**3GPP TSG- Meeting #**

**Bengaluru, India, 25 Aug - 29 Aug, 2025**

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| *CR-Form-v12.3* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  |  | **CR** |  | **rev** | **-** | **Current version:** |  |  |
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| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network | **X** | Core Network |  |

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| ***Source to WG:*** |  | | | | | | | | | |
| ***Source to TSG:*** | R2 | | | | | | | | | |
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| ***Work item code:*** |  | | | | |  | ***Date:*** | | |  |
|  |  | | | |  | |  | | |  |
| ***Category:*** | **B** |  | | | | | ***Release:*** | | |  |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)  Rel-20 (Release 20)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | Introduction of Release-19 Network Energy Savings Enhancements. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | This CR introduces Release-19 Network Energy Savings Enhancements for NR in TS 38.300. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | No support for Release-19 Network Energy Savings Enhancements. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 3.1, 3.2, 5.2.4, 5.2.5.5, 7.3.1, 7.3.2, 9.2.1.2, 9.2.5, 9.2.6, 9.2.7, 15.4.2.5, 15.4.2 | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | | **X** |  | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  | **X** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **X** | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

*Start of changes*

# 3 Abbreviations and Definitions

## 3.1 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1], in 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 TR 21.905 [1] and TS 36.300 [2].

5GC 5G Core Network

5GS 5G System

5QI 5G QoS Identifier

A2X Aircraft-to-Everything

A-CSI Aperiodic CSI

AGC Automatic Gain Control

AI Artificial Intelligence

AKA Authentication and Key Agreement

AMBR Aggregate Maximum Bit Rate

AMC Adaptive Modulation and Coding

AMF Access and Mobility Management Function

AR Augmented Reality

ARP Allocation and Retention Priority

ATG Air to Ground

BA Bandwidth Adaptation

BCCH Broadcast Control Channel

BCH Broadcast Channel

BFD Beam Failure Detection

BH Backhaul

BL Bandwidth reduced Low complexity

BPSK Binary Phase Shift Keying

BRID Broadcast Remote Identification

C-RNTI Cell RNTI

CAG Closed Access Group

CAPC Channel Access Priority Class

CBRA Contention Based Random Access

CCE Control Channel Element

CD-SSB Cell Defining SSB

cellDTRX-RNTI Cell Discontinuous Transmission and Reception RNTI

CFR Common Frequency Resource

CFRA Contention Free Random Access

CG Configured Grant

CHO Conditional Handover

CIoT Cellular Internet of Things

CLI Cross Link interference

CMAS Commercial Mobile Alert Service

CORESET Control Resource Set

CP Cyclic Prefix

CPA Conditional PSCell Addition

CPC Conditional PSCell Change

DAA Detect And Avoid

DAG Directed Acyclic Graph

DAPS Dual Active Protocol Stack

DFT Discrete Fourier Transform

DCI Downlink Control Information

DCP DCI with CRC scrambled by PS-RNTI

DCR Direct Communication Request

DL-AoD Downlink Angle-of-Departure

DL-SCH Downlink Shared Channel

DL-TDOA Downlink Time Difference Of Arrival

DMRS Demodulation Reference Signal

DRX Discontinuous Reception

DSR Delay Status Report

DTX Discontinuous Transmission

E-CID Enhanced Cell-ID (positioning method)

