is fail, he/she may request to analyze the log files to the vendors and suggest how to improve the interoperability between eNB and EPC in the Test Result Report)

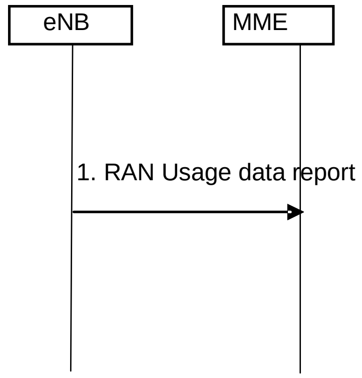
As example:

Testing Subject	Test Result	UE	eNB	EPC	Notes
eRAB modification procedure -SeNB Addition procedure	success/fail	after the procedure, the UE will be able to send data on NR and have a better throughput attach eNB's log	eNB initiates eRAB modification procedure & attach eNB's log	MME sets-up the new path towards gNB & attach EPC's log	
eRAB modification procedure -SeNB Modification procedure	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -SeNB Release procedure	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -Change of SeNB	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -MeNB to eNB Change	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -eNB to MeNB Change	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -Inter-MeNB(X2 Based) handover without SeNB Change	success/fail	*OOO*	*OOO*	*OOO*	
eRAB modification procedure -Inter-MeNB(S1 Based) handover without SeNB Change	success/fail	*OOO*	*OOO*	*OOO*	

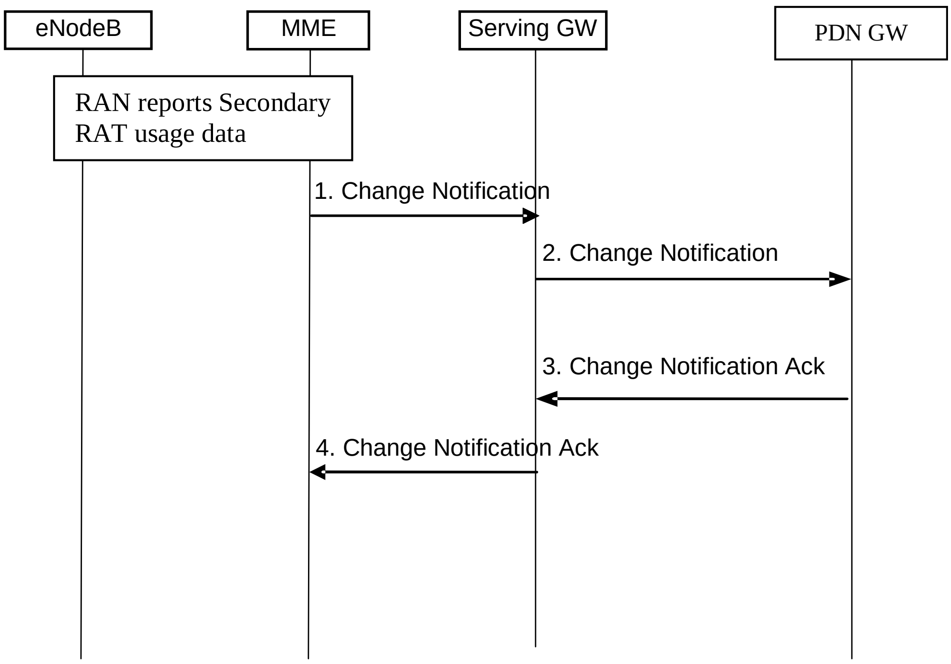
4.3.3.4 Case #3) Usage Data Reporting for Secondary RAT

Reference Call Flow &Test Scope

Usage Data Reporting for Secondary RAT information flows are described under below.



3GPP TS 23.401 Figure 5.7A.3-1: RAN Secondary RAT usage data Reporting procedure



3GPP TS 23.401 Figure 5.7A.3-2: GW Secondary RAT usage data Reporting procedure

4.3.3.4.1 Test Procedure

Testing Supervisor fulfills these steps and collects log at each side

- Prepare eNB which is support Dual Connectivity with Secondary RAT (using NR radio) and it is configured to report Secondary RAT usage data for the testing 5G NSA UE
- Data Volume Counting Test
  - Set the configuration to eNB for sending “RAN Usage data report” when UE consume some volume of Data Traffic.

