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Technical Specification

**3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR; NR and NG-RAN Overall Description;
Stage 2
(Release 15)**



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Keywords

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Contents

Foreword.....	6
1 Scope	7
2 References	7
3 Abbreviations and Definitions	8
3.1 Abbreviations.....	8
3.2 Definitions	8
4 Overall Architecture and Functional Split.....	9
4.1 Overall Architecture	9
4.2 Functional Split.....	9
4.3 Network Interfaces.....	11
4.3.1 NG Interface.....	11
4.3.1.1 NG User Plane.....	11
4.3.1.1 NG Control Plane	12
4.3.2 Xn Interface.....	13
4.3.2.1 Xn User Plane.....	13
4.3.2.2 Xn Control Plane	13
4.4 Radio Protocol Architecture	14
4.4.1 User Plane	14
4.4.2 Control Plane.....	14
4.5 Dual Connectivity.....	15
4.5.1 General	15
4.5.2 Radio Protocol Architecture	15
4.5.3 Network Interfaces	16
5 Physical Layer	16
6 Layer 2	16
6.1 Overview	16
6.2 MAC Sublayer	18
6.2.1 Services and Functions.....	18
6.2.2 Logical Channels.....	18
6.2.3 Mapping to Transport Channels	18
6.2.4 HARQ	19
6.3 RLC Sublayer	19
6.3.1 Transmission Modes	19
6.3.2 Services and Functions.....	19
6.3.3 ARQ	19
6.4 PDCP Sublayer.....	20
6.4.1 Services and Functions.....	20
6.4.2 Duplication.....	20
6.5 SDAP Sublayer.....	21
6.6 L2 Data Flow	21
6.7 Carrier Aggregation	21
6.8 Dual Connectivity	23
7 RRC.....	23
7.1 Services and Functions	23
7.2 Protocol States	24
7.3 System Information Handling.....	25
7.4 Access Control.....	25
7.5 UE Capability Retrieval framework	26
7.6 Transport of NAS Messages	26
7.7 Carrier Aggregation	26

8	NG Identities	26
9	Mobility and State Transitions	27
9.1	Overview	27
9.2	Intra-NR.....	28
9.2.1	Mobility in RRC_IDLE.....	28
9.2.1.1	Cell Selection.....	28
9.2.1.2	Cell Reselection.....	28
9.2.2	Mobility in RRC_INACTIVE.....	29
9.2.2.1	Overview	29
9.2.2.2	Cell Reselection.....	29
9.2.2.3	RAN-Based Notification Area.....	29
9.2.2.4	State Transitions	30
9.2.2.4.1	UE triggered transition from RRC_INACTIVE to RRC_CONNECTED	30
9.2.2.4.2	Network triggered transition from RRC_INACTIVE to RRC_CONNECTED.....	30
9.2.3	Mobility in RRC_CONNECTED.....	31
9.2.3.1	Overview	31
9.2.3.2	Handover	32
9.2.3.2.1	C-Plane Handling.....	32
9.2.3.2.2	U-Plane Handling.....	34
9.2.4	Measurements	34
9.2.5	Paging.....	36
9.2.6	Random Access Procedure.....	36
9.2.7	Radio Link Failure	37
9.3	Inter RAT.....	37
9.3.1	Cell Reselection	37
9.3.2	Handover.....	37
9.3.3	Measurements	38
9.4	Roaming and Access Restrictions.....	38
10	Scheduling.....	38
10.1	Basic Scheduler Operation.....	38
10.2	Downlink Scheduling	39
10.3	Uplink Scheduling	39
10.4	Measurements to Support Scheduler Operation.....	39
10.5	Rate Control.....	39
10.6	Activation/Deactivation Mechanism.....	39
11	UE Power Saving	40
12	QoS.....	40
13	Security	42
13.1	Overview and Principles.....	42
13.2	Security Termination Points	42
13.3	State Transitions and Mobility.....	42
14	Network Interfaces	42
15	Functional Split of the gNB	42
16	UE Capabilities	42
17	Verticals Support.....	43
17.1	Self-Configuration and Self-Optimisation	43
17.1.1	Definitions.....	43
17.1.2	UE Support for self-configuration and self-optimisation	43
17.1.3	Self-configuration	43
17.1.3.1	Dynamic configuration of the NG-C interface	43
17.1.3.1.1	Prerequisites.....	43
17.1.3.1.2	SCTP initialization.....	43
17.1.3.1.3	Application layer initialization.....	43
17.1.3.2	Dynamic Configuration of the Xn interface	44
17.1.3.2.1	Prerequisites.....	44
17.1.3.2.2	SCTP initialization.....	44

17.1.3.2.3	Application layer initialization.....	44
17.1.3.3	Automatic Neighbour Relation Function.....	44
17.1.3.3.1	General.....	44
17.1.3.3.2	Intra-system – intra NR Automatic Neighbour Relation Function	44
17.1.3.3.3	Intra-system – intra E-UTRA Automatic Neighbour Relation Function	44
17.1.3.3.4	Intra-system – inter RAT Automatic Neighbour Relation Function	44
17.1.3.3.5	Inter-system Automatic Neighbour Relation Function	44
17.1.3.4	Xn-C TNL address discovery	44
17.2	IMS Voice.....	45
17.3	Network Slicing.....	45
17.3.1	General Principles and Requirements	45
17.3.2	CN Instance and NW Slice Selection.....	46
17.3.2.1	CN-RAN interaction and internal RAN aspects	46
17.3.2.2	Radio Interface Aspects.....	46
17.3.3	Resource Isolation and Management	46
17.3.4	Signalling Aspects	47
17.3.4.1	General	47
17.3.4.2	CN Instance and NW Slice Selection	47
17.3.4.3	UE Context Handling	47
17.3.4.4	PDU Session Handling	48
17.3.4.5	Mobility	49
17.3	PWS.....	50
17.4	URLLC	50
Annex A (informative): QoS Handling in RAN.....		51
A.1	PDU Session Establishment	51
A.2	New QoS Flow without Explicit Signalling.....	51
A.3	New QoS Flow with NAS Reflective QoS and Explicit RRC Signalling.....	52
A.4	New QoS Flow with Explicit Signalling.....	53
A.5	Release of QoS Flow with Explicit Signalling.....	54
A.6	UE Initiated UL QoS Flow.....	54
Annex Z (informative): Change history		56

Foreword

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1 Scope

The present document provides an overview and overall description of the NG-RAN and focuses on the radio interface protocol architecture of NR connected to 5GC (E-UTRA connected to 5GC is covered in the 36 series). Details of the radio interface protocols are specified in companion specifications of the 38 series.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".
- [3] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".
- [4] 3GPP TS 38.401: "NG-RAN; Architecture description".
- [5] 3GPP TS 33.501: "Security Architecture and Procedures for 5G System".
- [6] 3GPP TS 37.340: "NR; Multi-connectivity; Overall description; Stage-2".
- [6] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification".
- [7] 3GPP TS 38.322: "NR; Radio Link Control (RLC) protocol specification".
- [8] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".
- [9] 3GPP TS 38.324: "NR; Service Data Protocol (SDAP) specification".
- [10] 3GPP TS 38.304: "NR; User Equipment (UE) procedures in idle mode".
- [11] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities".
- [12] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".
- [13] 3GPP TS 38.133: "NR; Requirements for support of radio resource management".

3 Abbreviations and Definitions

3.1 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1], in 3GPP TS 36.300 [2] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1] and 3GPP TS 36.300 [2].

5GC	5G Core Network
AMF	Access and Mobility Management Function
gNB	NR NodeB
NG-RAN	NG Radio Access Network
NCGI	NR Cell Global Identifier
NCR	Neighbour Cell Relation
NR	NR Radio Access
QFI	QoS Flow ID
RLAU	RAN-based Location Area Update
RNA	RAN-based Notification Area
SDAP	Service Data Adaptation Protocol
SMF	Session Management Function
UPF	User Plane Function
Xn-C	Xn-Control plane
Xn-U	Xn-User plane

3.2 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1], in 3GPP TS 36.300 [2] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1] and 3GPP TS 36.300 [2].

Master gNB: in dual connectivity, the gNB which terminates at least NG-C.

MCG bearer: in dual connectivity, a bearer whose radio protocols are only located in the MCG.

MCG split bearer: in dual connectivity, a bearer whose radio protocols are split at the MgNB and belong to both MCG and SCG.

MSG1: preamble transmission of the random access procedure.

MSG3: first scheduled transmission of the random access procedure.

NG-C: control plane interface between NG-RAN and 5GC.

NG-U: user plane interface between NG-RAN and 5GC.

Numerology: corresponds to one subcarrier spacing in the frequency domain. By scaling a reference subcarrier spacing by an integer N , different numerologies can be defined.

SCG bearer: in dual connectivity, a bearer whose radio protocols are only located in the SCG.

SCG split bearer: in dual connectivity, a bearer whose radio protocols are split at the SgNB and belong to both SCG and MCG.

Secondary gNB: in dual connectivity, the gNB that is providing additional radio resources for the UE but is not the Master node.

TTI duration: corresponds to a number of consecutive symbols in the time domain in one transmission direction. Different TTI durations can be defined when using different number of symbols.

Xn: network interface between gNBs and/or eNBs connected to 5GC.

4 Overall Architecture and Functional Split

4.1 Overall Architecture

An NG-RAN node is either:

- a gNB, providing NR user plane and control plane protocol terminations towards the UE; or
- an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE.

The gNBs and ng-eNBs are interconnected with each other by means of the Xn interface. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the AMF (Access and Mobility Management Function) by means of the NG-C interface and to the UPF (User Plane Function) by means of the NG-U interface (see 3GPP TS 23.501 [3]).

The NG-RAN architecture is illustrated in Figure 4.1-1 below.

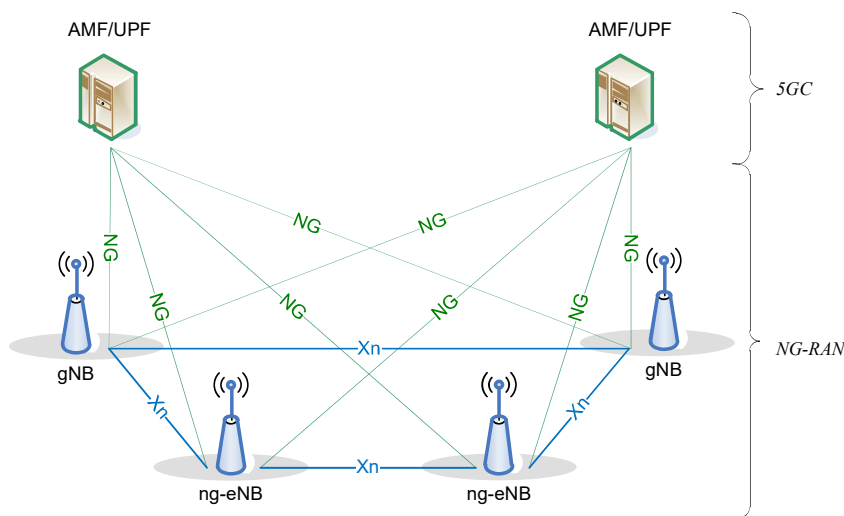


Figure 4.1-1: Overall Architecture

4.2 Functional Split

The **gNB** hosts the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
- IP header compression, encryption and integrity protection of data;
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE;
- Routing of User Plane data towards UPF(s);
- Routing of Control Plane information towards AMF;
- Connection setup and release;
- Scheduling and transmission of paging messages (originated from the AMF);
- Scheduling and transmission of system broadcast information (originated from the AMF or O&M);

- Measurement and measurement reporting configuration for mobility and scheduling;
- Transport level packet marking in the uplink;
- Session Management;
- Support of Network Slicing;
- QoS Flow management and mapping to data radio bearers;
- Support of UEs in inactive mode;
- Distribution function for NAS messages;
- Radio access network sharing;
- Dual Connectivity;
- Tight interworking between NR and E-UTRA.

The **AMF** hosts the following main functions (see 3GPP TS 23.501 [3]):

- NAS signalling termination;
- NAS signalling security;
- AS Security control;
- Inter CN node signalling for mobility between 3GPP access networks;
- Idle mode UE Reachability (including control and execution of paging retransmission);
- Registration Area management;
- Support of intra-system and inter-system mobility;
- Access Authentication;
- Access Authorization including check of roaming rights;
- Mobility management control (subscription and policies);
- Support of Network Slicing;
- SMF selection.

The **UPF** hosts the following main functions (see 3GPP TS 23.501 [3]):

- Anchor point for Intra-/Inter-RAT mobility (when applicable);
- External PDU session point of interconnect to Data Network;
- Packet routing & forwarding;
- Packet inspection and User plane part of Policy rule enforcement;
- Traffic usage reporting;
- Uplink classifier to support routing traffic flows to a data network;
- Branching point to support multi-homed PDU session;
- QoS handling for user plane, e.g. packet filtering, gating, UL/DL rate enforcement;
- Uplink Traffic verification (SDF to QoS flow mapping);
- Downlink packet buffering and downlink data notification triggering.

The Session Management function (**SMF**) hosts the following main functions (see 3GPP TS 23.501 [3]):

- Session Management;
- UE IP address allocation and management;
- Selection and control of UP function;
- Configures traffic steering at UPF to route traffic to proper destination;
- Control part of policy enforcement and QoS;
- Downlink Data Notification.

This is summarized on the figure below where yellow boxes depict the logical nodes and white boxes depict the main functions.

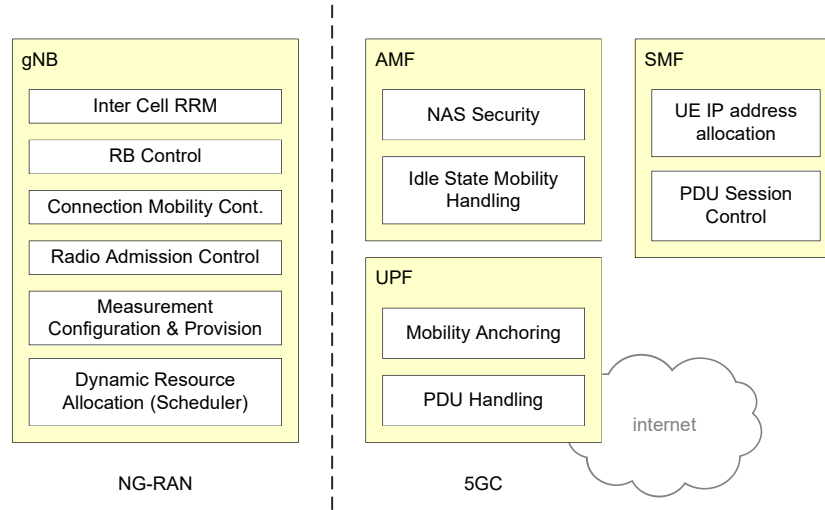


Figure 4.2-1: Functional Split between NG-RAN and 5GC

4.3 Network Interfaces

4.3.1 NG Interface

4.3.1.1 NG User Plane

The NG user plane interface (NG-U) is defined between the gNB/eNB and the UPF. The user plane protocol stack of the NG interface is shown on Figure 4.3.1.1-1. The transport network layer is built on IP transport and GTP-U is used on top of UDP/IP to carry the user plane PDUs between the gNB/eNB and the UPF.