EC Energy Cost

EHC Ethernet Header Compression

ePWS enhancements of Public Warning System

ETWS Earthquake and Tsunami Warning System

FS Feature Set

FSA ID Frequency Selection Area Identity

G-CS-RNTI Group Configured Scheduling RNTI

G-RNTI Group RNTI

GFBR Guaranteed Flow Bit Rate

GIN Group ID for Network selection

GNSS Global Navigation Satellite System

GSO Geosynchronous Orbit

H-SFN Hyper System Frame Number

HAPS High Altitude Platform Station

HRNN Human-Readable Network Name

IAB Integrated Access and Backhaul

IFRI Intra Frequency Reselection Indication

I-RNTI Inactive RNTI

INT-RNTI Interruption RNTI

KPAS Korean Public Alarm System

L2 Layer-2

L3 Layer-3

LBT Listen Before Talk

LDPC Low Density Parity Check

LEO Low Earth Orbit

LTM L1/L2 Triggered Mobility

MBS Multicast/Broadcast Services

MCE Measurement Collection Entity

MCCH MBS Control Channel

MDBV Maximum Data Burst Volume

MEO Medium Earth Orbit

MIB Master Information Block

MICO Mobile Initiated Connection Only

MFBR Maximum Flow Bit Rate

ML Machine Learning

MMTEL Multimedia telephony

MNO Mobile Network Operator

MO-SDT Mobile Originated SDT

MP Multi-Path

MPE Maximum Permissible Exposure

MRB MBS Radio Bearer

MT Mobile Termination

MT-SDT Mobile Terminated SDT

MTCH MBS Traffic Channel

MTSI Multimedia Telephony Service for IMS

MU-MIMO Multi User MIMO

Multi-RTT Multi-Round Trip Time

MUSIM Multi-Universal Subscriber Identity Module

N3C Non-3GPP Connection

NB-IoT Narrow Band Internet of Things

NCD-SSB Non Cell Defining SSB

NCGI NR Cell Global Identifier

NCL Neighbour Cell List

NCR Neighbour Cell Relation

NCRT Neighbour Cell Relation Table

NES Network Energy Savings

NGAP NG Application Protocol

NGSO Non-Geosynchronous Orbit

NID Network Identifier

NPN Non-Public Network

NR NR Radio Access

NSAG Network Slice AS Group

NTN Non-Terrestrial Network

OD-SIB1 On-demand SIB1

OD-SSB On-demand SSB

P-MPR Power Management Maximum Power Reduction

P-RNTI Paging RNTI

PCH Paging Channel

PCI Physical Cell Identifier

PDB Packet Delay Budget

PDC Propagation Delay Compensation

PDCCH Physical Downlink Control Channel

PDSCH Physical Downlink Shared Channel

PEI Paging Early Indication

PER Packet Error Rate

PH Paging Hyperframe

PLMN Public Land Mobile Network

PNI-NPN Public Network Integrated NPN

PF Paging Frame

PO Paging Occasion

PQI PC5 5QI

PRACH Physical Random Access Channel

PRB Physical Resource Block

PRG Precoding Resource block Group

PRS Positioning Reference Signal

PS-RNTI Power Saving RNTI

PSDB PDU Set Delay Budget

PSER PDU Set Error Rate

PSI PDU Set Importance

PSIHI PDU Set Integrated Handling Information

PSS Primary Synchronisation Signal

PTM Point to Multipoint

PTP Point to Point

PTW Paging Time Window

PUCCH Physical Uplink Control Channel

PUSCH Physical Uplink Shared Channel

PWS Public Warning System

QAM Quadrature Amplitude Modulation

QFI QoS Flow ID

QMC QoE Measurement Collection

QoE Quality of Experience

QPSK Quadrature Phase Shift Keying

RA Random Access

RA-RNTI Random Access RNTI

RACH Random Access Channel

RANAC RAN-based Notification Area Code

REG Resource Element Group

RIM Remote Interference Management

RLM Radio Link Monitoring

RMSI Remaining Minimum SI

RNA RAN-based Notification Area

RNAU RAN-based Notification Area Update

RNTI Radio Network Temporary Identifier

RQA Reflective QoS Attribute

RQoS Reflective Quality of Service

RS Reference Signal

RSRP Reference Signal Received Power

RSRQ Reference Signal Received Quality

RSSI Received Signal Strength Indicator

RSTD Reference Signal Time Difference

RTT Round Trip Time

RVQoE RAN visible QoE

SCS SubCarrier Spacing

SD Slice Differentiator

SDAP Service Data Adaptation Protocol

SDT Small Data Transmission

SD-RSRP Sidelink Discovery RSRP

SFI-RNTI Slot Format Indication RNTI

SHR Successful Handover Report

SIB System Information Block

SI-RNTI System Information RNTI

SLA Service Level Agreement

SL-PRS Sidelink Positioning Reference Signal

SL-RSRP Sidelink RSRP

SMC Security Mode Command

SMF Session Management Function

SMTC SS/PBCH block Measurement Timing Configuration

S-NSSAI Single Network Slice Selection Assistance Information

SNPN Stand-alone Non-Public Network

SNPN ID Stand-alone Non-Public Network Identity

SpCell Special Cell

SPR Successful PSCell Addition/Change Report

SPS Semi-Persistent Scheduling

SR Scheduling Request

SRAP Sidelink Relay Adaptation Protocol

SRS Sounding Reference Signal

SRVCC Single Radio Voice Call Continuity

SS Synchronization Signal

SSB SS/PBCH block

SSS Secondary Synchronisation Signal

SSSG Search Space Set Group

SST Slice/Service Type

SU-MIMO Single User MIMO

SUL Supplementary Uplink

TA Timing Advance

TB Transport Block

TCE Trace Collection Entity

TNL Transport Network Layer

TPC Transmit Power Control

TRP Transmit/Receive Point

TRS Tracking Reference Signal

TSS Timing Synchronization Status

U2N UE-to-Network

U2U UE-to-UE

UAV Uncrewed Aerial Vehicle

UCI Uplink Control Information

UDC Uplink Data Compression

UDM Unified Data Management

UE-Slice-MBR UE Slice Maximum Bit Rate

UL-AoA Uplink Angles of Arrival

UL-RTOA Uplink Relative Time of Arrival

UL-SCH Uplink Shared Channel

UPF User Plane Function

URLLC Ultra-Reliable and Low Latency Communications

VR Virtual Reality

V2X Vehicle-to-Everything

Xn-C Xn-Control plane

Xn-U Xn-User plane

XnAP Xn Application Protocol

XR eXtended Reality

## 3.2 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1], in 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 TR 21.905 [1] and TS 36.300 [2].

**2Rx XR UE**: two antenna port XR UE as specified in TS 38.101-1 [18].

**A2X communication**: A communication to support A2X services leveraging PC5 reference points. A2X services are realized by various types of A2X applications, i.e. BRID or DAA.

**Aerial UE communication:** functionality enabling Aerial UE function, as defined in 16.18.

**Air to Ground network:** An NG-RAN consisting of ground-based gNBs, which provide cell towers that send signals up to an aircraft's antenna(s) of onboard ATG terminal, with typical vertical altitude of around 10,000m and take-off/landing altitudes down to 3000m.

**BH RLC channel**: an RLC channel between two nodes, which is used to transport backhaul packets**.**

**Boundary IAB-node:** as defined in TS 38.401 [4].

**Broadcast MRB**:A radio bearer configured for MBS broadcast delivery.

**CAG Cell**:a PLMN cell broadcasting at least one Closed Access Group identity.

**CAG Member Cell**:for a UE, a CAG cell broadcasting the identity of the selected PLMN, registered PLMN or equivalent PLMN, and for that PLMN, a CAG identifier belonging to the Allowed CAG list of the UE for that PLMN.

**CAG-only cell**: a CAG cell that is only available for normal service for CAG UEs.

**Cell-Defining SSB**: an SSB with an RMSI associated.

**Child node**: IAB-DU's and IAB-donor-DU's next hop neighbour node; the child node is also an IAB-node.

**Conditional Handover (CHO**): a handover procedure that is executed only when execution condition(s) are met.

**CORESET#0**: the control resource set for at least SIB1 scheduling, can be configured either via MIB or via dedicated RRC signalling.

**DAPS Handover**: a handover procedure that maintains the source gNB connection after reception of RRC message for handover and until releasing the source cell after successful random access to the target gNB.

**Data Burst:** A set of multiple PDUs generated and sent by the application in a short period of time, as defined in TS 23.501 [3].

**Direct Path**: a type of UE-to-Network transmission path, where data is transmitted between a UE and the network without sidelink relaying.