- Test UE connects to Secondary RAT
- Test UE send and receive some volume of data: 100Mbyte / 200Mbyte / 300Mbyte / ~ / 1Gbyte
- Check the "Ran Usage data report" message

- Hand-Over Test
  - Set the configuration to eNB for sending "RAN Usage data report" when UE perform Hand-Over
  - Test UE connects to Secondary RAT
  - Test UE move from one eNB #1 to the other eNB #2 for making Hand Over
  - Check the "Ran Usage data report" message from eNB #1 to EPC

4.3.3.4.2 Logging at UE side and EPC side

On UE side:

- Packet Dump which is send or received by Secondary RAT

On eNB side:

- Packet Dump which is send or received by Secondary RAT
- S1-MME Messages

On EPC side:

- Packet Dump which is send or received by Secondary RAT
- NAS/GTP-C Messages for testing UE

4.3.3.4.3 Success Criteria

Check the "RAN Usage data report" and "Change Notification" messages between eNB and EPC
If the messages are delivered and the all parameters which are described on the reference document be set on the message, the test is success.

4.3.3.4.4 Test Result Report

Test supervisor has to make a simple report which are described under below and should attach the log files, whether success or fail. (And if the test is fail, he/she may request to analyze the log files to the vendors and suggest how to improve the interoperability between eNB and EPC in the Test Result Report)

As example:

Testing Subject	Test Result	UE	eNB	EPC	Notes
RAT usage data reporting - S1 release procedure	Success/Fail	*Describe UE's behavior & attach UE's log*	*Describe eNB's behavior & attach eNB's log*	*Describe EPC's behavior & attach EPC's log*	
RAT usage data reporting - Detach procedure	Success/Fail	*OOO*	*OOO*	*OOO*	
RAT usage data reporting - Bearer Deactivation	Success/Fail	*OOO*	*OOO*	*OOO*	

RAT usage data reporting - PDN Disconnection (When UE established Multiple PDN)	Success/Fail	*OOO*	*OOO*	*OOO*	
RAT usage data reporting - MME triggered Serving GW relocation	Success/Fail	*OOO*	*OOO*	*OOO*	
RAT usage data reporting - E-RAB modification procedure	Success/Fail	*OOO*	*OOO*	*OOO*	
RAT usage data reporting - Handover	Success/Fail	*OOO*	*OOO*	*OOO*	
RAT usage data reporting - Periodic Usage Data Reporting procedure	Success/Fail	*OOO*	*OOO*	*OOO*	

5 Interoperability in SA

Section 5 will be delivered with IOT Framework Document Version 2.0 which will be updated by end of 2018.

5.1 *RRC Connection Modes (RRC_INACTIVE / RRC_CONNECTED)*

- *RRC ConnectionResumeRequest message should be sent from UE to gNB (the UE resumes from RRC_INACTIVE, providing the I-RNTI (Inactive Radio Network Temporary Identifier) allocated by the last serving gNB)*
- *The gNB completes the resumption of the RRC connection through sending RRCConnectionResume message gNB can also decide to reject the Resume Request and keep the UE in RRC_INACTIVE.*