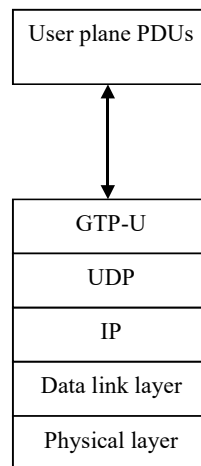


Figure 4.3.1.2-1: NG-U Protocol Stack

NG-U provides non-guaranteed delivery of user plane PDUs between the gNB/eNB and the UPF.

4.3.1.1 NG Control Plane

The NG control plane interface (NG-C) is defined between the gNB/eNB and the AMF. The control plane protocol stack of the NG interface is shown on Figure 4.3.1.2-1. The transport network layer is built on IP transport. For the reliable transport of signalling messages, SCTP is added on top of IP. The application layer signalling protocol is referred to as NG-AP (NG Application Protocol). The SCTP layer provides guaranteed delivery of application layer messages. In the transport, IP layer point-to-point transmission is used to deliver the signalling PDUs.

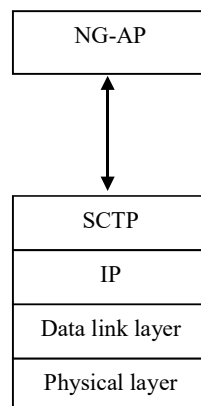


Figure 4.3.1.2-1: NG-C Protocol Stack

NG-C provides the following functions:

- Interface management: the functionality to manage the NG-C interface;
- UE context management: the functionality to manage the UE context between NG-RAN and 5GC;
- UE mobility management: the functionality to manage the UE mobility for connected mode between NG-RAN and 5GC;
- Transport of NAS messages: procedures to transfer NAS messages between 5GC and UE;
- Paging: the functionality to enable 5GC to generate paging messages sent to NG-RAN and to allow NG-RAN to page the UE in RRC_IDLE state;

- PDU Session Management: the functionality to establish, manage and remove PDU sessions and respective NG-RAN resources that are made of data flows carrying UP traffic;
- Configuration Transfer: the functionality to transfer the NG-RAN configuration information (e.g. transport layer addresses for establishment of Xn interface) between two NG-RAN nodes via 5GC;
- Warning Message Transmission: this functionality provides the means to start and overwrite the broadcasting of warning message (FFS).

4.3.2 Xn Interface

The node name in this section is FFS.

4.3.2.1 Xn User Plane

The Xn User plane (Xn-U) interface is defined between two gNBs connecting to 5GC, between gNB and eNB connecting to 5GC and between two eNBs connecting to 5GC. The user plane protocol stack on the Xn interface is shown in Figure 4.3.2.1-1. The transport network layer is built on IP transport and GTP-U is used on top of UDP/IP to carry the user plane PDUs.

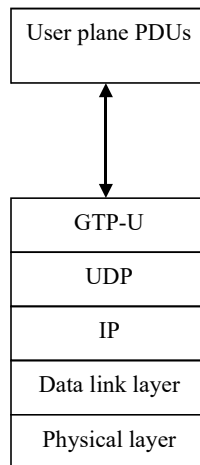


Figure 4.3.2.1-1: Xn-U Protocol Stack

Xn-U provides non-guaranteed delivery of user plane PDUs and supports the following functions:

- Data forwarding;
- Flow control.

4.3.2.2 Xn Control Plane

The Xn control plane interface (Xn-C) is defined between two gNBs connecting to 5GC, between gNB and eNB connecting to 5GC and between two eNBs connecting to 5GC. The control plane protocol stack of the Xn interface is shown on Figure 4.3.2.2-1. The transport network layer is built on SCTP on top of IP. The application layer signalling protocol is referred to as Xn-AP (Xn Application Protocol). The SCTP layer provides the guaranteed delivery of application layer messages. In the transport IP layer point-to-point transmission is used to deliver the signalling PDUs.

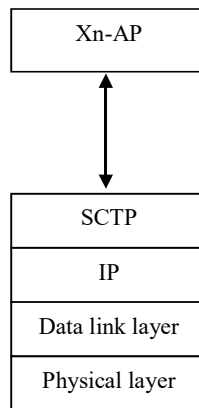


Figure 4.3.2.2-1: Xn-C Protocol Stack

The Xn-C interface supports the following functions:

- Xn interface management and error handling: the functionality to manage the Xn-C interface;
- Mobility support for UE in CM-CONNECTED: the functionality to manage the UE mobility for connected mode between nodes in the NG-RAN:
 - Context transfer from old serving NG-RAN node to new serving NG-RAN node;
 - Control of user plane tunnels between old serving NG-RAN node and new serving NG-RAN node.
- Dual connectivity: the functionality to enable usage of additional resources in a secondary node in the NG-RAN;
- Support of RAN Paging: sending of RAN paging by last serving NG-RAN node towards other nodes in the RAN-based notification area (RNA) for a UE in RRC_INACTIVE state.

4.4 Radio Protocol Architecture

4.4.1 User Plane

The figure below shows the protocol stack for the user plane, where SDAP, PDCP, RLC and MAC sublayers (terminated in gNB on the network side) perform the functions listed in subclause 6.

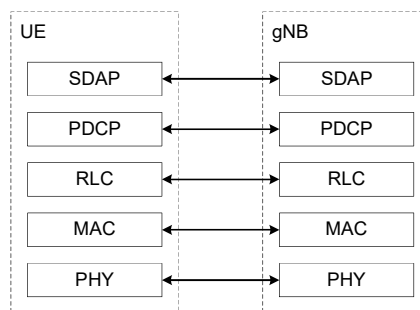


Figure 4.4.1-1: User Plane Protocol Stack

4.4.2 Control Plane

The figure below shows the protocol stack for the control plane, where:

- PDCP, RLC and MAC sublayers (terminated in gNB on the network side) perform the functions listed in subclause 6;

- RRC (terminated in gNB on the network side) performs the functions listed in subclause 7;
- NAS control protocol (terminated in AMF on the network side) performs the functions listed in 3GPP TS 23.501 [3]), for instance: authentication, mobility management, security control...

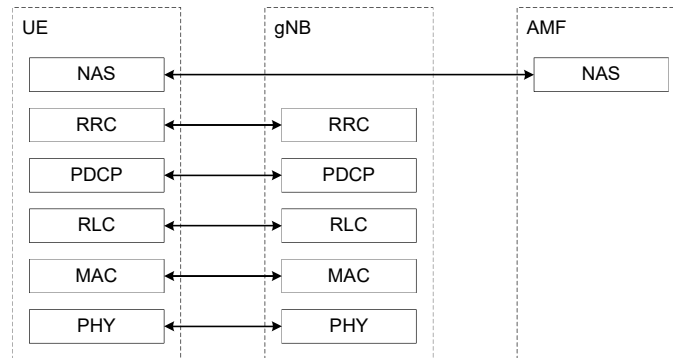


Figure 4.4.2-1: Control Plane Protocol Stack

4.5 Dual Connectivity

4.5.1 General

NR supports Dual Connectivity (DC) operation whereby a UE in RRC_CONNECTED is configured to utilise radio resources provided by two distinct schedulers, located in two gNBs connected via a non-ideal backhaul. gNBs involved in DC for a certain UE may assume two different roles: a gNB may either act as an MgNB or as an SgNB. In DC, a UE is connected to one MgNB and one SgNB.

4.5.2 Radio Protocol Architecture

In DC, the radio protocol architecture that a radio bearer uses depends on how the radio bearer is setup. Four bearer types exist: MCG bearer, MCG split bearer, SCG bearer and SCG split bearer. Those four bearer types are depicted on Figure 4.5.2-1 and 4.5.2-2 below.

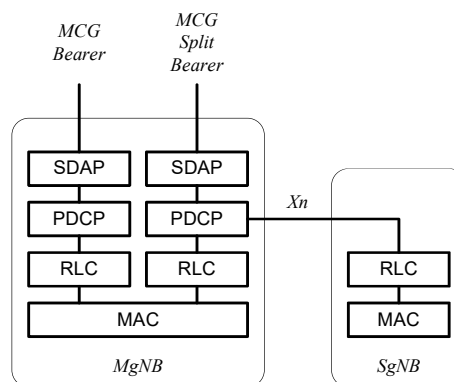


Figure 4.5.2-1: MgNB Bearers for Dual Connectivity

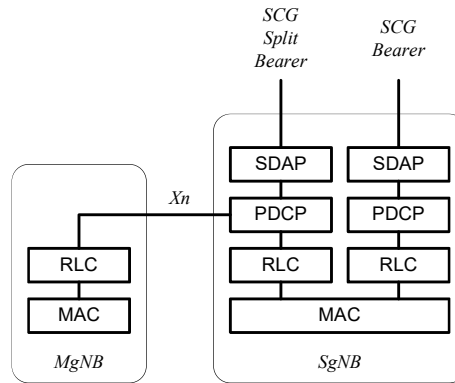


Figure 4.5.2-2: SgNB Bearers for Dual Connectivity

4.5.3 Network Interfaces

To be provided in cooperation with RAN3.

5 Physical Layer

To be provided by RAN1. Should at least contain an overview of downlink & uplink transmission schemes, beam management, channel structure, transport channels, mapping between transport channels and physical channels, definition of slots...

6 Layer 2

6.1 Overview

The layer 2 is split into the following sublayers: Medium Access Control (MAC), Radio Link Control (RLC), Packet Data Convergence Protocol (PDCP) and SDAP (Service Data Adaptation Protocol). The two figures below depict the Layer 2 architecture for downlink and uplink, where:

- The physical layer offers to the MAC sublayer transport channels;
- The MAC sublayer offers to the RLC sublayer logical channels;
- The RLC sublayer offers to the PDCP sublayer RLC channels;
- The PDCP sublayer offers to the SDAP sublayer radio bearers;
- The SDAP sublayer offers to 5GC QoS flows.
- *Comp.* refers to header compression and *segm.* to segmentation.
- Control channels (BCCH, PCCH are not depicted for clarity).

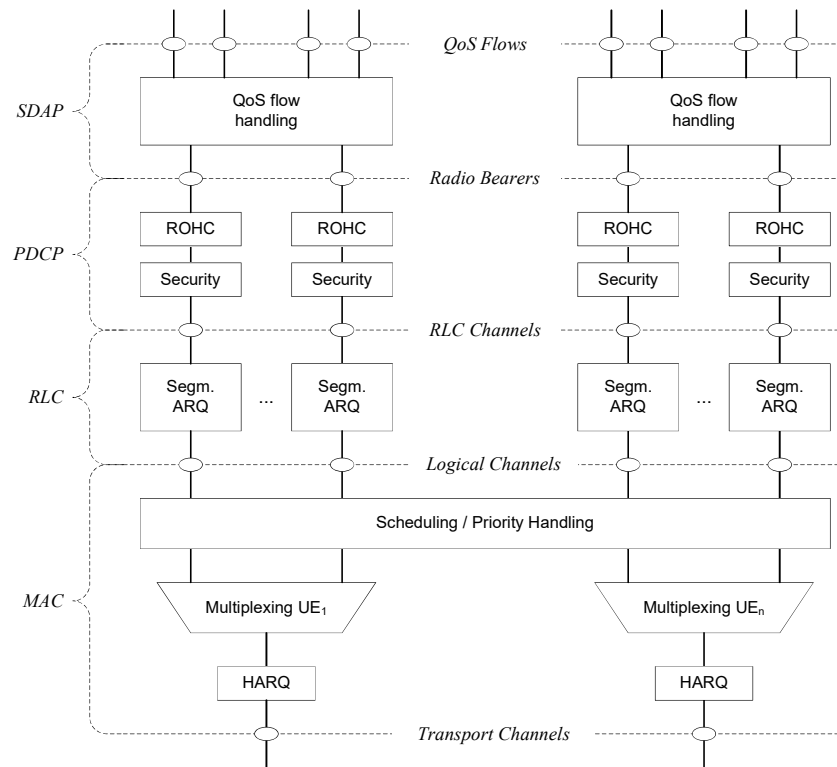


Figure 6.1-1: Downlink Layer 2 Structure

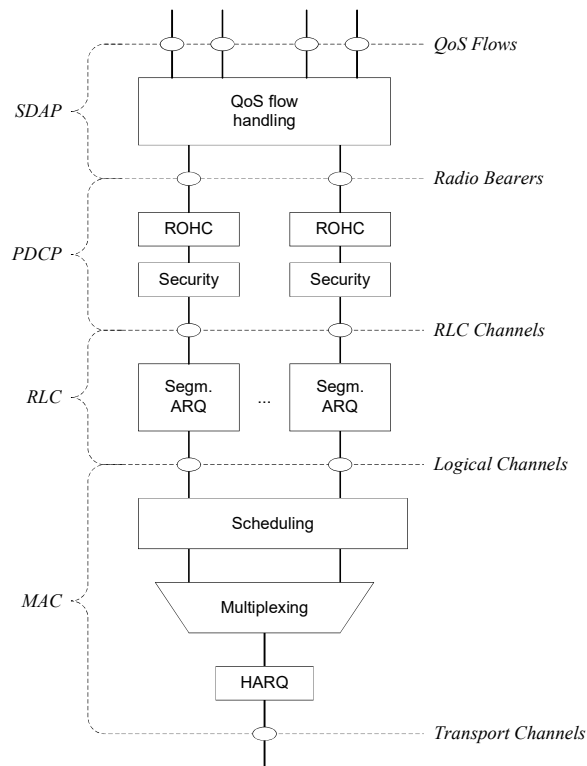


Figure 6.1-2: Uplink Layer 2 Structure

Radio bearers are categorized into two groups: data radio bearers (DRB) for user plane data and signalling radio bearers (SRB) for control plane data.

6.2 MAC Sublayer

6.2.1 Services and Functions

The main services and functions of the MAC sublayer include:

- Mapping between logical channels and transport channels;
- Multiplexing/demultiplexing of MAC SDUs belonging to one or different logical channels into/from transport blocks (TB) delivered to/from the physical layer on transport channels;
- Scheduling information reporting;
- Error correction through HARQ (one HARQ entity per carrier in case of CA);
- Priority handling between UEs by means of dynamic scheduling;
- Priority handling between logical channels of one UE by means of logical channel prioritisation;
- Padding.

A single MAC entity can support one or multiple numerologies and/or TTI durations and mapping restrictions in logical channel prioritisation controls which numerology and/or TTI duration a logical channel can use.

6.2.2 Logical Channels

Different kinds of data transfer services as offered by MAC. Each logical channel type is defined by what type of information is transferred. Logical channels are classified into two groups: Control Channels and Traffic Channels. Control channels are used for the transfer of control plane information only:

- Broadcast Control Channel (BCCH): a downlink channel for broadcasting system control information.
- Paging Control Channel (PCCH): a downlink channel that transfers paging information and system information change notifications.
- Common Control Channel (CCCH): channel for transmitting control information between UEs and network. This channel is used for UEs having no RRC connection with the network.

To be clarified whether CCCH applies to RRC-Inactive.

- Dedicated Control Channel (DCCH): a point-to-point bi-directional channel that transmits dedicated control information between a UE and the network. Used by UEs having an RRC connection.

Traffic channels are used for the transfer of user plane information only:

- Dedicated Traffic Channel (DTCH): point-to-point channel, dedicated to one UE, for the transfer of user information. A DTCH can exist in both uplink and downlink.

6.2.3 Mapping to Transport Channels

In Downlink, the following connections between logical channels and transport channels exist:

- BCCH can be mapped to BCH;
- BCCH can be mapped to DL-SCH;
- PCCH can be mapped to PCH;
- CCCH can be mapped to DL-SCH;

- DCCH can be mapped to DL-SCH;
- DTCH can be mapped to DL-SCH.