**Downstream**: direction toward child node or UE in IAB-topology.

**Early Data Forwarding**: data forwarding that is initiated before the UE executes the handover.

**Earth-centered, earth-fixed**: a global geodetic reference system for the Earth intended for practical applications of mapping, charting, geopositioning and navigation, as specified in NIMA TR 8350.2 [51].

**eRedCap UE**: a UE with enhanced reduced capabilities as specified in clause 4.2.22.1 in TS 38.306 [11].

**Feeder link**: wireless link between the NTN Gateway and the NTN payload.

**Geosynchronous Orbit**: earth-centered orbit at approximately 35786 kilometres above Earth's surface and synchronised with Earth's rotation. A geostationary orbit is a non-inclined geosynchronous orbit, i.e. in the Earth's equator plane.

**Group ID for Network Selection**: an identifier used during SNPN selection to enhance the likelihood of selecting a preferred SNPN that supports a Default Credentials Server or a Credentials Holder, as specified in TS 23.501 [3].

**gNB**: node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC.

**High Altitude Platform Station**: airborne vehicle embarking the NTN payload placed at an altitude between 8 and 50 km.

**IAB-donor**:gNB that provides network access to UEs via a network of backhaul and access links.

**IAB-donor-CU**: as defined in TS 38.401 [4].

**IAB-donor-DU**:as defined in TS 38.401 [4].

**IAB-DU**: gNB-DU functionality supported by the IAB-node to terminate the NR access interface to UEs and next-hop IAB-nodes, and to terminate the F1 protocol to the gNB-CU functionality, as defined in TS 38.401 [4], on the IAB-donor.

**IAB-MT**: IAB-node function that terminates the Uu interface to the parent node using the procedures and behaviours specified for UEs unless stated otherwise. IAB-MT function used in 38-series of 3GPP Specifications corresponds to IAB-UE function defined in TS 23.501 [3].

**IAB-node**: RAN node that supports NR access links to UEs and NR backhaul links to parent nodes and child nodes. The IAB-node does not support backhauling via LTE.

**IAB topology**: the unison of all IAB-nodes and IAB-donor-DUs whose F1 and/or RRC connections are terminated at the same IAB-donor-CU.

**Indirect Path**: a type of UE-to-Network transmission path, where data is forwarded via a U2N Relay UE between a U2N Remote UE and the network.

**Inter-donor partial migration:** migration of an IAB-MT to a parent node underneath a different IAB-donor-CU while the collocated IAB-DU and its descendant IAB-node(s), if any, are terminated at the initial IAB-donor-CU. The procedure renders the said IAB-node as a boundary IAB-node.

**Intra-system Handover**:handover that does not involve a CN change (EPC or 5GC).

**Inter-system Handover**:handover that involves a CN change (EPC or 5GC).

**Late Data Forwarding**: data forwarding that is initiated after the source NG-RAN node knows that the UE has successfully accessed a target NG-RAN node.

**L1/L2 Triggered Mobility**: a cell switch procedure that the network triggers via MAC CE based on L1 or L3 measurement report.

**Mapped Cell ID**: in NTN, it corresponds to a fixed geographical area.

**MBS Radio Bearer**: A radio bearer configured for MBS delivery.

**Mobile-IAB cell**: a cell of a mobile IAB-DU.

**Mobile IAB-DU**: gNB-DU functionality supported by the mobile IAB-node to terminate the NR access interface to UEs, and to terminate the F1 protocol to the gNB-CU functionality on the IAB-donor, as defined in TS 38.401 [4].

**Mobile IAB-DU migration**: procedure for a mobile IAB-node as defined in TS 38.401 [4].

**Mobile IAB-MT**: mobile IAB-node function that terminates the Uu interface to the parent node using the procedures and behaviours specified for UEs unless stated otherwise.

**Mobile IAB-MT migration**: procedure for a mobile IAB-MT as defined in TS 38.401 [4].

**Mobile IAB-node**: RAN node that supports NR access links to UEs and an NR backhaul link to a parent node, and that can conduct physical mobility across the RAN area. The mobile IAB-node function used in 38-series of 3GPP Specifications corresponds to the MBSR function defined in TS 23.501 [3].

**MP Relay UE**: a UE that provides functionality to support connectivity to the network for MP Remote UE(s).

**MP Remote UE**: a UE that communicates with the network via a direct Uu link and a MP Relay UE.

**MSG1**: preamble transmission of the random access procedure for 4-step random access (RA) type.

**MSG3**: first scheduled transmission of the random access procedure.

**MSGA**:preamble and payload transmissions of the random access procedure for 2-step RA type.

**MSGB**:response to MSGA in the 2-step random access procedure. MSGB may consist of response(s) for contention resolution, fallback indication(s), and backoff indication.

**Multicast/Broadcast Service**: A point-to-multipoint service as defined in TS 23.247 [45].

**Multicast MRB**:A radio bearer configured for MBS multicast delivery.

**Multi-hop backhauling**: using a chain of NR backhaul links between an IAB-node and an IAB-donor.

**NCR-Fwd**: Network-Controlled Repeater node function, which performs amplifying-and-forwarding of UL/DL RF signals between gNB and UE. The behaviour of the NCR-Fwd is controlled according to the side control information received by the NCR-MT from a gNB.

**NCR-Fwd access link**: link used for transmissions between the NCR-Fwd and UEs.

**NCR-Fwd backhaul link**: link used for backhauling between the NCR-Fwd and gNB.

**NCR-MT**: NCR-node entity which communicates with a gNB via a control link to receive side control information. The control link is based on NR Uu interface.

**NCR-node**: RAN node comprising NCR-MT and NCR-Fwd.

**ng-eNB**: node providing E-UTRA user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC.

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

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

**NG-RAN node**: either a gNB or an ng-eNB.

**Non-CAG Cell**: a PLMN cell which does not broadcast any Closed Access Group identity.

**Non-Cell Defining SSB**: an SSB without an RMSI associated.

**Non-Geosynchronous orbit**: earth-centered orbit with an orbital period that does not match Earth's rotation on its axis. This includes Low and Medium Earth Orbit (LEO and MEO). LEO operates at altitudes between 300 km and 1500 km and MEO at altitudes between 7000 km and 25000 km, approximately.