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6 Definitions

N/A N/A

7 Abbreviations

3GPP	Third Generation Partnership Project
ACR	Absolute category rating
AoA	Angle of arrival
API	Application programming interface
AR	Augmented reality
AS	Access stratum
BLER	Block error rate
BS	Base station
CDF	Cumulative distribution function
CN	Core network
CP	Carrier prefix
CPE	Customer premises equipment
CQI	Channel quality indicator
CSI-RS	Channel state information reference signal
DC	Dual connectivity
DMRS	Demodulation reference signal
eMBB	enhanced mobile broadband
EPC	Evolved packet core
E-SMLC	Enhanced serving mobile location center
E-UTRAN	Evolved UMTS Terrestrial Radio Access
eV2X	enhanced vehicle to everything
FDD	Frequency division duplex
FER	Frame erasure rate
FPS	Frame per second
FTP	File transfer protocol
gNB	5G NodeB
GPS	Global positioning system
GTP	GPRS tunneling protocol
GUI	Graphical user interface
HARQ	Hybrid automatic repeat request
IA	Refer to beam management initial access
IoT	Interference over thermal
IP	Internet protocol
KPI	Key performance indicator
LOS	Line of sight
LTE	Long term evolution
MCG	Master cell group
MCS	Modulation and coding scheme
MEC	Multi-access edge computing
MIMO	Multiple input multiple output
mMTC	massive machine type communication
MOS	Mean opinion score
MTU	Max transfer unit
NAS	Non-access stratum
NGCN	next generation core network
NGMN	Next generation mobile networks
NLOS	Non-line of sight

NR	New radio
NSA	Non-standalone
OSI	Open Systems Interconnection
OTDOA	Observed time difference of arrival
PBCH	Physical broadcast channel
PCC	Primary Component Carrier
PDCCH	Physical downlink control channel
PDCP	Packet Data Convergence Protocol
PDN	Packet data network
PDSCH	Physical downlink shared channel
PgNB	Primary 5G NodeB
PING	Packet internet groper
PLR	Packet loss rate
PoC	Proof of concept
PRB	Physical resource block
PSS	Primary synchronization signal
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel
QoE	Quality of experience
QoS	Quality of service
RAN	Radio access network
RAT	Radio access technology
RLC	Radio link control
RLF	Radio Link Failure
RRC	Radio resource control
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RTT	Round trip time
RWin	TCP receive window
SA	Standalone
SCC	Secondary Component Carrier
SCell	Secondary cell
SCG	Secondary cell group
SDU	Service data unit
SgNB	Secondary 5G NodeB
SINR	Signal to interference and noise ratio
SNR	Signal to noise ratio
SRS	Sounding reference signal
SSS	Secondary synchronization signal
TCP	Transmission control protocol
TDD	Time division duplex
ToA	Time of arrival
TTI	Trial & Testing Initiative
UDP	User datagram protocol
UE	User equipment
uRLLC	ultra-reliable low latency communications
vBBU	Virtualized baseband unit
VR	Virtual reality

8 Annexes

8.1 Annex A(Informative): QoS Handling in RAN

8.1.1 A.1 PDU Session Establishment

The following example message flow shows RAN procedures during a PDU session establishment procedure.