In Uplink, the following connections between logical channels and transport channels exist:

- CCCH can be mapped to UL-SCH;
- DCCH can be mapped to UL-SCH;
- DTCH can be mapped to UL-SCH.

6.2.4 HARQ

The HARQ functionality ensures delivery between peer entities at Layer 1. A single HARQ process supports one TB when the physical layer is not configured for downlink/uplink spatial multiplexing, and when the physical layer is configured for downlink/uplink spatial multiplexing, a single HARQ process supports one or multiple TBs.

6.3 RLC Sublayer

6.3.1 Transmission Modes

The RLC sublayer supports three transmission modes:

- Transparent Mode (TM);
- Unacknowledged Mode (UM);
- Acknowledged Mode (AM).

The RLC configuration is per logical channel with no dependency on numerologies and/or TTI durations, and ARQ can operate on any of the numerologies and/or TTI durations the logical channel is configured with.

For SRB0, paging and broadcast system information, TM mode is used. For other SRBs AM mode used. For DRBs, either UM or AM mode are used.

6.3.2 Services and Functions

The main services and functions of the RLC sublayer depend on the transmission mode and include:

- Transfer of upper layer PDUs;
- Sequence numbering independent of the one in PDCP (UM and AM);
- Error Correction through ARQ (AM only);
- Segmentation (AM and UM) and re-segmentation (AM only) of RLC SDUs;
- Reassembly of SDU (AM and UM);
- Duplicate Detection (AM only);
- RLC SDU discard (AM and UM);
- RLC re-establishment;
- Protocol error detection (AM only).

6.3.3 ARQ

The ARQ within the RLC sublayer has the following characteristics:

- ARQ retransmits RLC PDUs or RLC PDU segments based on RLC status reports;

- Polling for RLC status report is used when needed by RLC;
- RLC receiver can also trigger RLC status report after detecting a missing RLC PDU or RLC PDU segment.

6.4 PDCP Sublayer

6.4.1 Services and Functions

The main services and functions of the PDCP sublayer for the user plane include:

- Sequence Numbering;
- Header compression and decompression: ROHC only;
- Transfer of user data;
- Reordering and duplicate detection;
- PDCP PDU routing (in case of split bearers);
- Retransmission of PDCP SDUs;

FFS when to perform retransmission.

- Ciphering, deciphering and integrity protection;
- PDCP SDU discard;
- PDCP re-establishment and data recovery for RLC AM;
- Duplication of PDCP PDUs.

The main services and functions of the PDCP sublayer for the control plane include:

- Sequence Numbering;
- Ciphering, deciphering and integrity protection;
- Transfer of control plane data;
- Duplicate detection;
- Duplication of PDCP PDUs.

6.4.2 Duplication

When duplication is configured for a radio bearer by RRC, an additional RLC entity and an additional logical channel are added to the radio bearer to handle the duplicated PDCP PDUs. Duplication at PDCP therefore consists in sending the same PDCP PDUs twice: once on the original RLC entity and a second time on the additional RLC entity. When doing so, the original PDCP PDU and the corresponding duplicate shall not be transmitted on the same carrier. The two different logical channels can either belong to the same MAC entity (CA) or to different ones (DC). In the former case, logical channel mapping restrictions are used in MAC to ensure that the logical channel carrying the original PDCP PDUs and logical channel carrying the corresponding duplicates are not sent on the same carrier.

Once configured, duplication can be activated and de-activated per DRB by means of a MAC control element:

- In CA, when duplication is de-activated, the logical channel mapping restrictions are lifted;
- In DC, the UE applies the MAC CE commands regardless of their origin (MCG or SCG).

6.5 SDAP Sublayer

The main services and functions of SDAP include:

- Mapping between a QoS flow and a data radio bearer;
- Marking QoS flow ID (QFI) in both DL and UL packets.

A single protocol entity of SDAP is configured for each individual PDU session, except for DC where two entities can be configured (one for MCG and another one for SCG - see subclause 12).

6.6 L2 Data Flow

An example of the Layer 2 Data Flow is depicted on Figure 6.6-1, where a transport block is generated by MAC by concatenating two RLC PDUs from RB_x and one RLC PDU from RB_y . The two RLC PDUs from RB_x each corresponds to one IP packet (n and $n+1$) while the RLC PDU from RB_y is a segment of an IP packet (m).

NOTE: H depicts the headers and subheaders.

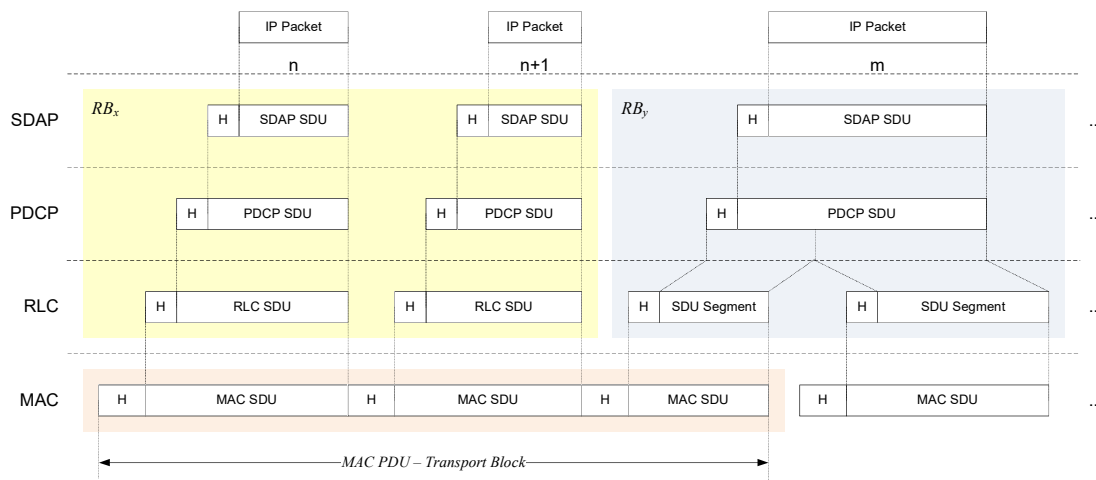


Figure 6.6-1: Data Flow Example

6.7 Carrier Aggregation

LTE Baseline for CA is used here as starting point. Possible changes to accommodate NR to be discussed. For instance, HARQ retransmission handling to be confirmed by RAN1/RAN2.

In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per TTI per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

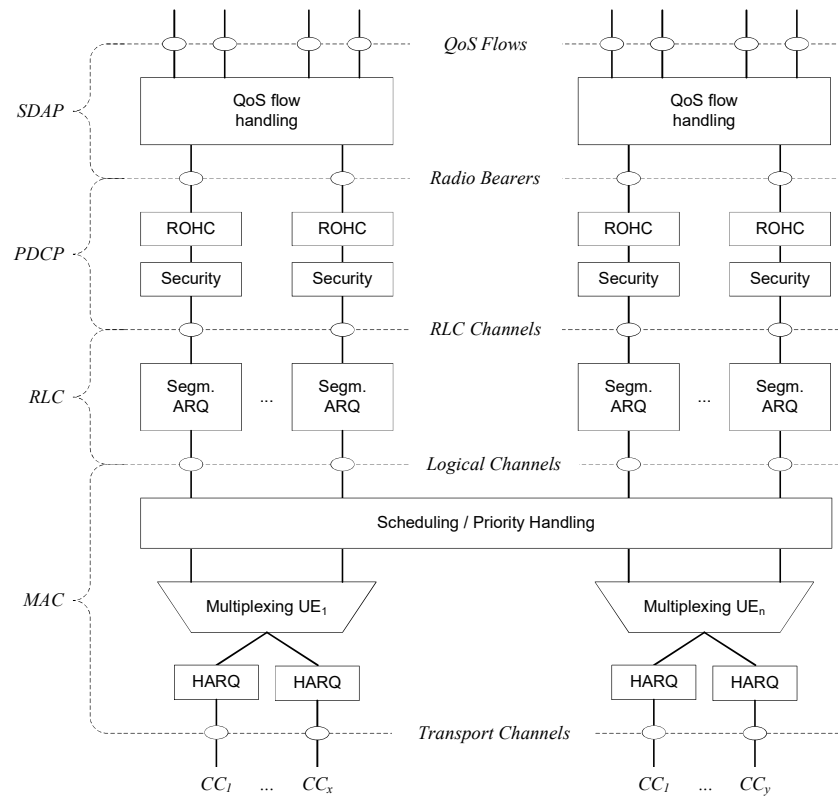


Figure 6.7-1: Layer 2 Structure for DL with CA configured

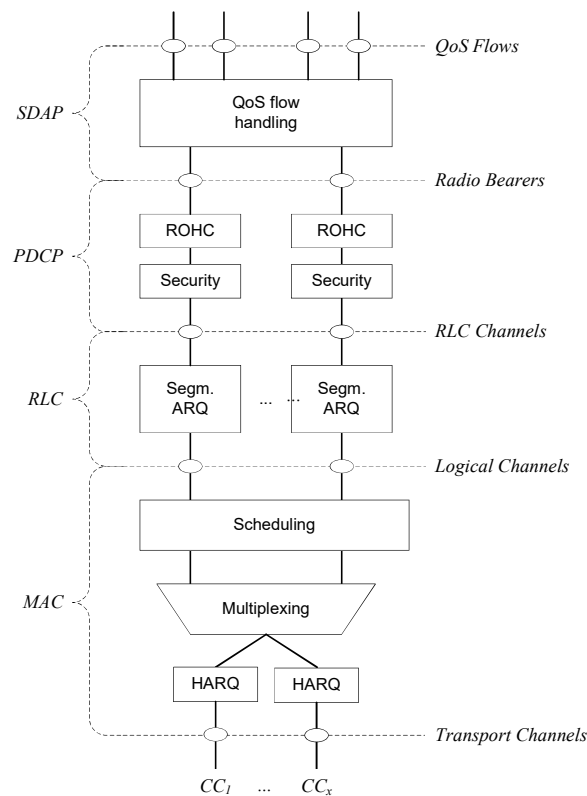


Figure 6.7-2: Layer 2 Structure for UL with CA configured

6.8 Dual Connectivity

In case of DC, the UE is configured with two MAC entities: one MAC entity for the MCG and one MAC entity for the SCG. For a split bearer, UE is configured over which link (or both) the UE transmits UL PDCP PDUs. On the link which is not responsible for UL PDCP PDUs transmission, the RLC layer only transmits corresponding ARQ feedback for the downlink data.

Further details of DC operation can be found in 3GPP TS 37.340 [6].

7 RRC

7.1 Services and Functions

The main services and functions of the RRC sublayer include:

- Broadcast of System Information related to AS and NAS;
- Paging initiated by 5GC or NG-RAN;
- Establishment, maintenance and release of an RRC connection between the UE and NG-RAN including:
 - Addition, modification and release of carrier aggregation;
 - Addition, modification and release of Dual Connectivity in NR or between E-UTRA and NR.
- Security functions including key management;

- Establishment, configuration, maintenance and release of Signalling Radio Bearers (SRBs) and Data Radio Bearers (DRBs);
- Mobility functions including:
 - Handover and context transfer;
 - UE cell selection and reselection and control of cell selection and reselection;
 - Inter-RAT mobility.
- QoS management functions;
- UE measurement reporting and control of the reporting;
- Detection of and recovery from radio link failure;
- NAS message transfer to/from NAS from/to UE.

7.2 Protocol States

RRC supports the following states which can be characterised as follows:

- **RRC_IDLE:**
 - PLMN selection;
 - Broadcast of system information;
 - Cell re-selection mobility;
 - Paging (initiated and area managed by 5GC);
 - DRX for CN paging configured by NAS.

FFS whether the UE AS context is not stored in any gNB or in the UE.

- **RRC_INACTIVE:**
 - Broadcast of system information;
 - Cell re-selection mobility;
 - 5GC - NG-RAN connection (both C/U-planes) is established for UE;
 - The UE AS context is stored in at least one gNB and the UE;
 - Paging is initiated by NG-RAN;
 - DRX for NG-RAN paging configured by NG-RAN;
 - RAN-based notification area (RNA) is managed by NG- RAN;
 - NG-RAN knows the RNA which the UE belongs to.

FFS if data transmission is possible in INACTIVE. FFS if PLMN selection is supported in INACTIVE.

- **RRC_CONNECTED:**
 - The UE has an NG-RAN RRC connection;
 - The UE has an AS context in NG-RAN;
 - NG-RAN knows the cell which the UE belongs to;
 - Transfer of unicast data to/from the UE;

- Network controlled mobility including measurements.

7.3 System Information Handling

System Information (SI) is divided into Minimum SI and Other SI. Minimum SI is periodically broadcast and comprises basic information required for initial access and information for acquiring any other SI broadcast periodically or provisioned on-demand, i.e. scheduling information. The Other SI encompasses everything not broadcast in the Minimum SI and may either be broadcast, or provisioned in a dedicated manner, either triggered by the network or upon request from the UE as illustrated in Figure 7.3-1 below.

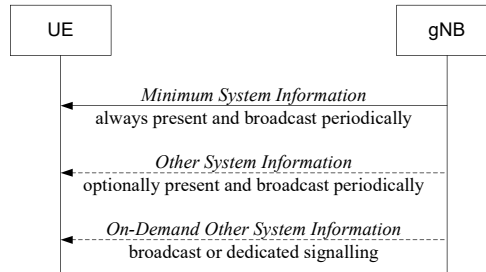


Figure 7.3-1: System Information Provisioning

Exact names pending Stage 3 agreements.

For UEs in RRC_CONNECTED, dedicated RRC signalling is used for the request and delivery of the Other SI. For UEs in RRC_IDLE and RRC_INACTIVE, the request triggers a random access procedure (see subclause 9.2.6) and is carried over MSG3 unless the requested SI is associated to a subset of the PRACH resources, in which case MSG1 can be used. When MSG1 is used, the minimum granularity of the request is one SI message (i.e. a set of SIBs), one RACH preamble can be used to request multiple SI messages and the gNB acknowledges the request in MSG2. When MSG 3 is used, the gNB acknowledges the request in MSG4.

The Other SI may be broadcast at a configurable periodicity and for a certain duration. It is a network decision whether the other SI is broadcast or delivered through dedicated and UE specific RRC signalling.

Each cell on which the UE is allowed to camp broadcasts at least some contents of the Minimum SI, while there may be cells in the system on which the UE cannot camp and do not broadcast the Minimum SI.

For a cell/frequency that is considered for camping by the UE, the UE is not required to acquire the contents of the minimum SI of that cell/frequency from another cell/frequency layer. This does not preclude the case that the UE applies stored SI from previously visited cell(s).

If the UE cannot determine the full contents of the minimum SI of a cell (by receiving from that cell or from valid stored SI from previous cells), the UE shall consider that cell as barred.

When multiple numerologies are mixed on a single carrier, only the default one is used for system information broadcast and paging.

FFS whether initial access from RRC_INACTIVE also relies on the default numerology.

7.4 Access Control

NG-RAN should support overload and access control functionality such as RACH back off, RRC Connection Reject, RRC Connection Release and UE based access barring mechanisms.

One unified access barring mechanism for NR should be introduced to address all the use cases and scenarios that E-UTRA addressed with different specialized mechanisms. The unified access barring mechanism should be forward compatible in order to cope with future use cases/scenarios.

In NR, the unified access barring mechanism should be applicable for all RRC states in NR (RRC_IDLE, RRC_CONNECTED and RRC_INACTIVE).