**Non-terrestrial network**: an NG-RAN consisting of gNBs, which provide non-terrestrial NR access to UEs by means of an NTN payload embarked on an airborne or space-borne NTN vehicle and an NTN Gateway.

**NR backhaul link**: NR link used for backhauling between an IAB-node and an IAB-donor, and between IAB-nodes in case of a multi-hop backhauling.

**NR sidelink communication**: AS functionality enabling at least V2X communication as defined in TS 23.287 [40] and/or A2X communication as defined in TS 23.256 [60] and/or the ProSe communication (including ProSe non-Relay and UE-to-Network Relay communication) as defined in TS 23.304 [48], between two or more nearby UEs, using NR technology but not traversing any network node.

**NR sidelink discovery**: AS functionality enabling ProSe non-Relay Discovery and ProSe UE-to-Network Relay discovery for Proximity based Services as defined in TS 23.304 [48] between two or more nearby UEs, using NR technology but not traversing any network node.

**NTN Gateway**: an earth station located at the surface of the earth, providing connectivity to the NTN payload using the feeder link. An NTN Gateway is a TNL node.

**NTN payload**: a network node, embarked on board a satellite or high altitude platform station, providing connectivity functions, between the service link and the feeder link. In the current version of this specification, the NTN payload is a TNL node.

**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.

**Parent node**: IAB-MT's or mobile IAB-MT's next hop neighbour node; the parent node can be an IAB-node or IAB-donor-DU

**PC5 Relay RLC channel**: an RLC channel between L2 U2N Remote UE and L2 U2N Relay UE, or between L2 U2U Remote UE and L2 U2U Relay UE, which is used to transport packets over PC5 for L2 UE-to-Network/UE-to-UE Relay**.**

**PDU Set**: one or more PDUs carrying the payload of one unit of information generated at the application level (e.g. frame(s) or video slice(s) for XR Services), as defined in TS 23.501 [3].

**PLMN Cell**: a cell of the PLMN.

**RACH-less LTM**: an LTM cell switch procedure where UE skips the random access procedure.

**RedCap UE**: a UE with reduced capabilities as specified in clause 4.2.21.1 in TS 38.306 [11].

**Relay discovery**: AS functionality enabling 5G ProSe UE-to-Network Relay Discovery as defined in TS 23.304 [48], using NR technology but not traversing any network node.

**Satellite**:a space-borne vehicle orbiting the Earth embarking the NTN payload.

**Service link**:wireless link between the NTN payload and UE.

**Sidelink Discovery RSRP:** RSRP measurements on PC5 link related to NR sidelink discovery.

**Sidelink RSRP:** RSRP measurements on PC5 link related to NR sidelink communication.

**SNPN Access Mode**: mode of operation whereby a UE only accesses SNPNs.

**SNPN-only cell**: a cell that is only available for normal service for SNPN subscribers.

**SNPN Identity**: the identity of Stand-alone NPN defined by the pair (PLMN ID, NID).

**Special Cell:** For Dual Connectivity operation the term Special Cell refers to the PCell of the MCG or the PSCell of the SCG, otherwise, in case of NR Standalone, the term Special Cell refers to the PCell.

**Transmit/Receive Point**:part of the gNB transmitting and receiving radio signals to/from UE according to physical layer properties and parameters inherent to that element.

**U2N Relay UE**: a UE that provides functionality to support connectivity to the network for U2N Remote UE(s).

**U2N Remote UE**: a UE that communicates with the network via a U2N Relay UE.

**U2U Relay UE**: a UE that provides functionality to support connectivity between two U2U Remote UEs.

**U2U Remote UE**: a UE that communicates with other UE(s) via a U2U Relay UE.

**Upstream**: direction toward parent node in IAB-topology.

**Uu Relay RLC channel**: an RLC channel between L2 U2N Relay UE or MP Relay UE and gNB, which is used to transport packets over Uu for L2 UE-to-Network Relay or for indirect path in case of MP.

**V2X sidelink communication**: AS functionality enabling V2X communication as defined in TS 23.285 [41], between nearby UEs, using E-UTRA technology but not traversing any network node.

**Xn**: network interface between NG-RAN nodes.

*Unchanged Text is omitted*

### 5.2.4 Synchronization signal and PBCH block

The Synchronization Signal and PBCH block (SSB) consists of primary and secondary synchronization signals (PSS, SSS), each occupying 1 symbol and 127 subcarriers, and PBCH spanning across 3 OFDM symbols and 240 subcarriers, but on one symbol leaving an unused part in the middle for SSS as show in Figure 5.2.4-1. For the 3 MHz channel bandwidth, the PBCH is further equally punctured from both edges to span 144 subcarriers. The possible time locations of SSBs within a half-frame are determined by sub-carrier spacing and the periodicity of the half-frames where SSBs are transmitted is configured by the network. During a half-frame, different SSBs may be transmitted in different spatial directions (i.e. using different beams, spanning the coverage area of a cell).

Within the frequency span of a carrier, multiple SSBs can be transmitted. The PCIs of SSBs transmitted in different frequency locations do not have to be unique, i.e. different SSBs in the frequency domain can have different PCIs. However, when an SSB is associated with an RMSI, the SSB is referred to as a Cell-Defining SSB (CD-SSB). A PCell is always associated to a CD-SSB located on the synchronization raster.

When an SSB is not associated with an RMSI, the SSB is referred to as a non-Cell Defining SSB (NCD-SSB), which can be used to perform RLM, BFD, and RRM measurements and measurements for RA resource selection inside the active DL BWP when the active BWP does not contain the CD-SSB. A UE may be configured with multiple SSBs provided that each BWP is configured with at most one SSB (CD-SSB or NCD-SSB).



Figure 5.2.4-1: Time-frequency structure of SSB

Polar coding is used for PBCH.

The UE may assume a band-specific sub-carrier spacing for the SSB unless a network has configured the UE to assume a different sub-carrier spacing.

PBCH symbols carry its own frequency-multiplexed DMRS.