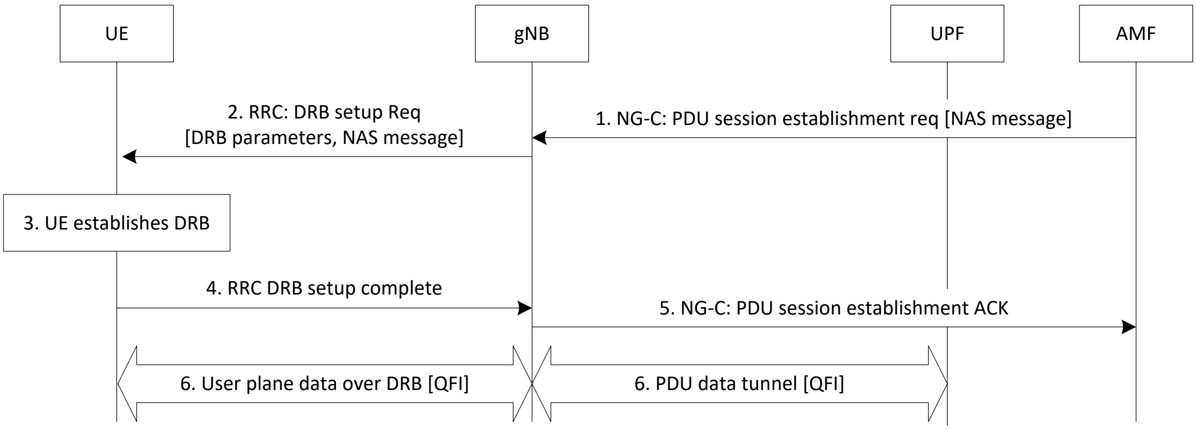

Figure A.1-1: PDU session establishment

1. 5GC sends gNB with a PDU session establishment message. It includes the NAS message to be sent to the UE with NAS QoS related information (see 3GPP TS 23.501 [3]).
2. gNB sends a DRB set up Request message to the UE including DRB parameters and the NAS message received at Step 1.
3. UE establishes at least default DRB associated with the new PDU session. It creates the QFI to DRB mapping.
4. UE sends an RRC DRB set up complete message.
5. gNB sends PDU session establishment ACK message to 5GC.
6. Data is sent over the PDU session to gNB and then over the DRB to the UE. The data packets may optionally include, if configured, a QoS marking (same as or corresponding to QFI) in the SDAP header. UE sends UL packets over the DRB. If configured in step 2, UL data packets include a QoS marking (same as or corresponding to QFI) in the SDAP header.

8.1.2 A.2 New QoS Flow without Explicit Signalling

The following figure shows an example message flow where Reflective QoS is activated via User Plane and AS use reflective QFI to DRB mapping. In this example, the gNB receives a first downlink packet over NG-U interface associated with a new QoS Flow ID (QFI) for which the QoS parameters is already available in gNB, and there is no association to an existent DRB. gNB decides to use an already existent DRB for this QoS flow.

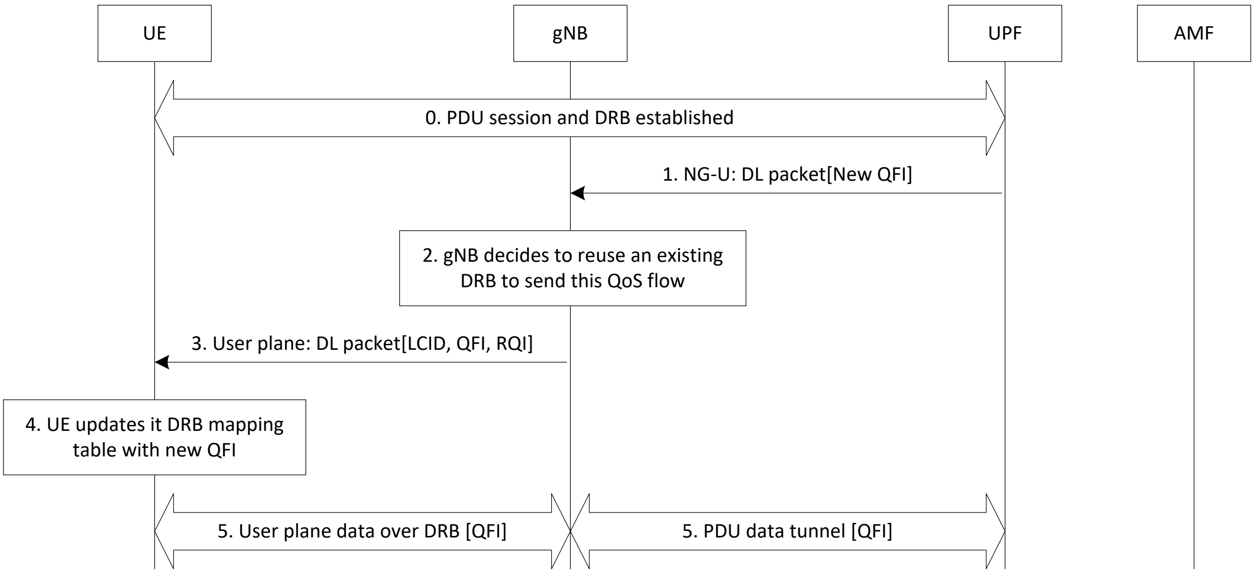

Figure A.2-1: DL data with new QFI sent over existing DRB

0. PDU session and DRB have been already established.

1. gNB receives a downlink packet with a new QFI for Reflective mapping over the NG-U interface.