These are only high level requirements, once the corresponding mechanisms are actually agreed, this subclause should be changed.

In RRC_IDLE, the UE NAS informs RRC of the access category and the Connection Request includes some information to enable the gNB to decide whether to reject the request.

FFS what NAS does for RRC_INACTIVE and FFS for RRC_IDLE whether the information is directly provided by NAS, derived from the access category....

7.5 UE Capability Retrieval framework

The UE reports its UE radio access capabilities which are static at least when the network requests. The gNB can request what capabilities for the UE to report (e.g. similar band and band combination requests as in E-UTRAN). The change of UE capabilities is just to, temporarily (e.g. under network control), limit the availability of some capabilities, e.g. due to hardware sharing, interference or overheating. The temporary capability restriction should be transparent to 5GC. Namely, only static capabilities are stored in 5GC. The UE signals the temporary capability restriction request to the gNB.

Should statements require more work.

7.6 Transport of NAS Messages

To be captured once agreements are made.

7.7 Carrier Aggregation

LTE Baseline for CA is used here as starting point. Possible changes to accommodate NR to be discussed. PCell change, activation, re-establishment FFS.

When CA is configured, the UE only has one RRC connection with the network. At RRC connection establishment/re-establishment/handover, one serving cell provides the NAS mobility information, and at RRC connection re-establishment/handover, one serving cell provides the security input. This cell is referred to as the Primary Cell (PCell). Depending on UE capabilities, Secondary Cells (SCells) can be configured to form together with the PCell a set of serving cells. The configured set of serving cells for a UE therefore always consists of one PCell and one or more SCells.

The reconfiguration, addition and removal of SCells can be performed by RRC. At intra-NR handover, RRC can also add, remove, or reconfigure SCells for usage with the target PCell. When adding a new SCell, dedicated RRC signalling is used for sending all required system information of the SCell i.e. while in connected mode, UEs need not acquire broadcasted system information directly from the SCells.

8 NG Identities

The text in this section is FFS, needs further inputs from RAN1, RAN3 and SA2.

The following identities are used in NG-RAN for identifying a specific network entity, TS 38.413 [xx]:

- AMF Identifier: used to identify an AMF.

This is a placeholder and should be defined following input from SA2.

- NR Cell Global Identifier (NCGI): used to identify NR cells globally. The NCGI is constructed from the PLMN identity the cell belongs to and the NR Cell Identity (NCI) of the cell.

It is assumed that the E-UTRA Cell Identifier as defined for E-UTRAN is also used within NG-RAN.

- gNB Identifier (gNB ID): used to identify gNBs within a PLMN. The gNB ID is contained within the NCI of its cells.

The definition of the gNB ID is related to the architecture definition.

How to use the gNB ID in the context of mobility in RRC_INACTIVE and the corresponding identification of the UE Context ("Resume ID") has to be discussed. This also contains discussions on possible size limitations of the "Resume ID".

- Global gNB ID: used to identify gNBs globally. The Global gNB ID is constructed from the PLMN identity the gNB belongs to and the gNB ID. The MCC and MNC are the same as included in the NCGI.
- Tracking Area identity (TAI): used to identify tracking areas. The TAI is constructed from the PLMN identity the tracking area belongs to and the TAC (Tracking Area Code) of the Tracking Area.

It is FFS and subject to SA2 whether TAIs in the NG-RAN have the same format (or share same ID space) as TAIs in E-UTRAN.

- Single Network Slice Selection Assistance information (S-NSSAI): identifies a network slice.

The format of the S-NSSAI is FFS subject to SA2.

9 Mobility and State Transitions

FFS whether serving/non-serving cell may be termed 'serving/non-serving set of beam.'

FFS how the cell in connected relates to the cell in idle.

9.1 Overview

Load balancing is achieved in NR with handover, redirection mechanisms upon RRC release and through the usage of inter-frequency and inter-RAT absolute priorities and inter-frequency Qoffset parameters.

Measurements to be performed by a UE for connected mode mobility are classified in at least three measurement types:

- Intra-frequency measurements;
- Inter-frequency measurements;
- Inter-RAT measurements;

For each measurement type one or several measurement objects can be defined (a measurement object defines e.g. the carrier frequency to be monitored).

For each measurement object one or several reporting configurations can be defined (a reporting configuration defines the reporting criteria). Three reporting criteria are used: event triggered reporting, periodic reporting and event triggered periodic reporting.

The association between a measurement object and a reporting configuration is created by a measurement identity (a measurement identity links together one measurement object and one reporting configuration of the same RAT). By using several measurement identities (one for each measurement object, reporting configuration pair) it is then possible to:

- associate several reporting configurations to one measurement object and;
- associate one reporting configuration to several measurement objects.

The measurements identity is as well used when reporting results of the measurements.

Measurement quantities are considered separately for each RAT.

Measurement commands are used by NG-RAN to order the UE to start, modify or stop measurements.

9.2 Intra-NR

9.2.1 Mobility in RRC_IDLE

9.2.1.1 Cell Selection

The principles of PLMN selection in NR are based on the 3GPP PLMN selection principles. Cell selection is required on transition from RM-DEREGISTERED to RM-REGISTERED, from CM-IDLE to CM-CONNECTED and from CM-CONNECTED to CM-IDLE and is based on the following principles:

- The UE NAS layer identifies a selected PLMN and equivalent PLMNs;
- The UE searches the NR frequency bands and for each carrier frequency identifies the strongest cell. It reads cell system information broadcast to identify its PLMN(s):
 - The UE may search each carrier in turn ("initial cell selection") or make use of stored information to shorten the search ("stored information cell selection").
- The UE seeks to identify a suitable cell; if it is not able to identify a suitable cell it seeks to identify an acceptable cell. When a suitable cell is found or if only an acceptable cell is found it camps on that cell and commence the cell reselection procedure:
 - A suitable cell is one for which the measured cell attributes satisfy the cell selection criteria; the cell PLMN is the selected PLMN, registered or an equivalent PLMN; the cell is not barred or reserved and the cell is not part of a tracking area which is in the list of "forbidden tracking areas for roaming";
 - An acceptable cell is one for which the measured cell attributes satisfy the cell selection criteria and the cell is not barred.

Transition to RRC_IDLE:

On transition from RRC_CONNECTED to RRC_IDLE, a UE should camp on the last cell for which it was in RRC_CONNECTED or a cell/any cell of set of cells or frequency be assigned by RRC in the state transition message.

Recovery from out of coverage:

The UE should attempt to find a suitable cell in the manner described for stored information or initial cell selection above. If no suitable cell is found on any frequency or RAT, the UE should attempt to find an acceptable cell.

In multi-beam operations, the cell quality is derived amongst the beams corresponding to the same cell (see subclause 9.2.4).

FFS whether initial access from RRC_IDLE relies on the default numerology.

9.2.1.2 Cell Reselection

A UE in RRC_IDLE performs cell reselection. The principles of the procedure are the following:

- The UE makes measurements of attributes of the serving and neighbour cells to enable the reselection process:
 - For the search and measurement of inter-frequency neighbouring cells, only the carrier frequencies need to be indicated.
- Cell reselection identifies the cell that the UE should camp on. It is based on cell reselection criteria which involves measurements of the serving and neighbour cells:
 - Intra-frequency reselection is based on ranking of cells;
 - Inter-frequency reselection is based on absolute priorities where a UE tries to camp on the highest priority frequency available;

- An NCL can be provided by the serving cell to handle specific cases for intra- and inter-frequency neighbouring cells;
- Black lists can be provided to prevent the UE from reselecting to specific intra- and inter-frequency neighbouring cells;
- Cell reselection can be speed dependent;
- Service specific prioritisation.

FFS for which services the service specific frequency prioritisation is applied and how it applies for the case of network slices.

In multi-beam operations, the cell quality is derived amongst the beams corresponding to the same cell (see subclause 9.2.4).

9.2.2 Mobility in RRC_INACTIVE

9.2.2.1 Overview

RRC_INACTIVE is a state where a UE remains in CM-CONNECTED and can move within an area configured by NG-RAN (the RNA) without notifying NG-RAN. In RRC_INACTIVE, the last serving NG-RAN node keeps the UE context and the UE-associated NG connection with the serving AMF and UPF. The UE notifies the network if it moves out of the configured RNA.

If the last serving NG-RAN node receives DL data from the UPF or DL signalling from the AMF while the UE is in RRC_INACTIVE, it pages in the cells corresponding to the RNA and may send Xn-AP RAN Paging to neighbour NG-RAN node(s) if the RNA includes cells of neighbour NG-RAN node(s).

FFS whether upon RAN paging failure, the last serving NG-RAN node shall release the NG connection of the UE.

If the UE accesses an NG-RAN node other than the last serving NG-RAN node, the receiving NG-RAN node triggers the Xn-AP Retrieve UE Context procedure to get the UE context from the last serving NG-RAN node and may also trigger a Data Forwarding procedure including tunnel information for potential recovery of data from the last serving NG-RAN node. Upon successful context retrieval, the receiving NG-RAN node becomes the new serving NG-RAN node and it further triggers the NG-AP Path Switch Request procedure. After the path switch procedure, the NG-RAN node triggers release of the UE context at the old NG-RAN node by means of the Xn-AP UE Context Release procedure.

9.2.2.2 Cell Reselection

Can we assume the same principle as for RRC-IDLE?

9.2.2.3 RAN-Based Notification Area

A UE in the RRC_INACTIVE state can be configured with an RNA, where:

- the RNA can cover a single or multiple cells, and can be smaller than CN area;
- a RAN-based location area update (RLAU) is periodically sent by the UE and is also sent when the cell reselection procedure of the UE selects a cell that does not belong to the configured RNA.

There are several different alternatives on how the RNA can be configured:

- List of cells:
 - A UE is provided an explicit list of cells (one or more) that constitute the RNA.
- List of RAN areas:
 - A UE is provided (at least one) RAN area ID, where a RAN area is a subset of a CN Tracking Area;

- A cell broadcasts (at least one) RAN area ID in the system information so that a UE knows which area the cell belongs to.

FFS whether one alternative or both are agreed.

9.2.2.4 State Transitions

9.2.2.4.1 UE triggered transition from RRC_INACTIVE to RRC_CONNECTED

Editor's Note: some general text to be provided, mainly from RAN3. RRC signalling is FFS.

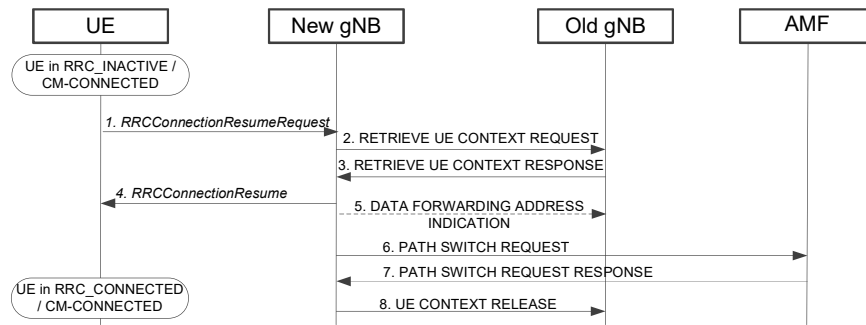


Figure 9.2.2.4.1-1: UE triggered transition from RRC_INACTIVE to RRC_CONNECTED

1. The UE resumes from RRC_INACTIVE, providing the Resume ID, allocated by the old gNB.

Applicability of the term Resume ID for NG-RAN is pending RAN2.

2. The new gNB, if able to resolve the gNB identity contained in the Resume ID, requests the old gNB to provide UE Context data.

Applicability of the term Resume ID for NG-RAN is pending RAN2.

3. The old gNB provides UE context data.
4. The new gNB completes the resumption of the RRC connection.
5. If loss of DL user data buffered in the old serving gNB shall be prevented, the new gNB provides forwarding addresses.
- 6./7. The new gNB performs path switch.
8. The new gNB triggers the release of the UE resources at the old gNB.

More details to be added.

9.2.2.4.2 Network triggered transition from RRC_INACTIVE to RRC_CONNECTED

Some general text to be provided, mainly from RAN3

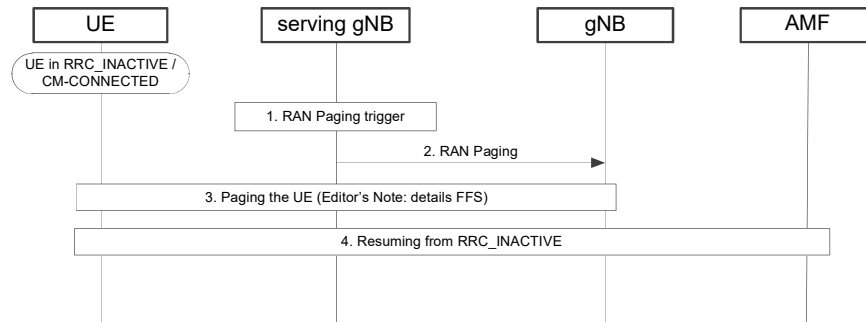


Figure 9.2.2.4.2-1: Network triggered transition from RRC_INACTIVE to RRC_CONNECTED

1. A RAN paging trigger event occurs (incoming DL user plane, DL signalling from 5GC, etc.)
2. RAN paging is triggered; either only in the cells controlled by the serving gNB or also by means of Xn RAN Paging, in other gNBs, being member of the RAN Paging area the UE is registered with.
3. The UE is paged with an NG-RAN allocated UE identity.

Details are FFS.

4. If the UE has been successfully reached, it attempts to resume from RRC_INACTIVE, as described in other sections.

More details to be added.

9.2.3 Mobility in RRC_CONNECTED

9.2.3.1 Overview

Network controlled mobility applies to UEs in RRC_CONNECTED and is categorized into two types of mobility: cell level mobility and beam level mobility.

Cell Level Mobility requires explicit RRC signalling to be triggered, i.e. handover. For inter-gNB handover, the signalling procedures consist of at least the following elemental components illustrated in Figure 10.2.3-1:

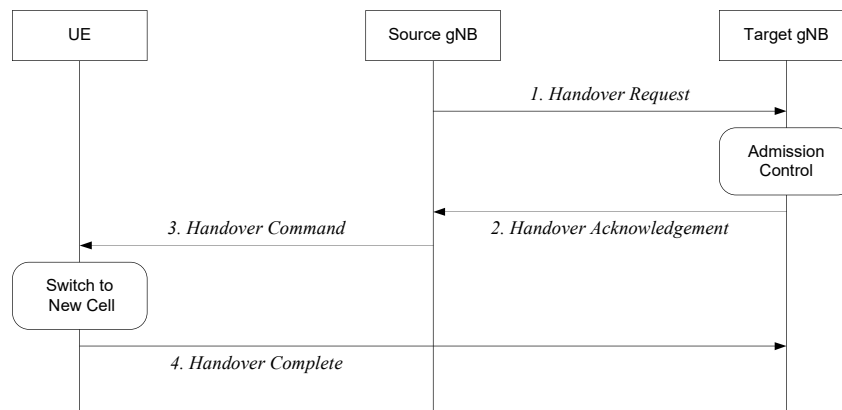


Figure 9.2.3-1: Inter-gNB handover procedures

1. The source gNB initiates handover and issues a Handover Request over the Xn interface.
2. The target gNB performs admission control and provides the RRC configuration as part of the Handover Acknowledgement.