QPSK modulation is used for PBCH.

The PBCH physical layer model is described in TS 38.202 [20].

### 5.2.5 Physical layer procedures

#### 5.2.5.1 Link adaptation

Link adaptation (AMC: adaptive modulation and coding) with various modulation schemes and channel coding rates is applied to the PDSCH. The same coding and modulation is applied to all groups of resource blocks belonging to the same L2 PDU scheduled to one user within one transmission duration and within a MIMO codeword.

For channel state estimation purposes, the UE may be configured to measure CSI-RS and estimate the downlink channel state based on the CSI-RS measurements. The UE feeds the estimated channel state back to the gNB to be used in link adaptation.

#### 5.2.5.2 Power Control

Downlink power control can be used.

#### 5.2.5.3 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the Cell ID of that cell. NR cell search is based on the primary and secondary synchronization signals, and PBCH DMRS, located on the synchronization raster.

#### 5.2.5.4 HARQ

Asynchronous Incremental Redundancy Hybrid ARQ is supported. The gNB provides the UE with the HARQ-ACK feedback timing either dynamically in the DCI or semi-statically in an RRC configuration. Retransmission of HARQ-ACK feedback is supported by using enhanced dynamic codebook and/or one-shot triggering of HARQ-ACK transmission for (i) all configured CCs and HARQ processes in the PUCCH group, (ii) a configured subset of CCs and/or HARQ processes in the PUCCH group, or (iii) a dynamically indicated HARQ-ACK feedback instance. For HARQ-ACK of SPS PDSCH without associated PDCCH, in case of HARQ-ACK dropping due to TDD specific collisions, the HARQ-ACK feedback can be deferred to a next available PUCCH transmission occasion.

The UE may be configured to receive code block group based transmissions where retransmissions may be scheduled to carry a sub-set of all the code blocks of a TB.

#### 5.2.5.5 Reception of SIB1

The Master Information Block (MIB) on PBCH provides the UE with parameters (e.g. CORESET#0 configuration) for monitoring of PDCCH for scheduling PDSCH that carries the System Information Block 1 (SIB1). PBCH may also indicate that there is no associated SIB1, in which case the UE may be pointed to another frequency from where to search for an SSB that is associated with a SIB1 as well as a frequency range where the UE may assume no SSB associated with SIB1 is present. The indicated frequency range is confined within a contiguous spectrum allocation of the same operator in which SSB is detected. MIB on PBCH may also indicate that SIB1 is not being broadcast, in which case the UE may transmit OD-SIB1 request if it has a valid OD-SIB1 request configuration for this cell as described in 15.4.2.x2.

### 5.2.6 Downlink Reference Signals and Measurements for Positioning

The DL Positioning Reference Signals (DL PRS) are defined to facilitate support of different positioning methods such as DL-TDOA, DL-AoD, multi-RTT through the following set of UE measurements DL RSTD, DL PRS-RSRP/DL PRS-RSRPP, and UE Rx-Tx time difference respectively as described in TS 38.305 [42]. The DL PRS also facilitates Carrier Phase Positioning measurements such as DL-RSCP and DL-RSCPD as described in TS 38.305 [42].

Besides DL PRS signals, UE can use SSB and CSI-RS for RRM (RSRP and RSRQ) measurements for E-CID type of positioning.

*Unchanged Text is omitted*

# 7 RRC

## 7.1 Services and Functions

The main services and functions of the RRC sublayer over the Uu interface 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.

The sidelink specific services and functions of the RRC sublayer over the Uu interface include:

- Configuration of sidelink resource allocation via system information or dedicated signalling;

- Reporting of UE sidelink information;

- Measurement configuration and reporting related to sidelink;

- Reporting of UE assistance information for SL traffic pattern(s).

## 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 for mobile terminated data is initiated by 5GC;

- Transfer of MBS broadcast data to the UE over MRB(s);

- DRX for CN paging configured by NAS.

- **RRC\_INACTIVE**:

- PLMN selection;

- Broadcast of system information;

- Cell re-selection mobility;

- Paging is initiated by NG-RAN (RAN paging);

- RAN-based notification area (RNA) is managed by NG- RAN;

- DRX for RAN paging configured by NG-RAN;

- 5GC - NG-RAN connection (both C/U-planes) is established for UE;

- The UE Inactive AS context is stored in NG-RAN and the UE;

- NG-RAN knows the RNA which the UE belongs to;

- Transfer of MBS multicast/broadcast data to the UE over MRB(s);

- Transfer of unicast data and/or signalling to/from the UE over radio bearers configured for SDT.

- **RRC\_CONNECTED**:

- 5GC - NG-RAN connection (both C/U-planes) is established for UE;

- The UE AS context is stored in NG-RAN and the UE;

- NG-RAN knows the cell which the UE belongs to;

- Transfer of unicast data to/from the UE;

- Transfer of MBS multicast/broadcast data to the UE over MRB(s);

- Network controlled mobility including measurements.

## 7.3 System Information Handling

### 7.3.1 Overview

System Information (SI) consists of a MIB and a number of SIBs, which are divided into Minimum SI and Other SI:

- **Minimum SI** comprises basic information required for initial access and information for acquiring any other SI. Minimum SI consists of:

- *MIB* contains cell barred status information and essential physical layer information of the cell required to receive further system information, e.g. CORESET#0 configuration. *MIB* is periodically broadcast on BCH.

- *SIB1* defines the scheduling of other system information blocks and contains information required for initial access. SIB1 is also referred to as Remaining Minimum SI (RMSI) and can either be periodically broadcast on DL-SCH, sent in a dedicated manner on DL-SCH to UEs in RRC\_CONNECTED, or broadcast on-demand upon OD-SIB1 request from UEs in RRC\_IDLE, RRC\_INACTIVE or RRC\_CONNECTED state when T311 is running if a UE and cell support OD-SIB1 as described in 15.4.2.x2.