2. gNB decides to send the QoS flow over an existing DRB. If gNB decides to send it over a new DRB, it needs to establish the DRB first.

3. gNB sends DL packet over the DRB with the new QFI and RQI in the SDAP header.

4. UE identifies the QFI and RQI on the received DL packet and the DRB on which the packet has been received. The AS reflective QoS mapping table shall be updated if there is a new match of QFI to DRB for this PDU session.

5. UL packets received by UE AS uses this QFI to identify the DRB over which the packet is to be sent. gNB sends UL packets over NG-U and includes the corresponding QFI.

8.1.3 A.3 New QoS Flow with NAS Reflective QoS and Explicit RRC Signalling

The following figure shows an example message flow where Reflective QoS is activated via User Plane in NAS while explicit QFI to DRB mapping with RRC signalling is used in AS. In this example, the gNB receives a downlink packet over NG-U interface associated with a new QFI for which the QoS parameters is already available in gNB, and there is no association to an existent DRB. gNB decides to map this QoS flow to an existing DRB with explicit RRC signalling.

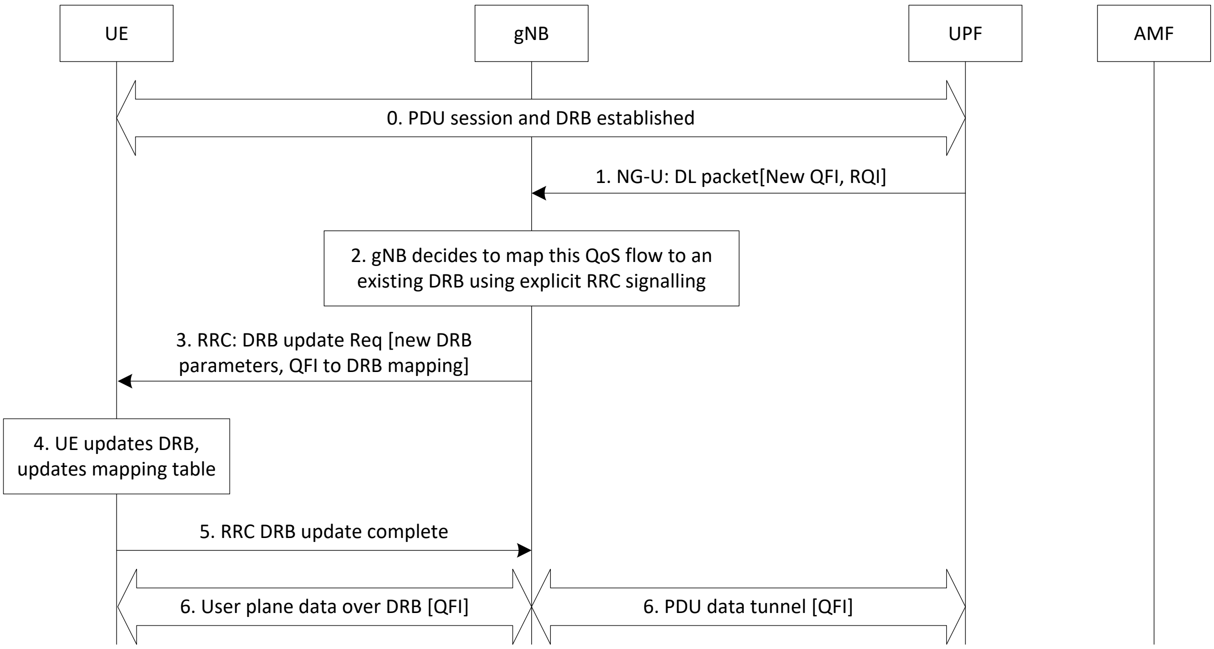

Figure A.3-1: DL data with new QFI sent over existing DRB

0. PDU session and DRB have been already established.
1. gNB receives a downlink packet with new QFI and RQI over the NG-U interface.
2. gNB decides to send the QoS flow over an existing DRB using explicit RRC signalling for AS mapping.
3. gNB sends a DRB update request to the UE with the new QoS flow to DRB mapping. gNB may also update the DRB parameters if required to meet the QoS requirements for the new QoS Flow.
4. UE updates the AS QFI to DRB mapping table. If received, UE will also update the DRB parameters.
5. UE sends an RRC DRB update complete message.
6. gNB sends DL packets for this QFI on this DRB. UL packets received in UE AS with the QFI are sent over the DRB decided by the QFI to DRB mapping table.