3. The source gNB provides the RRC configuration to the UE in the Handover Command. The Handover Command message includes at least cell ID and all information required to access the target cell so that the UE can access the target cell without reading system information. For some cases, the information required for contention based and contention free random access can be included in the Handover Command message. The access information to the target cell may include beam specific information, if any.
4. The UE moves the RRC connection to the target gNB and replies the Handover Complete.

Exact message name FFS. Further enhancements and modifications can be considered.

The handover mechanism triggered by RRC requires the UE at least to reset the MAC entity and re-establish RLC. For DRBs using RLC AM mode, PDCP can either be re-established together with a security key change or initiate a data recovery procedure without a key change. For DRBs using RLC UM mode and for SRBs, PDCP can either be re-established together with a security key change or remain as it is without a key change.

Data forwarding, in-sequence delivery and duplication avoidance at handover can be guaranteed when the target gNB uses the same DRB configuration and QoS flow to DRB mapping as the source gNB.

FFS whether QoS flow can be remapped at handover and, if supported, whether the handover is lossless in this case.

Beam Level Mobility does not require explicit RRC signalling to be triggered - it is dealt with at lower layers - and RRC is not required to know which beam is being used at a given point in time.

FFS whether there may be cases for which intra-cell mobility needs to be handled by RRC.

9.2.3.2 Handover

9.2.3.2.1 C-Plane Handling

The intra-NR RAN handover performs the preparation and execution phase of the handover procedure performed without involvement of the 5GC, i.e. preparation messages are directly exchanged between the gNBs. The release of the resources at the source gNB during the handover completion phase is triggered by the target gNB. The figure below depicts the basic handover scenario where neither the AMF nor the UPF changes:

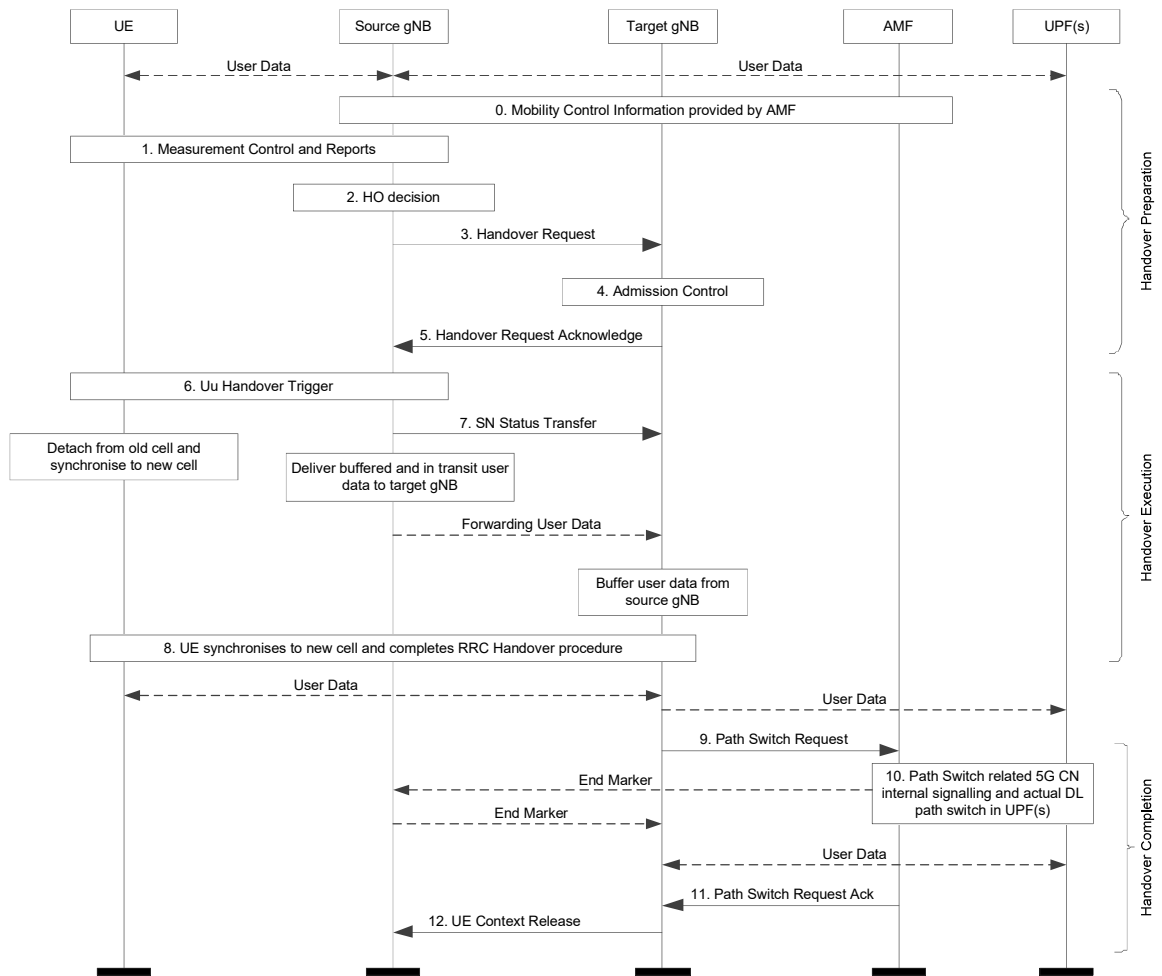


Figure 9.2.3.2.1-1: Intra-AMF/UPF Handover

0. The UE context within the source gNB contains information regarding roaming and access restrictions which were provided either at connection establishment or at the last TA update.
1. The source gNB configures the UE measurement procedures and the UE reports according to the measurement configuration.
2. The source gNB decides to handover the UE, based on MEASUREMENT REPORT and RRM information.
3. The source gNB issues a HANDOVER REQUEST message to the target gNB passing necessary information to prepare the HO at the target side
4. Admission Control may be performed by the target gNB.
5. The target gNB prepares HO with L1/L2 and sends the HANDOVER REQUEST ACKNOWLEDGE to the source gNB.
6. The target gNB generates the RRC message to perform the handover.
7. The source gNB sends the SN STATUS TRANSFER message to the target gNB.
8. The UE synchronises to the target cell and completes the RRC handover procedure.
9. The target gNB sends a PATH SWITCH REQUEST message to AMF to trigger 5GC to switch the DL data path towards the target gNB and to establish an NG-C interface instance towards the target gNB.

10. 5GC switches the DL data path towards the target gNB
11. The AMF confirms the PATH SWITCH REQUEST message with the PATH SWITCH REQUEST ACKNOWLEDGE message.
12. By sending the UE CONTEXT RELEASE message, the target gNB informs the source gNB about the success of HO and triggers the release of resources by the source gNB. The target gNB sends this message after the PATH SWITCH REQUEST ACKNOWLEDGE message is received from the AMF. Upon reception of the UE CONTEXT RELEASE message, the source gNB can release radio and C-plane related resources associated to the UE context. Any ongoing data forwarding may continue.

More details to be added by RAN2 and RAN3 in coordination with SA2.

9.2.3.2.2 U-Plane Handling

9.2.4 Measurements

In RRC_CONNECTED, the UE measures multiple beams (at least one) of a cell and the measurements results (power values) are averaged to derive the cell quality. In doing so, the UE is configured to consider a subset of the detected beams: the N best beams above an absolute threshold. Filtering takes place at two different levels: at the physical layer to derive beam quality and then at RRC level to derive cell quality from multiple beams. Cell quality from beam measurements is derived in the same way for the serving cell(s) and for the non-serving cell(s). Measurement reports may contain the measurement results of the X best beams if the UE is configured to do so by the gNB.

Possible difference between serving and non-serving could be the value of “N” i.e. N best beams - FFS.

The corresponding high-level measurement model is described below:

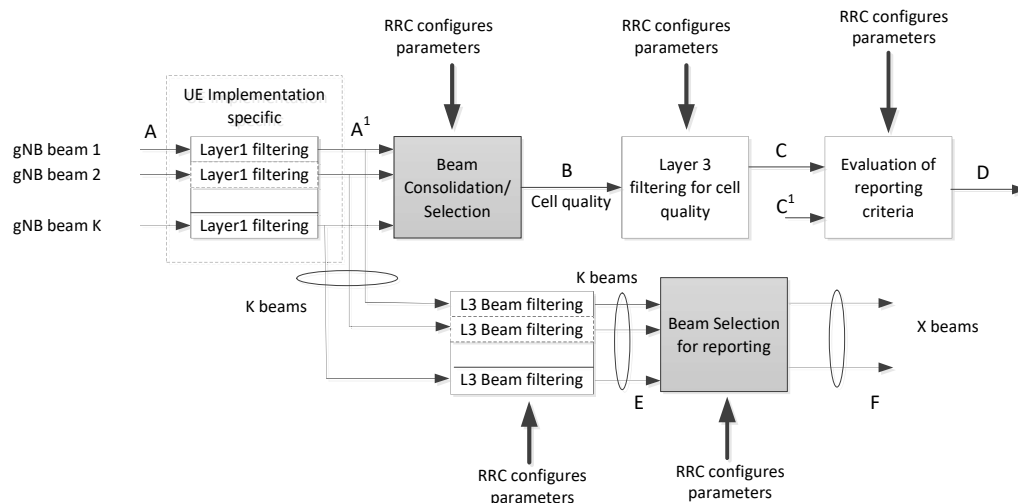


Figure 9.2.4-1: Measurement Model

NOTE: K beams correspond to the measurements on NR-SS block or CSI-RS resources configured for L3 mobility by gNB and detected by UE at L1.

- A: measurements (beam specific samples) internal to the physical layer.
- **Layer 1 filtering**: internal layer 1 filtering of the inputs measured at point A. Exact filtering is implementation dependent. How the measurements are actually executed in the physical layer by an implementation (inputs A and Layer 1 filtering) is not constrained by the standard.
- A¹: measurementss (i.e. beam specific measurements) reported by layer 1 to layer 3 after layer 1 filtering.

- **Beam Consolidation/Selection:** beam specific measurements are consolidated to derive cell quality if $N > 1$, else when $N = 1$ the best beam measurement is selected to derive cell quality. The behaviour of the Beam consolidation/selection is standardised and the configuration of this module is provided by RRC signalling. Reporting period at B equals one measurement period at A¹.
- **B:** a measurement (i.e. cell quality) derived from beam-specific measurements reported to layer 3 after beam consolidation/selection.
- **Layer 3 filtering for cell quality:** filtering performed on the measurements provided at point B. The behaviour of the Layer 3 filters is standardised and the configuration of the layer 3 filters is provided by RRC signalling. Filtering reporting period at C equals one measurement period at B.
- **C:** a measurement after processing in the layer 3 filter. The reporting rate is identical to the reporting rate at point B. This measurement is used as input for one or more evaluation of reporting criteria.
- **Evaluation of reporting criteria:** checks whether actual measurement reporting is necessary at point D. The evaluation can be based on more than one flow of measurements at reference point C e.g. to compare between different measurements. This is illustrated by input C and C¹. The UE shall evaluate the reporting criteria at least every time a new measurement result is reported at point C, C¹. The reporting criteria are standardised and the configuration is provided by RRC signalling (UE measurements).
- **D:** measurement report information (message) sent on the radio interface.
- **L3 Beam filtering:** filtering performed on the measurements (i.e. beam specific measurements) provided at point A¹. The behaviour of the beam filters is standardised and the configuration of the beam filters is provided by RRC signalling. Filtering reporting period at E equals one measurement period at A¹.
- **E:** a measurement (i.e. beam-specific measurement) after processing in the beam filter. The reporting rate is identical to the reporting rate at point A¹. This measurement is used as input for selecting the X measurements to be reported.
- **Beam Selection for beam reporting:** selects the X measurements from the measurements provided at point E. The behaviour of the beam selection is standardised and the configuration of this module is provided by RRC signalling.
- **F:** beam measurement information included in measurement report (sent) on the radio interface.

Layer 1 filtering introduces a certain level of measurement averaging. How and when the UE exactly performs the required measurements is implementation specific to the point that the output at B fulfils the performance requirements set in 3GPP TS 38.133 [13]. Layer 3 filtering for cell quality and related parameters used are specified in 3GPP TS 38.331 [12] and does not introduce any delay in the sample availability between B and C. Measurement at point C, C¹ is the input used in the event evaluation. L3 Beam filtering and related parameters used are specified in 3GPP TS 38.331 [12] and do not introduce any delay in the sample availability between E and F.

Measurement reports are characterized by the following:

- Measurement reports include the measurement identity of the associated measurement configuration that triggered the reporting;
- Cell and beam measurement quantities to be included in measurement reports are configured by the network;

FFS whether cell and beam measurements need to be consistent.

- The number of non-serving cells to be reported can be limited through configuration by the network;
- Cells belonging to a blacklist configured by the network are not used in event evaluation and reporting, and conversely when a whitelist is configured by the network, only the cells belonging to the whitelist are used in event evaluation and reporting;
- Beam measurements to be included in measurement reports are configured by the network (beam identifier only, measurement result and beam identifier, or no beam reporting);

9.2.5 Paging

The UE in RRC_IDLE and RRC_INACTIVE states may use DRX in order to reduce power consumption. While in RRC_IDLE the UE monitors 5GC-initiated paging, in RRC_INACTIVE the UE is reachable via RAN-initiated paging and 5GC-initiated paging. RAN and 5GC paging occasions overlap and same paging mechanism is used. The UE monitors one paging occasion per DRX cycle for the reception of paging as follows:

- Paging DRX cycle length is configurable:
 - A default DRX cycle for CN paging is configurable via system information;
 - A UE specific DRX cycle for CN paging is configurable via UE dedicated signalling;
 - An NG-RAN node can configure a UE with a DRX cycle for RAN paging. This configuration can be UE specific.
- The number of paging occasions in a DRX cycle is configurable via system information:
 - A network may distribute UEs to the paging occasions based on UE id when multiple paging occasions are configured in the DRX cycle.
- Paging occasion can consist of multiple time slots (e.g. subframe or OFDM symbol). The number of time slots in a paging occasion is configurable via system information:
 - A network may transmit a paging using a different set of DL Tx beam(s) or repetitions in each time slot.

Transmission mechanism of paging in each time slot is up to RAN1 decision. Content of paging (e.g. paging message or paging indicator) is FFS when using beam sweeping.

9.2.6 Random Access Procedure

The random access procedure is triggered by a number of events, for instance:

- Initial access from RRC_IDLE;
- RRC Connection Re-establishment procedure;
- Handover;
- DL or UL data arrival during RRC_CONNECTED when UL synchronisation status is "non-synchronised";
- Transition from RRC_INACTIVE;
- Request for Other SI (see subclause 7.3).

Furthermore, the random access procedure takes two distinct forms: contention based and non-contention based as shown on Figure 9.2-1 below. Normal DL/UL transmission can take place after the random access procedure.

RAN2 should strive for as much commonality in random access procedure as possible across all use cases.

FFS whether the gNB can be provided with more information (compared to LTE) from the UE on the Msg.3 to provide.