- **Other SI** encompasses all SIBs not broadcast in the Minimum SI. Those SIBs can either be periodically broadcast on DL-SCH, broadcast on-demand on DL-SCH (i.e. upon request from UEs in RRC\_IDLE, RRC\_INACTIVE, or RRC\_CONNECTED), or sent in a dedicated manner on DL-SCH to UEs in RRC\_CONNECTED (i.e., upon request, if configured by the network, from UEs in RRC\_CONNECTED or when the UE has an active BWP with no common search space configured or when the UE configured with inter cell beam management is receiving DL-SCH from a TRP with PCI different from serving cell's PCI). Other SI consists of:

- *SIB2* contains cell re-selection information, mainly related to the serving cell;

- *SIB3* contains information about the serving frequency and intra-frequency neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SIB4* contains information about other NR frequencies and inter-frequency neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters), which can also be used for NR idle/inactive measurements;

- *SIB5* contains information about E-UTRA frequencies and E-UTRA neighbouring cells relevant for cell re-selection (including cell re-selection parameters common for a frequency as well as cell specific re-selection parameters);

- *SIB6* contains an ETWS primary notification;

- *SIB7* contains an ETWS secondary notification;

- *SIB8* contains a CMAS warning notification;

- *SIB9* contains information related to GPS time and Coordinated Universal Time (UTC);

- *SIB10* contains the Human-Readable Network Names (HRNN) of the NPNs listed in SIB1;

- *SIB11* contains information related to idle/inactive measurements;

- *SIB15* contains information related to disaster roaming;

*- SIB16* contains slice-based cell reselection information;

- *SIB17* and *SIB17bis* contain information related to TRS configuration for UEs in RRC\_IDLE/RRC\_INACTIVE;

- *SIBpos* contains positioning assistance data as defined in TS 37.355 [43] and TS 38.331 [12];

- *SIB18* contains information related to the Group IDs for Network selection (GINs) associated with SNPNs listed in SIB1.

*- SIB19* in TN contains NTN-specific parameters for NTN neighbour cells as defined in TS 38.331 [12].

*- SIBxx* contains OD-SIB1 request configurations of serving and neighbour cells which support OD-SIB1 as defined in TS 38.331 [12].

For sidelink, Other SI also includes:

- *SIB12* contains information related to NR sidelink communication, ranging and sidelink positioning;

- *SIB13* contains information related to *SystemInformationBlockType21* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.28 [29];

- *SIB14* contains information related to *SystemInformationBlockType26* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.33 [29];

- *SIB23* contains information related to ranging and sidelink positioning.

For non-terrestrial network, Other SI also includes:

- *SIB19* contains NTN-specific parameters for serving cell and optionally NTN-specific parameters for neighbour cells as defined in TS 38.331 [12].

- *SIB25* contains TN coverage information as defined in TS 38.331 [12].

For MBS broadcast, Other SI also includes:

- *SIB20* contains MCCH configuration;

- *SIB21* contains information related to service continuity for MBS broadcast reception.

For MBS multicast reception in RRC\_INACTIVE state, Other SI also includes:

- *SIB24* contains the information required to acquire the multicast MCCH/MTCH configuration as defined in TS 38.331 [12].

For ATG network, Other SI also includes:

- *SIB22* contains ATG-specific parameters for serving cell and optionally ATG-specific parameters for neighbour cells as defined in TS 38.331 [12].

Figure 7.3.1-1 below summarises System Information provisioning.



Figure 7.3.1-1: System Information Provisioning

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, the UE shall consider that cell as barred.

In case of BA, the UE only acquires SI on the active BWP.

If the UE is configured with inter cell beam management:

- the UE is not required to acquire the SI from the serving cell while it is receiving DL-SCH from a TRP with PCI different from serving cell's PCI.

### 7.3.2 Scheduling

The MIB is mapped on the BCCH and carried on BCH while all other SI messages are mapped on the BCCH, where they are dynamically carried on DL-SCH. The scheduling of SI messages part of Other SI is indicated by *SIB1*.

For UEs in RRC\_IDLE and RRC\_INACTIVE while SDT procedure is not ongoing (see clause 18), a request for Other SI triggers a random access procedure (see clause 9.2.6) where MSG3 includes the SI request message unless the requested SI is associated to a subset of the PRACH resources, in which case MSG1 is used for indication of the requested Other SI. When MSG1 is used, the minimum granularity of the request is one SI message (i.e. a set of SIBs), one RACH preamble and/or PRACH resource 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. For UEs in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED when T311 is running, a request for OD-SIB1 triggers a random access procedure, in which case MSG1 is used for indicating OD-SIB1 request and the gNB acknowledges the request in MSG2.

For UEs in RRC\_CONNECTED, a request for Other SI may be sent to the network, if configured by the network, in a dedicated manner (i.e., via UL-DCCH) and the granularity of the request is one SIB. The gNB may respond with an *RRCReconfiguration* including the requested SIB(s). It is a network choice to decide which requested SIBs are delivered in a dedicated or broadcasted manner.

The Other SI may be broadcast at a configurable periodicity and for a certain duration. The Other SI may also be broadcast when it is requested by UE in RRC\_IDLE/RRC\_INACTIVE/RRC\_CONNECTED.

For a UE to be allowed to camp on a cell it must have acquired the contents of the Minimum SI from that cell. There may be cells in the system that do not broadcast the Minimum SI and where the UE therefore cannot camp.

### 7.3.3 SI Modification

Change of system information (other than for ETWS/CMAS, see clause 16.4) only occurs at specific radio frames, i.e. the concept of a modification period is used. System information may be transmitted a number of times with the same content within a modification period, as defined by its scheduling. The modification period is configured by system information.

When the network changes (some of the) system information, it first notifies the UEs about this change, i.e. this may be done throughout a modification period. In the next modification period, the network transmits the updated system information. Upon receiving a change notification, the UE acquires the new system information from the start of the next modification period. The UE applies the previously acquired system information until the UE acquires the new system information.

*Unchanged Text is omitted*

# 9 Mobility and State Transitions

## 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 four measurement types:

- Intra-frequency NR measurements;

- Inter-frequency NR measurements;

- Inter-RAT measurements for E-UTRA;

- Inter-RAT measurements for UTRA.