8.1.4 A.4 New QoS Flow with Explicit Signalling

The following figure shows an example message flow when the gNB receives a new QoS flow establishment request from CN that involves explicit signalling. The QoS flow establishment request that involves NAS signalling provides the gNB and UE with the QoS parameters for the QFI. In this example, the gNB decides to establish a new DRB (rather than re-use an existing one) for this QoS flow and provides the mapping of QFI to DRB over RRC signalling.

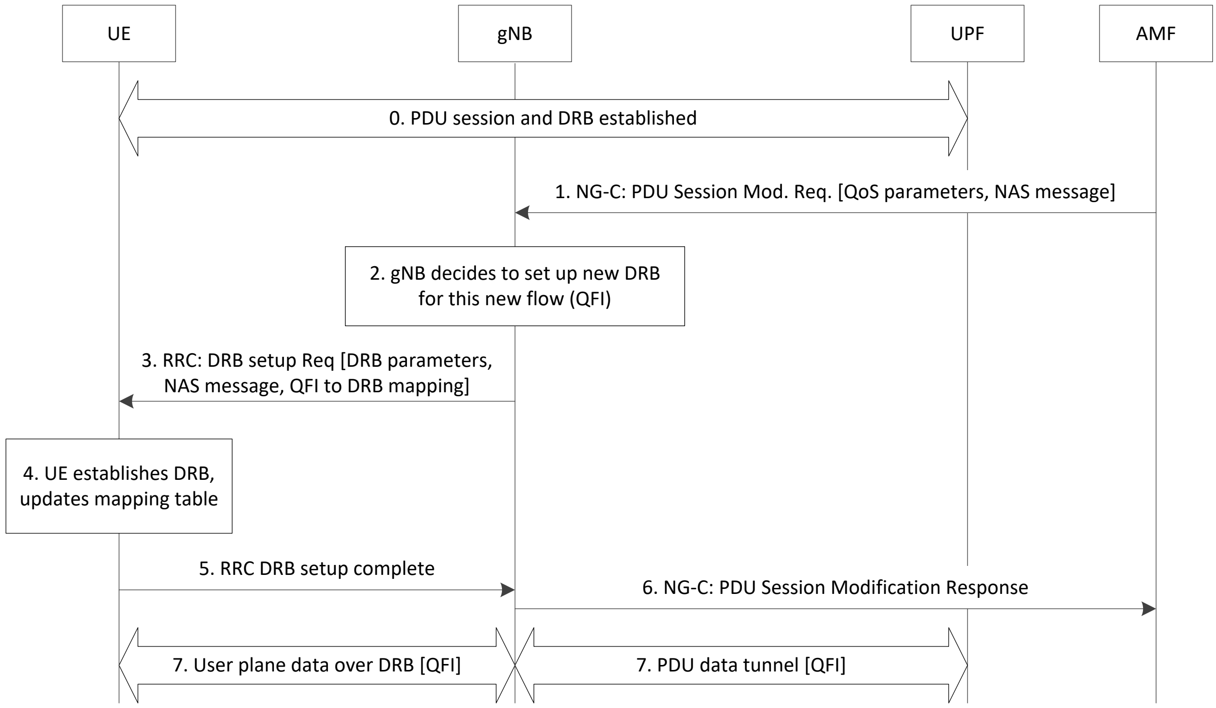

Figure A.4-1: DL data with new QoS Flow ID sent over new DRB with explicit signalling