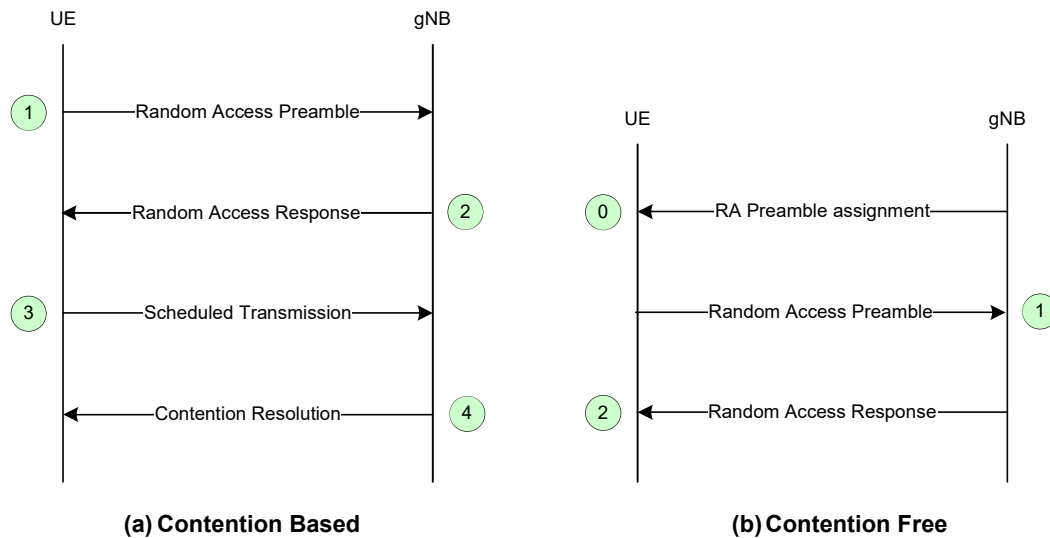


Figure 9.2.5-1: Random Access Procedures

More details can be added like in LTE if required (once agreed).

9.2.7 Radio Link Failure

In RRC_CONNECTED, the UE declares Radio Link Failure (RLF) when one of the following criteria are met:

- Expiry of a timer started after indication of radio problems from the physical layer;
- Random access procedure failure;
- RLC failure.

9.3 Inter RAT

9.3.1 Cell Reselection

Cell reselection is characterised by the following:

- Cell reselection between NR RRC_IDLE and E-UTRA RRC_IDLE is supported;

9.3.2 Handover

Inter RAT mobility is characterised by the following:

- Source RAT should be able to support and configure Target RAT measurement and reporting.

Inter RAT mobility within NG-RAN is characterised further by the following:

- The in-sequence and lossless handover is supported for the handover between RAN nodes of NG-RAN (eNB and gNB).

Inter RAT mobility between 5GC and EPC is characterised further by the following:

- Both Xn and CN handover between E-UTRA connected to 5GC and NR is supported. The target RAT receives the UE NG-C context information and based on this information configures the UE with a complete RRC message and Full configuration (not delta). Whether the handover is over Xn or CN is transparent to the UE.

Support for HO between NR and LTE connected to EPC depends on SA2 decisions and support of NGx with context mapping between 5GC and EPC. If supported, from RAN2 perspective, a “conventional” S1/NG based HO procedure is used where the target RAT receives the UE S1 context information and based on this information configures the UE with a complete RRC message and Full configuration (not delta).

9.3.3 Measurements

To be captured once agreements are made.

9.4 Roaming and Access Restrictions

The description detail needs further check, e.g., whether more restriction information is needed.

The roaming and access restriction information for a UE includes information on restrictions to be applied for subsequent mobility action during CM-CONNECTED state. It may be provided by the AMF and also may be updated by the AMF later.

It includes the forbidden RAT, the forbidden area and the service area restrictions as specified in 3GPP TS 23.501 [3]. It also includes serving PLMN and may include a list of equivalent PLMNs.

Upon receiving the roaming and access restriction information for a UE, if applicable, the gNB should use it to determine whether to apply restriction handling for subsequent mobility action, e.g., handover, redirection.

If the roaming and access restriction information is not available for a UE at the gNB, the gNB shall consider that there is no restriction for subsequent mobility actions.

Only if received over NG or Xn signalling, the roaming and access restriction information shall be propagated over Xn by the source gNB during Xn handover. If the Xn handover results in a change of serving PLMN (to an equivalent PLMN), the source gNB shall replace the serving PLMN with the identity of the target PLMN and move the serving PLMN to the equivalent PLMN list, before propagating the roaming and access restriction information.

SCG selection for DC at the MeNB is based on roaming and access restriction information. If roaming and access restriction information is not available at the MeNB, the MeNB shall consider that there is no restriction for SCG selection.

10 Scheduling

10.1 Basic Scheduler Operation

In order to utilise radio resources efficiently, MAC in gNB includes dynamic resource schedulers that allocate physical layer resources for the downlink and the uplink. In this subclause, an overview of the scheduler is given in terms of scheduler operation, signalling of scheduler decisions, and measurements.

Scheduler Operation:

- Taking into account the UE buffer status and the QoS requirements of each UE and associated radio bearers, schedulers assign resources between UEs;
- Schedulers may assign resources taking account the radio conditions at the UE identified through measurements made at the gNB and/or reported by the UE;
- Schedulers assign radio resources in a unit of TTI (e.g. one mini-slot, one slot, or multiple slots);
- Resource assignment consists of radio resources (resource blocks).

Signalling of Scheduler Decisions:

- UEs identify the resources by receiving a scheduling (resource assignment) channel.

Measurements to Support Scheduler Operation:

- Uplink buffer status reports (measuring the data that is buffered in the logical channel queues in the UE) are used to provide support for QoS-aware packet scheduling.
- The buffer reporting scheme used in uplink is flexible to support different types of data services. Constraints on how often uplink buffer reports are signalled from the limits the overhead from sending the reports in the uplink.

10.2 Downlink Scheduling

In the downlink, the gNB can dynamically allocate resources to UEs at each TTI. A UE always monitors the downlink in order to find possible allocation when its downlink reception is enabled (activity governed by DRX when configured). In addition, NR can periodically allocate semi-persistent downlink resources for the first HARQ transmissions to UEs via RRC.

More details on possible channel names, SPS and retransmission handling can be added if agreed/needed.

10.3 Uplink Scheduling

In the uplink, the gNB can dynamically allocate resources to UEs at each TTI. A UE always monitors the downlink in order to find possible allocation for uplink transmission when its downlink reception is enabled (activity governed by DRX when configured). In addition, NR can periodically allocate semi-persistent uplink resources for the first HARQ transmissions to UEs via RRC but when the UE does not have any data to transmit, it ignores such resources.

More details on possible channel names, SPS and retransmission handling can be added if agreed/needed.

10.4 Measurements to Support Scheduler Operation

Measurement reports are required to enable the scheduler to operate in both uplink and downlink. These include transport volume and measurements of a UEs radio environment.

Uplink buffer status reports (BSR) are needed to provide support for QoS-aware packet scheduling. In NR, uplink buffer status reports refer to the data that is buffered in for a group of logical channel (LCG) in the UE. Four LCGs and two formats are used for reporting in uplink:

- A short format for which only one BSR (of one LCG) is reported;
- A long format for which all four BSRs (of all four LCGs) are reported.

Uplink buffer status reports are transmitted using MAC signalling.

In DC, the BSR configuration, triggering and reporting are independently performed per CG. For split bearers, the PDCP data is considered in BSR in the CG(s) configured by RRC.

LTE baseline captured. Further enhancements at least related to numerologies and granularity to be discussed.

10.5 Rate Control

To be captured once agreements are made.

10.6 Activation/Deactivation Mechanism

LTE Baseline for CA is used here as starting point. Possible changes to accommodate NR to be discussed, for instance initial the state of the SCells.

To enable reasonable UE battery consumption when CA is configured, an activation/deactivation mechanism of Cells is supported. When a Cell is deactivated, the UE does not need to receive the corresponding PDCCH or PDSCH, cannot transmit in the corresponding uplink, nor is it required to perform CQI measurements. Conversely, when a Cell is active, the UE shall receive PDSCH and PDCCH (if the UE is configured to monitor PDCCH from this SCell), and is expected to be able to perform CQI measurements.

At reconfiguration without mobility control information:

- SCells added to the set of serving cells are initially deactivated;
- SCells which remain in the set of serving cells (either unchanged or reconfigured) do not change their activation status (*activated* or *deactivated*).

At reconfiguration with mobility control information (i.e. handover):

- SCells are deactivated.

11 UE Power Saving

The PDCCH monitoring activity of the UE is governed by DRX. When DRX is configured, the UE does not have to continuously monitor PDCCH. DRX is characterized by the following:

- **on-duration**: duration that the UE waits for, after waking up, to receive PDCCHs. If the UE successfully decodes a PDCCH, the UE stays awake and starts the inactivity timer;
- **inactivity-timer**: duration that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH, failing which it can go back to sleep. The UE shall restart the inactivity timer following a single successful decoding of a PDCCH for a first transmission only (i.e. not for retransmissions).
- **retransmission-timer**: duration until a retransmission can be expected.
- **cycle**: specifies the periodic repetition of the on-duration followed by a possible period of inactivity (see figure 11-1 below).

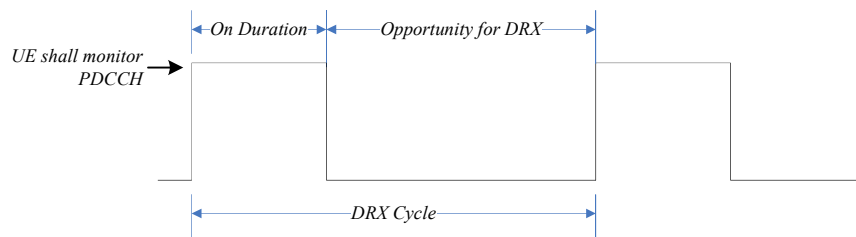


Figure 11-1: DRX Cycle

PDCCH naming needs to be confirmed.

12 QoS

The QoS architecture in NG-RAN is depicted in the Figure 13-1 and described in the following:

- For each UE, 5GC establishes one or more PDU Sessions.
- For each UE, the NG-RAN establishes one or more Data Radio Bearers (DRB) per PDU Session. The NG-RAN maps packets belonging to different PDU sessions to different DRBs. Hence, the NG-RAN establishes at least one default DRB for each PDU Session indicated by 5GC upon PDU Session establishment.
- NAS level packet filters in the UE and in the 5GC associate UL and DL packets with QoS Flows.
- AS-level mapping in the UE and in the NG-RAN associate UL and DL QoS Flows with DRBs.

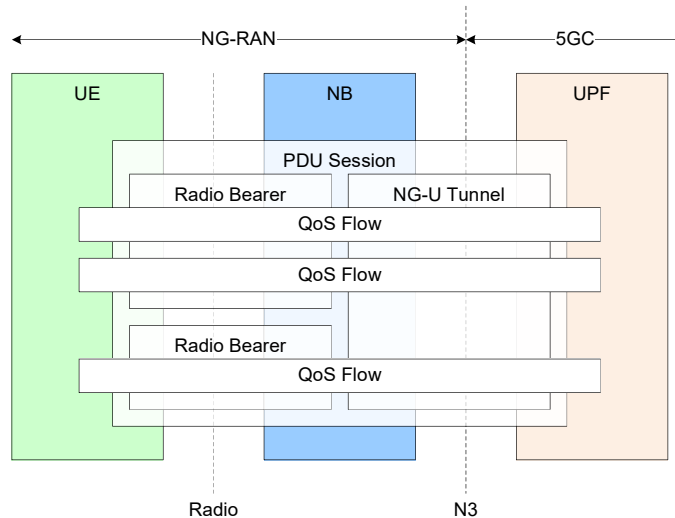


Figure 12-1: QoS architecture

NG-RAN and 5GC ensure quality of service (e.g. reliability and target delay) by mapping packets to appropriate QoS Flows and DRBs. Hence there is a 2-step mapping of IP-flows to QoS flows (NAS) and from QoS flows to DRBs (Access Stratum).

In NG-RAN, the data radio bearer (DRB) defines the packet treatment on the radio interface (Uu). A DRB serves packets with the same packet forwarding treatment. Separate DRBs may be established for QoS flows requiring different packet forwarding treatment. In the downlink, the NG-RAN maps QoS Flows to DRBs based on NG-U marking (QoS Flow ID) and the associated QoS profiles. In the uplink, the UE marks uplink packets over Uu with the QFI for the purposes of marking forwarded packets to the CN.

In the uplink, the NG-RAN may control the mapping of QoS Flows to DRB in two different ways:

- Reflective mapping: for each DRB, the UE monitors the QFI(s) of the downlink packets and applies the same mapping in the uplink; that is, for a DRB, the UE maps the uplink packets belonging to the QoS flows(s) corresponding to the QFI(s) and PDU Session observed in the downlink packets for that DRB. To enable this reflective mapping, the NG-RAN marks downlink packets over Uu with QFI.

It is FFS whether the marking with a QFI can be semi-statically configured (to not include the QoS flow ID when not needed).

- Explicit Configuration: besides the reflective mapping, the NG-RAN may configure by RRC an uplink "QoS Flow to DRB mapping".
- The UE shall always apply the latest update of the mapping rules regardless of whether it is performed via reflecting mapping or explicit signalling.

For each PDU session, a default DRB is configured. If an incoming UL packet matches neither an RRC configured nor a reflective "QoS Flow ID to DRB mapping", the UE shall map that packet to the default DRB of the PDU session.

Within each PDU session, 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, but mechanisms to optimise these cases are not within the scope of standardization. The timing of establishing non-default DRB(s) between NG-RAN and UE for QoS flow configured during establishing a PDU session can be different from the time when the PDU session is established. It is up to NG-RAN when non-default DRBs are established.

In DC, the QoS flows belonging to the same PDU session can be mapped to different bearer types (see subclause 4.5.2) and as a result there can be two different SDAP entities configured for the same PDU session: one for MCG and another one for SCG (for instance when one MCG bearer and one SCG bearer are used for two different QoS flows).

The support for PDU session mapped to different bearers is pending conclusions in SA2 and RAN3.

13 Security

13.1 Overview and Principles

The following principles apply to NG-RAN security, see 3GPP TS 33.501 [5]:

- For user data, ciphering and integrity protection;
- For RRC signalling, ciphering and integrity protection;

NOTE: Ciphering and integrity protections are optionally configured except for RRC signalling for which integrity protection is always configured.

FFS whether possible exceptions are possible (SA3).

- For key management and data handling, any entity processing cleartext shall be protected from physical attacks and located in a secure environment.

13.2 Security Termination Points

The table below describes the security termination points.

Table 13.2-1 Security Termination Points

	Ciphering	Integrity Protection
NAS Signalling	AMF	AMF
RRC Signalling	gNB	gNB
User Plane Data	gNB	gNB

13.3 State Transitions and Mobility

Security key refresh is not performed at every mobility procedure (i.e. handover), at least for the case of mobility where the PDCP anchor point is not changed.

It is to be confirmed by SA3 considering whether it has any implication on the inputs for key derivation, e.g. PCI.

14 Network Interfaces

To be provided by RAN3. Should contain an overview of the network interfaces. Coordination with SA2 expected, but from RAN3 side.

15 Functional Split of the gNB

NG-RAN may support a functional split of the gNB. The architecture and the F1 interface between a gNB-CU and a gNB-DU are defined in TS 38.401 [x].

16 UE Capabilities

Generic UE capability description should be added e.g. split between AS and NAS, enquiry...

The UE capabilities in NR rely on UE categories associated to at least specific peak data rates.

To limit signalling overhead, the gNB can request the UE to provide NR capabilities for a restricted set of band combinations. When responding, the UE can skip a subset of the requested band combinations when the corresponding UE capabilities are the same.

RAN2 aim not to duplicate band combinations to indicate the combination of DL bands and UL bands and RAN2 aim to introduce per UE baseband capabilities separated from the band combinations (e.g. FD-MIMO capabilities, number of CSI processes, etc) and minimise per band combination signalling.