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 used as well 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.

Handover can be performed within the same RAT and/or CN, or it can involve a change of the RAT and/or CN.

Inter system fallback towards E-UTRAN is performed when 5GC does not support emergency services, voice services, for load balancing etc. Depending on factors such as CN interface availability, network configuration and radio conditions, the fallback procedure results in either RRC\_CONNECTED state mobility (handover procedure) or RRC\_IDLE state mobility (redirection), see TS 23.501 [3] and TS 38.331 [12].

SRVCC from 5G to UTRAN, if supported by both the UE and the network, may be performed to handover a UE with an ongoing voice call from NR to UTRAN. The overall procedure is described in TS 23.216 [34]. See also TS 38.331 [12] and TS 38.413 [26].

In the NG-C signalling procedure, the AMF based on support for emergency services, voice service, any other services or for load balancing etc, may indicate the target CN type as EPC or 5GC to the gNB node. When the target CN type is received by gNB, the target CN type is also conveyed to the UE in *RRCRelease* Message.

Inter-gNB CSI-RS based mobility, i.e. handover, is supported between two neighbour gNBs by enabling that neighbour gNBs can exchange and forward their own CSI-RS configurations and on/off status.

## 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;

- Cell selection is always based on CD-SSBs located on the synchronization raster (see clause 5.2.4):

- The UE searches the NR frequency bands and for each carrier frequency identifies the strongest cell as per the CD-SSB. It then 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.

- The IAB-MT and NCR-MT apply the cell selection procedure as described for the UE with the following differences:

- The IAB-MT and NCR-MT ignore cell-barring or cell-reservation indications contained in cell system information broadcast;

- The IAB-MT only considers a cell as a candidate for cell selection if the cell system information broadcast indicates IAB support for the selected PLMN or the selected SNPN, and the NCR-MT only considers a cell as a candidate for cell selection if the cell system information broadcast indicates Network-Controlled Repeater support.

- The mobile IAB-MT applies the cell selection procedure as described for the IAB-MT with the following differences:

- The mobile IAB-MT only considers a cell as a candidate cell for cell selection if the cell system information broadcast indicates mobile IAB support.

Transition to RRC\_IDLE:

On transition from RRC\_CONNECTED or RRC\_INACTIVE to RRC\_IDLE, a UE should camp on a cell as result of cell selection according to the frequency be assigned by RRC in the state transition message if any.

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 clause 9.2.4).

#### 9.2.1.2 Cell Reselection

A UE in RRC\_IDLE performs cell reselection. The principles of the procedure are the following:

- Cell reselection is always based on CD-SSBs located on the synchronization raster (see clause 5.2.4).

- 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;

- A Neighbour Cell List (NCL) can be provided by the serving cell to handle specific cases for intra- and inter-frequency neighbouring cells;

- Exclude-lists can be provided to prevent the UE from reselecting to specific intra- and inter-frequency neighbouring cells;

- Allow-lists can be provided to request the UE to reselect to only specific intra- and inter-frequency neighbouring cells;

- Cell reselection can be speed dependent;

- Service specific prioritisation;

- Slice-based cell reselection information can be provided to facilitate the UE to reselect a cell that supports specific slices.

#### In multi-beam operations, the cell quality is derived amongst the beams corresponding to the same cell (see clause 9.2.4).9.2.1.3 State Transitions

The following figure describes the UE triggered transition from RRC\_IDLE to RRC\_CONNECTED (for the NAS part, see TS 23.502 [22]):



Figure 9.2.1.3-1: UE triggered transition from RRC\_IDLE to RRC\_CONNECTED

1. The UE requests to setup a new connection from RRC\_IDLE.

2/2a. The gNB completes the RRC setup procedure.

NOTE: The scenario where the gNB rejects the request is described below.

3. The first NAS message from the UE, piggybacked in *RRCSetupComplete*, is sent to AMF.

4/4a/5/5a. Additional NAS messages may be exchanged between UE and AMF, see TS 23.502 [22].

6. The AMF prepares the UE context data (including PDU session context, the Security Key, UE Radio Capability and UE Security Capabilities, etc.) and sends it to the gNB.

7/7a. The gNB activates the AS security with the UE.

8/8a. The gNB performs the reconfiguration to setup SRB2 and DRBs for UE, or SRB2 and optionally DRBs for IAB-MT.

9. The gNB informs the AMF that the setup procedure is completed.

NOTE 1: RRC messages in step 1 and 2 use SRB0, all the subsequent messages use SRB1. Messages in steps 7/7a are integrity protected. From step 8 on, all the messages are integrity protected and ciphered.

NOTE 2: For signalling only connection, step 8 is skipped since SRB2 and DRBs are not setup.

The following figure describes the rejection from the network when the UE attempts to setup a connection from RRC\_IDLE:



Figure 9.2.1.3-2: Rejection of UE triggered transition from RRC\_IDLE

1. UE attempts to setup a new connection from RRC\_IDLE.

2. The gNB is not able to handle the procedure, for instance due to congestion.

3. The gNB sends *RRCReject* (with a wait time) to keep the UE in RRC\_IDLE.

### 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 gNB node keeps the UE context and the UE-associated NG connection with the serving AMF and UPF.

For a UE in RRC\_INACTIVE with eDRX cycle longer than 10.24 seconds, the NG-RAN node may, based on implementation, send a request to the AMF to perform MT Communication Handling as described in TS 23.501 [3]. If the UE accesses a gNB other than the last serving gNB and upon successful UE context retrieval, the AMF considers that the UE is reachable (i.e., the MT Communicating Handling is deactivated) and triggers the MT DL data/signalling delivery upon receiving the NGAP Path Switch Request message.

If the last serving gNB receives DL data from the UPF or DL UE-associated signalling from the AMF (except the UE Context Release Command message) while the UE is in RRC\_INACTIVE, it pages in the cells corresponding to the RNA and may send XnAP RAN Paging to neighbour gNB(s) if the RNA includes cells of neighbour gNB(s).