0. PDU session and at least one default DRB have been already established.
1. gNB receives a PDU Session Modification Request from 5GC for a new flow establishment including the NAS message.
2. If the gNB cannot find an existing DRB to map this QoS flow, gNB decides to establish a new DRB for this QoS flow.
3. gNB sends a DRB set up request to the UE including DRB parameters together with the NAS message.
4. UE establishes the DRB for the QoS flow associated with this PDU session. It updates the AS QFI to DRB mapping table.
5. UE sends an RRC DRB set up complete message.
6. gNB sends PDU Session Modification Response over NG-C to 5GC.
7. UL packets received in AS with the QFI are sent over the DRB decided by the QFI to DRB mapping table.

8.1.5 A.5 Release of QoS Flow with Explicit Signalling

The following figure shows an example message flow when the gNB receives a request to release a QoS flow from CN that involves explicit signalling. In this example, the gNB had used explicit signalling to establish the QFI to DRB mapping and uses explicit signalling to release the QFI to DRB mapping using explicit RRC signalling.

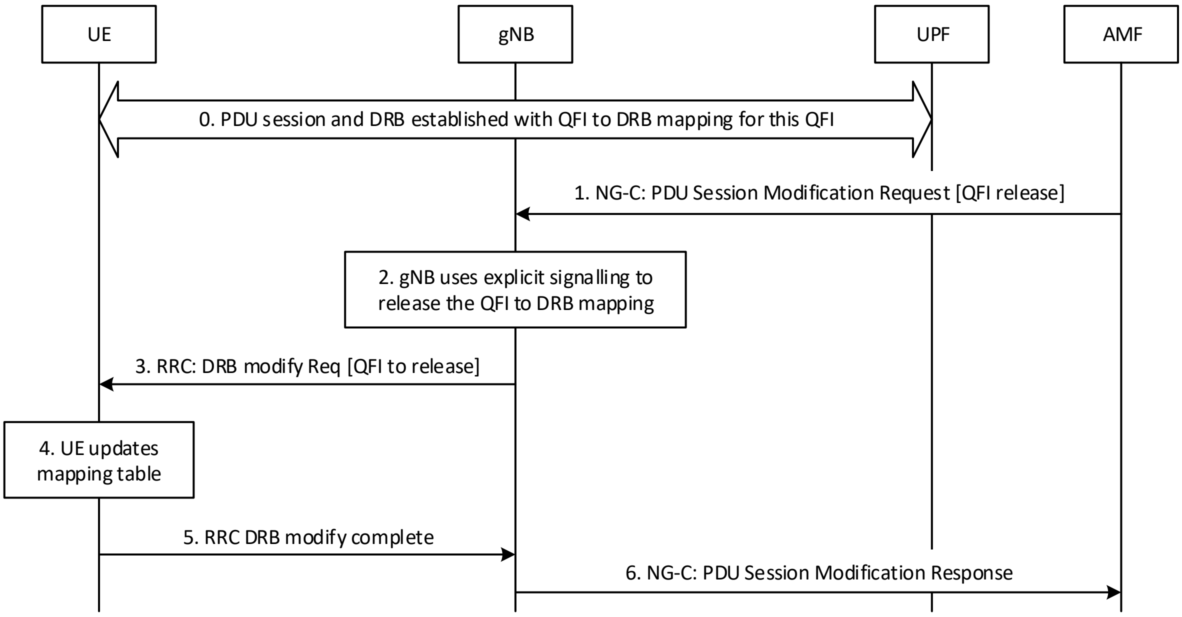

Figure A.5-1: DL data with new QoS Flow ID sent over new DRB with explicit signalling

0. PDU session and with DRB and mapping for QFI to DRB has been already established using explicit RRC signalling.
1. gNB receives a PDU Session Modification Request from 5GC to release the QFI.
2. The gNB decides to use explicit signalling to release the QFI to DRB mapping. The DRB also carries other QoS flows and hence the DRB is not released.
3. gNB sends an RRC DRB modify request to the UE to release the QFI to DRB mapping.
4. UE updates the AS QFI to DRB mapping table to release this QFI to DRB mapping.
5. UE sends an RRC DRB modify complete message.
6. gNB sends PDU Session Modification Response over NG-C to 5GC.