17 Verticals Support

17.1 Self-Configuration and Self-Optimisation

17.1.1 Definitions

Text similar to section 22.1 of 36.300. Needs to be probably revisited

17.1.2 UE Support for self-configuration and self-optimisation

Text similar to section 22.2 of 36.300. Needs to be probably revisited.

17.1.3 Self-configuration

17.1.3.1 Dynamic configuration of the NG-C interface

17.1.3.1.1 Prerequisites

The following prerequisites are assumed:

- An initial remote IP end point to be used for SCTP initialisation is provided to the gNB for each AMF the gNB is supposed to connect to.

How the gNB gets the remote IP end point(s) and its own IP address are outside the scope of this specification.

Further 5GC functions, like provision of further AMF pool information and other concepts that may come from SA2 are FFS.

17.1.3.1.2 SCTP initialization

This is a place holder, text similar to section 22.3.1.2 of 36.300.

17.1.3.1.3 Application layer initialization

Once SCTP connectivity has been established, the gNB and the AMF shall exchange application level configuration data over the NG-C application protocol with the NG Setup Procedure, which is needed for these two nodes to interwork correctly on the NG interface.

- The gNB provides the relevant configuration information to the AMF, which includes list of supported TA(s), etc.
- The AMF provides the relevant configuration information to the gNB, which includes PLMN ID, etc.
- When the application layer initialization is successfully concluded, the dynamic configuration procedure is completed and the NG-C interface is operational.

Text similar to TS 36.300 seems to be sufficient description on that level, further input is FFS.

17.1.3.2 Dynamic Configuration of the Xn interface

17.1.3.2.1 Prerequisites

The following prerequisites are necessary:

- An initial remote IP end point to be used for SCTP initialisation is provided to the gNB.

17.1.3.2.2 SCTP initialization

This is a place holder, text similar to section 22.3.2.2 of TS 36.300.

17.1.3.2.3 Application layer initialization

Once SCTP connectivity has been established, the gNB and its candidate peer gNB are in a position to exchange application level configuration data over the Xn application protocol needed for the two nodes to interwork correctly on the Xn interface.

*Note, that Xn Setup would have to cater for E-UTRA and NR RAT. This may also be expected to be reflected in the definition of the gNB ID. Another aspect is the fact that one cell of a certain RAT may have neighbours from 2 different RATs. Also the current mandate of reporting *all* served cells might need to be revisited. Further details are FFS.*

17.1.3.3 Automatic Neighbour Relation Function

17.1.3.3.1 General

The purpose of the Automatic Neighbour Relation (ANR) function is to relieve the operator from the burden of manually managing Neighbour Relations (NRs).

Further details FFS, text similar to section 22.3.2a of TS 36.300.

17.1.3.3.2 Intra-system – intra NR Automatic Neighbour Relation Function

If PCI concept is inherited by NR (and there is some likelihood that this is the case), probably this chapter can be merged with the intra-E-UTRA chapter. Expected to contain similar text (apart from interface and RAT specific adaptations) section 22.3.3 of TS 36.300.

17.1.3.3.3 Intra-system – intra E-UTRA Automatic Neighbour Relation Function

Expected to contain a text similar as section 22.3.3 of TS 36.300.

17.1.3.3.4 Intra-system – inter RAT Automatic Neighbour Relation Function

This could be a short chapter describing the necessity for UEs to report inter-RAT neighbours within the NG-RAN.

17.1.3.3.5 Inter-system Automatic Neighbour Relation Function

This chapter to show inter-RAT (NR-E-UTRA) and intra-RAT (E-UTRA – E-UTRA) ANR between NG-RAN and E-UTRAN (only).

17.1.3.4 Xn-C TNL address discovery

If the gNB is aware of the gNB ID of the candidate gNB (e.g. via the ANR function) but not of a TNL address suitable for SCTP connectivity, then the gNB can utilize the 5GC (an AMF it is connected to) to help resolving the TNL address.

Text, similar to TS 36.300 is expected.

17.2 IMS Voice

The WID limits the support to IMS voice. To be captured once agreements are made.

17.3 Network Slicing

17.3.1 General Principles and Requirements

In this sub clause, the general principles and requirements related to the realization of network slicing in the NG-RAN are given.

Support of Network Slicing relies on the principle that traffic for different slices is handled by different PDU sessions. Network can realise the different network slices by scheduling and also by providing different L1/L2 configurations. UE should be able to provide assistance information for network slice selection in RRC message, if it has been provided by NAS.

NOTE 1: It is FFS whether it is possible to provide different PRACH, access barring and congestion control information for different slices.

NOTE 2: The above agreements and FFS are also applicable for E-UTRA connected to 5GC.

Network Slicing is a concept to allow differentiated treatment depending on each customer requirements. With slicing, it is possible for Mobile Network Operators (MNO) to consider customers as belonging to different tenant types with each having different service requirements that govern in terms of what slice types each tenant is eligible to use based on Service Level Agreement (SLA) and subscriptions.

NSSAI (Network Slice Selection Assistance Information) includes one or more S-NSSAIs (Single NSSAI). Each network slice is uniquely identified by a S-NSSAI, as defined in TS 23.501 [3].

The following key principles apply for support of Network Slicing in NG-RAN:

RAN awareness of slices

- NG-RAN supports a differentiated handling of traffic for different network slices which have been pre-configured. How NG-RAN supports the slice enabling in terms of NG-RAN functions (i.e. the set of network functions that comprise each slice) is implementation dependent.

Selection of RAN part of the network slice

- NG-RAN supports the selection of the RAN part of the network slice, by assistance information provided by the UE or the 5GC which unambiguously identifies one or more of the pre-configured network slices in the PLMN.

Resource management between slices

- NG-RAN supports policy enforcement between slices as per service level agreements. It should be possible for a single NG-RAN node to support multiple slices. The NG-RAN should be free to apply the best RRM policy for the SLA in place to each supported slice.

Support of QoS

- NG-RAN supports QoS differentiation within a slice.

RAN selection of CN entity

- For initial attach, the UE may provide assistance information to support the selection of an AMF. If available, NG-RAN uses this information for routing the initial NAS to an AMF. If the NG-RAN is unable to select an AMF using this information or the UE does not provide any such information the NG-RAN sends the NAS signalling to a default AMF.
- For subsequent accesses, the UE provides a Temp ID, which is assigned to the UE by the 5GC, to enable the NG-RAN to route the NAS message to the appropriate AMF as long as the Temp ID is valid (NG-RAN is aware of and can reach the AMF which is associated with the Temp ID). Otherwise, the methods for initial attach applies.

Resource isolation between slices

- the NG-RAN supports resource isolation between slices. NG-RAN resource isolation may be achieved by means of RRM policies and protection mechanisms that should avoid that shortage of shared resources in one slice breaks the service level agreement for another slice. It should be possible to fully dedicate NG-RAN resources to a certain slice. How NG-RAN supports resource isolation is implementation dependent.

Slice Availability

- Some slices may be available only in part of the network. Awareness in the NG-RAN of the slices supported in the cells of its neighbours may be beneficial for inter-frequency mobility in connected mode. It is assumed that the slice configuration does not change within the UE's registration area.
- The NG-RAN and the 5GC are responsible to handle a service request for a slice that may or may not be available in a given area. Admission or rejection of access to a slice may depend by factors such as support for the slice, availability of resources, support of the requested service by other slices.

Support for UE associating with multiple network slices simultaneously

- In case a UE is associated with multiple slices simultaneously, only one signalling connection is maintained.

Granularity of slice awareness

- Slice awareness in NG-RAN is introduced at PDU session level, by indicating the S-NSSAI corresponding to the PDU Session, in all signalling containing PDU session resource information.

Validation of the UE rights to access a network slice

- It is the responsibility of the 5GC to validate that the UE has the rights to access a network slice. Prior to receiving the Initial Context Setup Request message, the NG-RAN may be allowed to apply some provisional/local policies, based on awareness of which slice the UE is requesting access to. During the initial context setup, the NG-RAN is informed for all network slices for which resources are being requested.

17.3.2 CN Instance and NW Slice Selection

17.3.2.1 CN-RAN interaction and internal RAN aspects

NG-RAN selects AMF based on a Temp ID or assistance information provided by the UE over RRC. The mechanisms used in the RRC protocol are described in the next sub clause.

Table 17.3.2.1-1 AMF selection based on Temp ID and assistance information

Temp ID	Assistance Info	AMF Selection by NG-RAN
not available or invalid	not available	Default AMF is selected
not available or invalid	present	Selects AMF which supports UE requested slices
valid	not available, or present	Selects AMF per CN identity information in Temp ID

17.3.2.2 Radio Interface Aspects

17.3.3 Resource Isolation and Management

Resource isolation enables specialized customization and avoids one slice affecting another slice.

Hardware/software resource isolation is up to implementation. Each slice may be assigned with either shared or dedicated radio resource up to RRM implementation and SLA.

To enable differentiated handling of traffic for network slices with different SLA:

- NG-RAN is configured with a set of different configurations for different network slices;

- To select the appropriate configuration for the traffic for each network slice, NG-RAN receives relevant information indicating which of the configurations applies for this specific network slice.

17.3.4 Signalling Aspects

It is FFS whether signalling procedures will be kept in this section or moved to other sections describing procedures.

17.3.4.1 General

In this sub clause, signalling flows related to the realization of network slicing in the NG-RAN are given.

17.3.4.2 CN Instance and NW Slice Selection

RAN selects the AMF based on a Temp ID or assistance information provided by the UE.

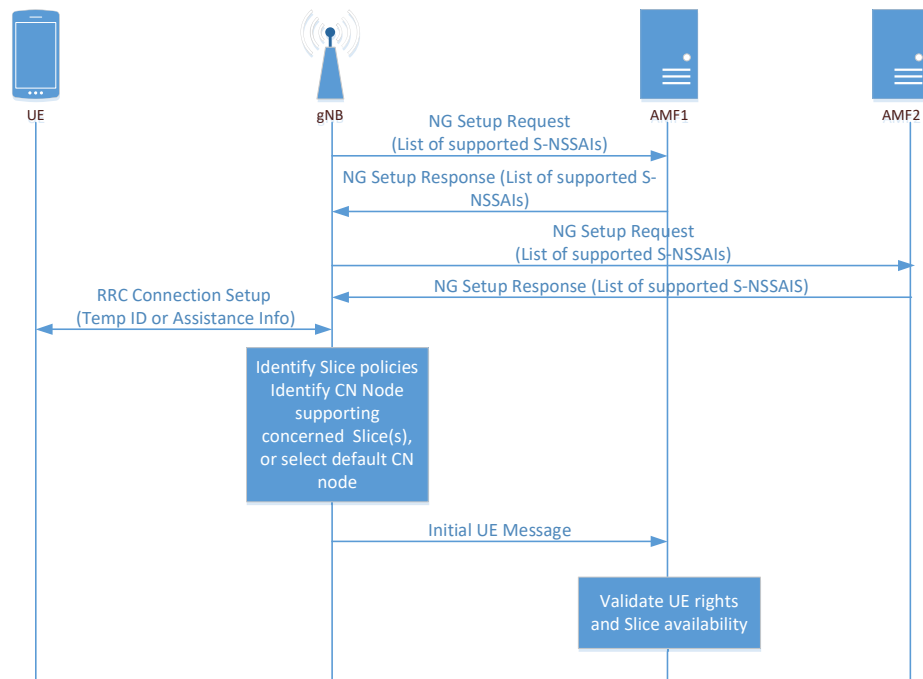


Figure 17.3.4.1-1: AMF instance selection

In case a Temp ID is not available, the RAN uses the assistance information provided by the UE at RRC connection establishment to select the appropriate AMF instance (the information is provided after MSG3 of the random access procedure). If such information is also not available, the RAN routes the UE to a default AMF instance.

The gNB uses the list of supported S-NSSAI(s) previously received in the NG Setup Response message when selecting the AMF with the assistance information. This list may be updated via the AMF Configuration Update message.

17.3.4.3 UE Context Handling

Following the initial access, the establishment of the RRC connection and the selection of the correct AMF, the AMF establishes the complete UE context by sending the Initial Context Setup Request message to the NG-RAN over NG-C. The message contains the S-NSSAI as part of the PDU session/s resource description. Upon successful establishment of the UE context and allocation of PDU resources to the relevant NW slice/s, the NG-RAN responds with the Initial Context Setup Response message.

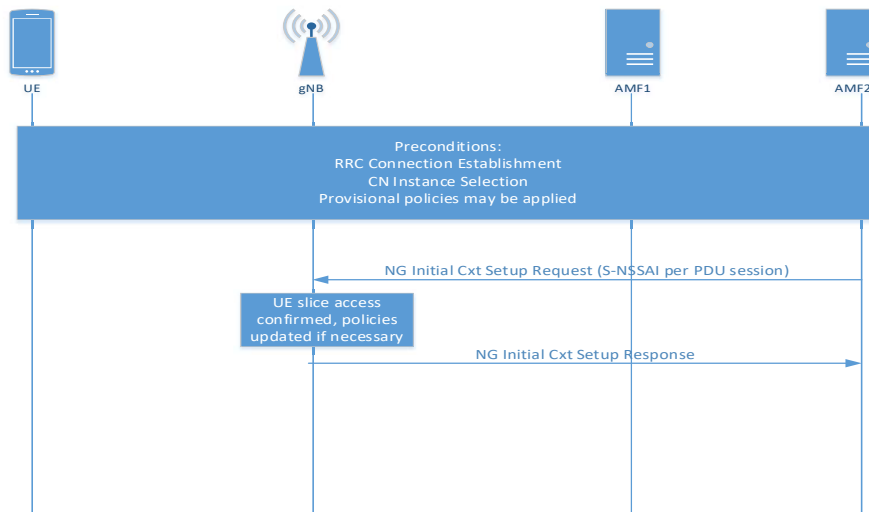


Figure 17.3.4.3-1: Network Slice-aware Initial Context Setup

17.3.4.4 PDU Session Handling

When new PDU sessions need to be established or existing ones modified or released, the 5GC requests the NG-RAN to allocate/release resources relative to the relevant PDU sessions by means of the PDU Session Setup/Modify/Release procedures over NG-C. In case of network slicing, S-NSSAI information is added per PDU session, so NG-RAN is enabled to apply policies at PDU session level according to the SLA represented by the network slice, while still being able to apply (for example) differentiated QoS within the slice.

NG-RAN confirms the establishment/modification/release of a PDU session associated to a certain NW slice by responding with the PDU Session Setup/Modify/Release Response message over the NG-C interface.

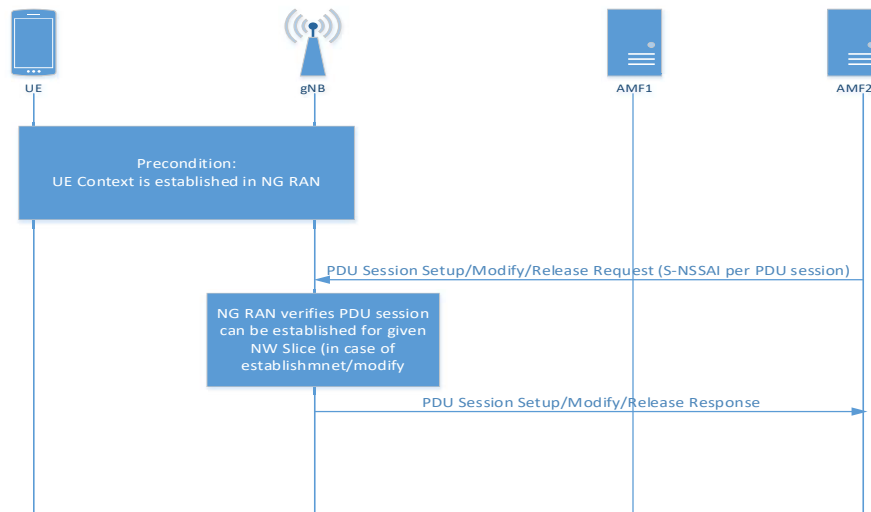


Figure 17.3.4.3-1: Network Slice-aware PDU Session Setup/Modify/Release

17.3.4.5 Mobility

To make mobility slice-aware in case of Network Slicing, S-NSSAI is introduced as part of the PDU session information that is transferred during mobility signalling. This enables slice-aware admission and congestion control.

An example for the case of active mode mobility across different Registration Areas, is shown in Figure 17.3.4.5-1 for the case of 5GC involved handover.

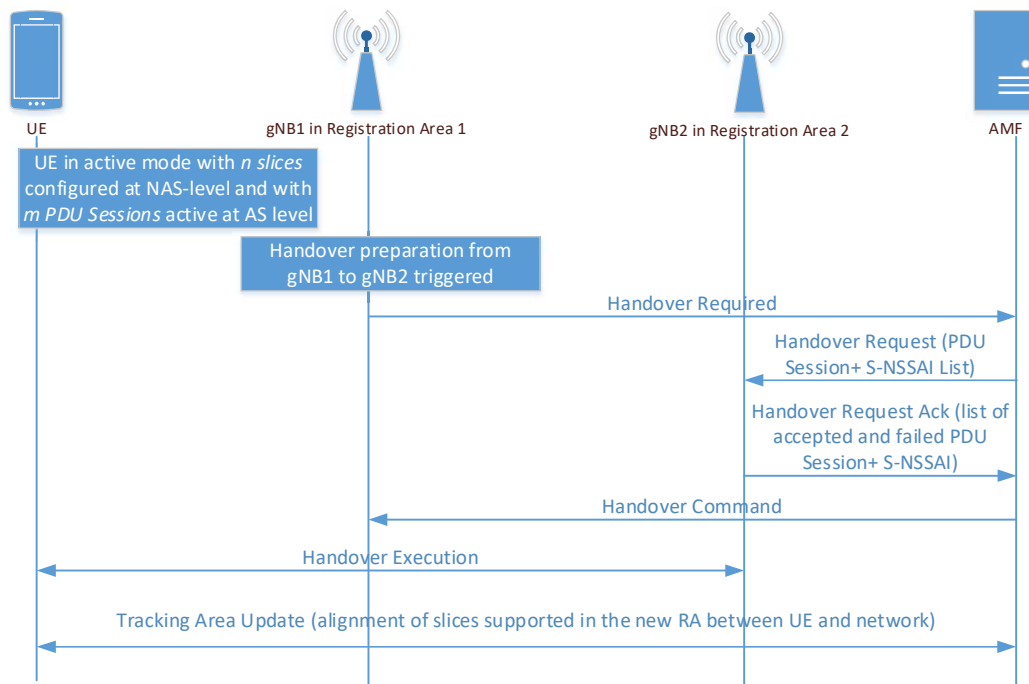


Figure 17.3.4.5-1: Active mode CN involved mobility across different Registration Areas

17.3 PWS

To be captured once agreements are made.

17.4 URLLC

To provide an overview of the mechanisms agreed for URLLC.

Annex A (informative): QoS Handling in RAN

When and if to include the QFI in full or in shortened form and RQI in SDAP is FFS.

All message names and parameters are FFS.

These reflect current status and may need to be updated based on further decisions.

A.1 PDU Session Establishment

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

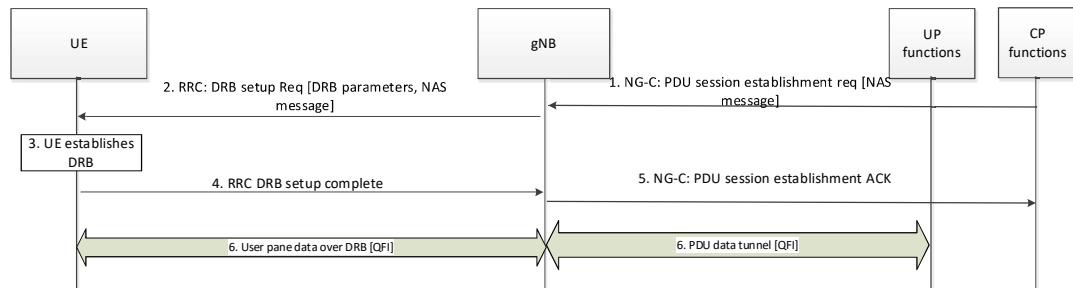


Figure A.1-1: PDU session establishment

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.
FFS whether NAS message is carried in a separate RRC message.
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 a QoS marking (same as or corresponding to QFI) in the SDAP header. UE sends UL packets over the DRB, optionally including a QoS marking. If configured in step 2, UL data packets include a QoS marking (same as or corresponding to QFI) in the SDAP header.

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.

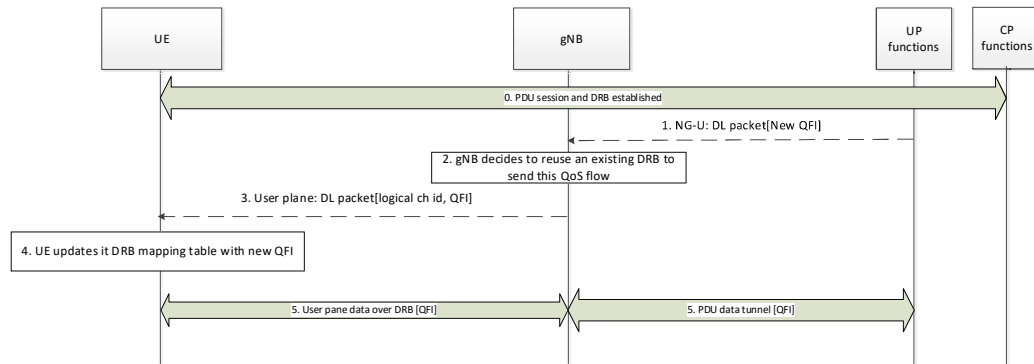


Figure A.2-1: DL data with new QFI sent over existing DRB

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 in the SDAP header.
4. UE identifies the QFI 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.

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.

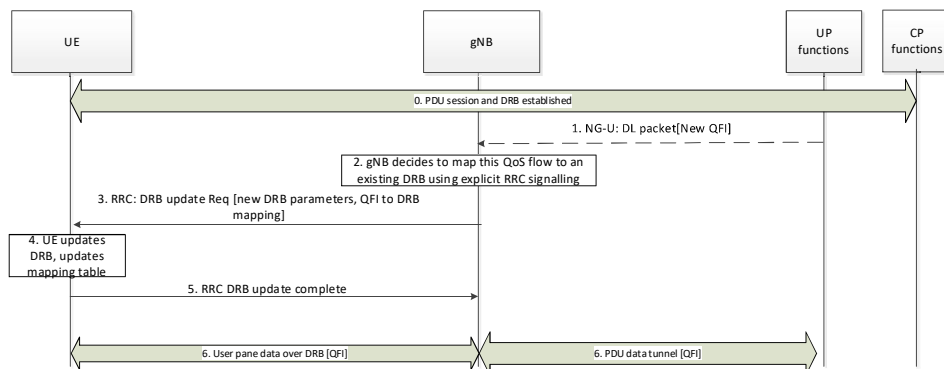


Figure A.3-1: DL data with new QFI sent over existing DRB

0. PDU session and DRB have been already established.

1. gNB receives a downlink packet with new QFI with NAS Reflective QoS 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 up 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.

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.

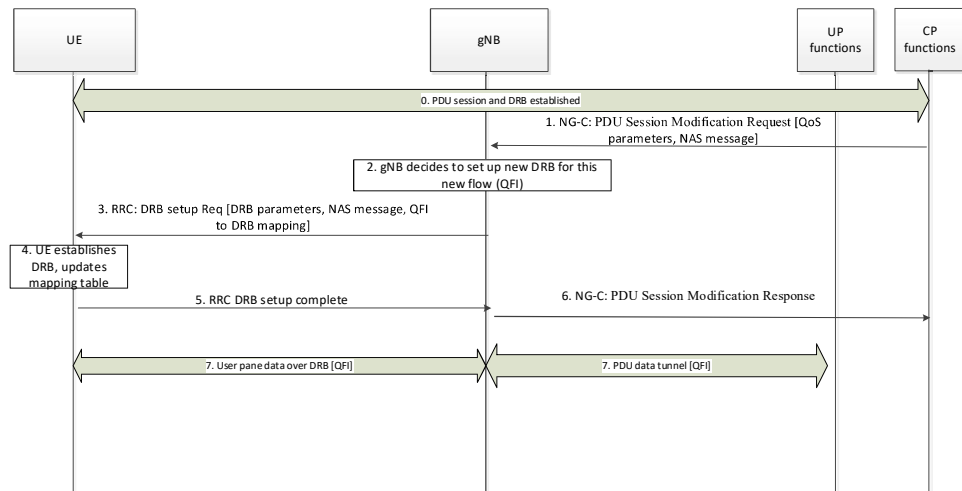


Figure A.4-1: DL data with new QoS Flow ID sent over new DRB with explicit signalling

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.

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.

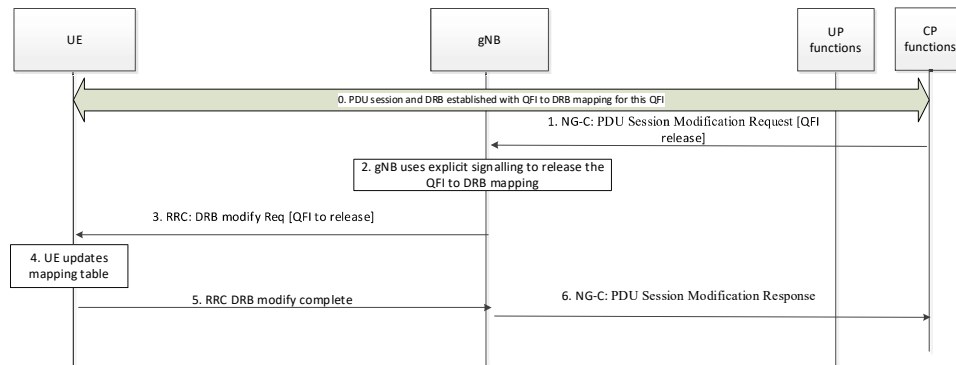


Figure A.5-1: DL data with new QoS Flow ID sent over new DRB with explicit signalling

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.

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.

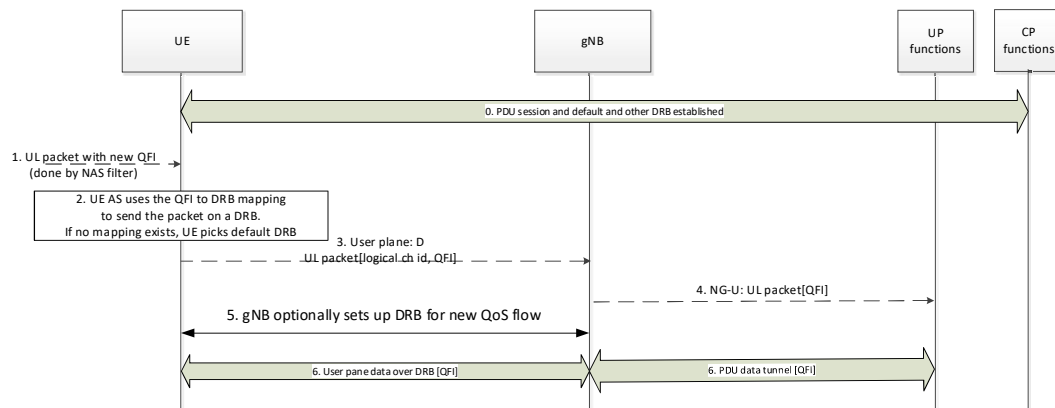


Figure A.6-1: UL packet with a new QoS flow for which a mapping does not exist in UE

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 packet on the default DRB. The UE includes the QFI in the SDAP header if SDAP has been configured for this DRB.
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 X.2-1 and Figure X.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.

Annex Z (informative): Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	Version
2017.03	RAN2 97bis	R2-1702627	-	-	-	First version.	0.1.0
2017.04	RAN2 97bis	R2-1703825	-	-	-	Editorial Updates: - Stage 2 Details of ARQ operation marked as FFS - Placeholder for CU/DU Split overview added - Outdated editor notes removed - Protocol Architecture updated - NG-RAN terminology aligned - Header placement in the L2 overview put as FFS	0.1.1
2017.04	RAN2 97bis	R2-1703952	-	-	-	Editorial Updates: - description of measurements for mobility clarified - some cell reselection details put FFS - outdated references removed	0.1.2
2017.04	RAN2 98	R2-1704296	-	-	-	Editorial updates: - NG interfaces naming aligned to RAN3 - 5GC used consistently - Statement on lossless delivery removed from 9.3.2 - Overview of PDCP function for CP detailed	0.1.3
2017.05	RAN2 98	R2-1704298	-	-	-	Agreements of RAN2#97bis captured: - overview of duplication operation - RLC modes for DRBs and SRBs - Condition for lossless mobility - L2 handling at handover - RLF triggers - Measurement details (filtering, beams, quality...) - QoS flow handling in DC - RACH procedure message usage for on-demand SI - Random Access Procedure triggers - DRX baseline	0.2.0
2017.05	RAN2 98	R2-1704452	-	-	-	RAN3 agreements captured (R3-171329) 5G logo and specification title updated	0.2.1
2017.05	RAN2 98	R2-1705994	-	-	-	RLC failure for RLF generalized.	0.3.0
2017.06	RAN2 98	R2-1706204	-	-	-	Agreements of RAN2#98 captured: - Duplication Control - RLC mode for SRB0 and System Info - Provision of Assistance Info for AMF Selection - QoS Handling from R2-1706011 - Beam measurements combining - MSG1 request details for on-demand SI - RNA and RLAU terminology introduced for INACTIVE - Skipping of SPS resources when nothing to transmit - Duplication detection at RLC only for AM - Provision of access category by NAS for connection control Editorial updates in addition: - QFI used consistently	0.3.1
2017.06	RAN2 98	R2-1706205				RAN3 agreements captured (R3-171932)	0.4.0
2017.06	RAN2 98	R2-1706206				Corrections: - provision of AC in INACTIVE is FFS - agreements on measurement moved from 9.2.1.1 to 9.2.4	0.4.1
2017.06	NR Adhoc 2	R2-1706540				Editorial corrections Agreement on RLC Segmentation captured Duplicated statement in 9.2.1.1. and 7.3 removed	0.5.0
2017.08	RAN2 99	R2-1707748				Agreements of RAN2 NR June Adhoc captured: - TP on Security in R2-1707466 - TP on Measurement Model in R2-1707480 - NCR Acronym addition - Duplication control details - UE capabilities and band combinations - Disabling of PDPC reordering as PDCP function - On-Demand SI and RACH details - Measurement Report Characteristics - Mapping rules update handling - UE Capabilities and Band Combination handling In addition: - ARQ overview aligned with Stage 3 agreements	0.6.0

						- L2 Data Flow aligned with Stage 3 agreements - References updated RAN3 TP incorporated (R3-172610)	