8.1.6 A.6 UE Initiated UL QoS Flow

The following figure shows an example message flow when the UE AS receives an UL packet for a new QoS flow for which a QFI for DRB does not exist.

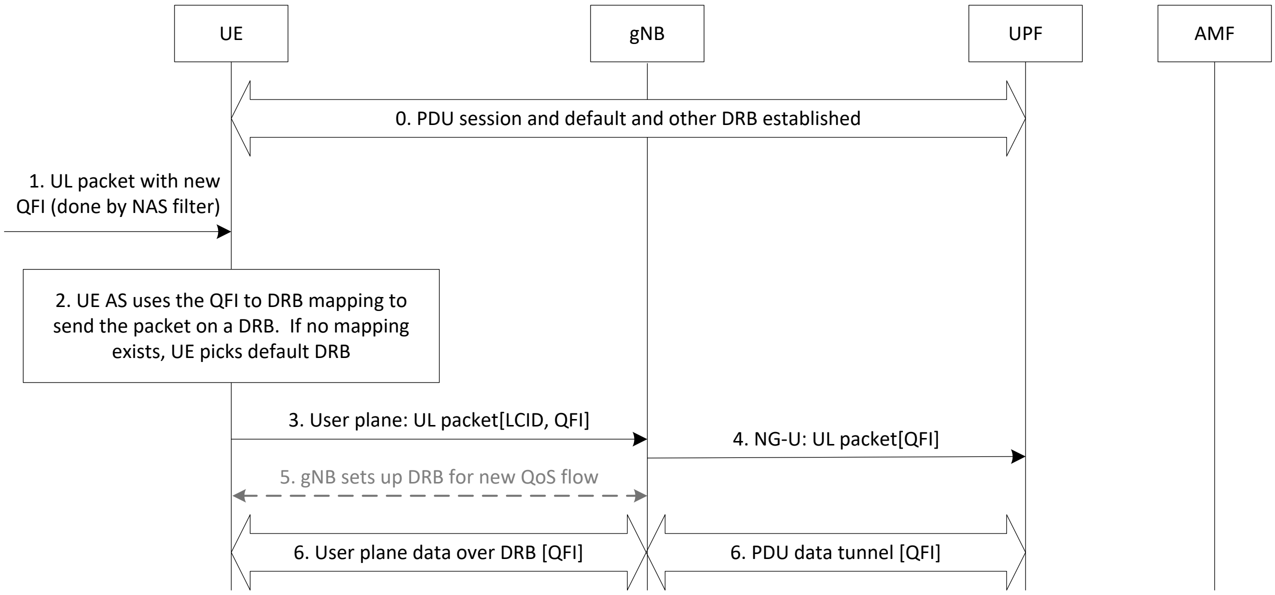

Figure A.6-1: UL packet with a new QoS flow for which a mapping does not exist in UE

0. PDU session and DRBs (including a default DRB) have been already established.
1. UE AS receives a packet with a new QFI from UE NAS.
2. UE uses the QFI of the packet to map it to a DRB. If there is no mapping of the QFI to a DRB in the AS mapping table for this PDU session, then the packet is assigned to the default DRB.
3. UE sends the UL packet on the default DRB. The UE includes the QFI in the SDAP header.
4. gNB sends UL packets over NG-U and includes the corresponding QFI.
5. If gNB wants to use a new DRB for this QoS flow, it sets up a DRB. It can also choose to move the QoS flow to an existing DRB using RRC signalling or AS reflective mapping procedures discussed above. Details of this are as shown in Figure A.2-1 and Figure A.3-1.
6. UL packets received in UE AS with the QFI are sent over the DRB decided by the QFI to DRB mapping table. If configured in step 5, UL data packets include a QoS marking (same as or corresponding to QFI) in the SDAP header.

9 References

End of Document