Upon receiving the RAN Paging Request message from the AMF while the UE is in RRC\_INACTIVE with eDRX beyond 10.24 seconds, the last serving gNB may page in its cells comprised in the RNA and may send XnAP RAN Paging to neighbour gNB(s) if the RNA includes cells of neighbour gNB(s), in order to trigger the UE to resume connection in RRC\_CONNECTED state, or in RRC\_INACTIVE state for DL SDT, based on the DL data size if included in the NGAP RAN Paging Request message.

Upon receiving the UE Context Release Command message while the UE is in RRC\_INACTIVE, the last serving gNB may page in the cells corresponding to the RNA and may send XnAP RAN Paging to neighbour gNB(s) if the RNA includes cells of neighbour gNB(s), in order to release UE explicitly.

Upon receiving the NG RESET message while the UE is in RRC\_INACTIVE, the last serving gNB may page involved UEs in the cells corresponding to the RNA and may send XnAP RAN Paging to neighbour gNB(s) if the RNA includes cells of neighbour gNB(s) in order to explicitly release involved UEs.

Upon RAN paging failure, the gNB behaves according to TS 23.501 [3].

The AMF provides to the NG-RAN node the Core Network Assistance Information to assist the NG-RAN node's decision whether the UE can be sent to RRC\_INACTIVE, and to assist UE configuration and paging in RRC\_INACTIVE. The Core Network Assistance Information includes the registration area configured for the UE, the Periodic Registration Update timer, and the UE Identity Index value, and may include the UE specific DRX, an indication if the UE is configured with Mobile Initiated Connection Only (MICO) mode by the AMF, the Expected UE Behaviour, the UE Radio Capability for Paging, the PEI with Paging Subgrouping assistance information, the NR Paging eDRX Information, the Paging Cause Indication for Voice Service, the Hashed UE Identity Index Value and the CN support indication for MT Communication Handling. The UE registration area is taken into account by the NG-RAN node when configuring the RNA. The UE specific DRX and UE Identity Index value are used by the NG-RAN node for RAN paging. The Periodic Registration Update timer is taken into account by the NG-RAN node to configure Periodic RNA Update timer. The NG-RAN node takes into account the Expected UE Behaviour to assist the UE RRC state transition decision. The NG-RAN node may use the UE Radio Capability for Paging during RAN Paging. The NG-RAN node takes into account the PEI with Paging Subgrouping assistance information for subgroup paging in RRC\_INACTIVE except when the UE context contains an emergency PDU session in which case the PEI with Paging Subgrouping assistance information shall not be used according to TS 24.501 [28]. When sending the XnAP RAN Paging to neighbour NG-RAN node(s), the PEI with Paging Subgrouping assistance information may be included. The NG-RAN node takes into account the NR Paging eDRX Information to configure the RAN Paging when the NR UE is in RRC\_INACTIVE. When sending XnAP RAN Paging to neighbour NG-RAN node(s), the NR Paging eDRX Information for RRC\_IDLE and for RRC\_INACTIVE may be included. The NG-RAN node takes into consideration the Paging Cause Indication for Voice Service to include the Paging Cause in RAN Paging for a UE in RRC\_INACTIVE state. When sending XnAP RAN Paging to neighbour NG-RAN node(s), the Paging Cause may be included. When sending XnAP RAN Paging to neighbour NG-RAN node(s), the Hashed UE Identity Index Value may be included to determine the start point of PTW. The NG-RAN takes into account the CN support indication for MT Communication Handling when deciding to request the AMF for MT Communication Handling for a UE in RRC\_INACTIVE state with long eDRX beyond 10.24 seconds as described in TS 23.501 [3].

At transition to RRC\_INACTIVE the NG-RAN node may configure the UE with a periodic RNA Update timer value. At periodic RNA Update timer expiry without notification from the UE, the gNB behaves as specified in TS 23.501 [3].

If the UE accesses a gNB other than the last serving gNB, the receiving gNB triggers the XnAP Retrieve UE Context procedure to get the UE context from the last serving gNB and may also trigger an Xn-U Address Indication procedure including tunnel information for potential recovery of data from the last serving gNB. Upon successful UE context retrieval, the receiving gNB shall perform the slice-aware admission control in case of receiving slice information and becomes the serving gNB and it further triggers the NGAP Path Switch Request and applicable RRC procedures. After the path switch procedure, the serving gNB triggers release of the UE context at the last serving gNB by means of the XnAP UE Context Release procedure.

In case the UE is not reachable at the last serving gNB, the gNB shall fail any AMF initiated UE-associated class 1 procedure which allows the signalling of unsuccessful operation in the respective response message. It may trigger the NAS Non Delivery Indication procedure to report the non-delivery of any non PDU Session related NAS PDU received from the AMF as specified in TS 38.413 [26].

If the UE accesses a gNB other than the last serving gNB and the receiving gNB does not find a valid UE Context, the receiving gNB can perform establishment of a new RRC connection instead of resumption of the previous RRC connection. UE context retrieval will also fail and hence a new RRC connection needs to be established if the serving AMF changes.

A UE in the RRC\_INACTIVE state is required to initiate RNA update procedure when it moves out of the configured RNA. When receiving RNA update request from the UE, the receiving gNB triggers the XnAP Retrieve UE Context procedure to get the UE context from the last serving gNB and may decide to send the UE back to RRC\_INACTIVE state, move the UE into RRC\_CONNECTED state, or send the UE to RRC\_IDLE. In case of periodic RNA update, if the last serving gNB decides not to relocate the UE context, it fails the Retrieve UE Context procedure and sends the UE back to RRC\_INACTIVE, or to RRC\_IDLE directly by an encapsulated *RRCRelease* message.

#### 9.2.2.2 Cell Reselection

A UE in RRC\_INACTIVE performs cell reselection. The principles of the procedure are as for the RRC\_IDLE state (see clause 9.2.1.2).

#### 9.2.2.3 RAN-Based Notification Area

A UE in the RRC\_INACTIVE state can be configured by the last serving NG-RAN node with an RNA, where:

- the RNA can cover a single or multiple cells, and shall be contained within the CN registration area; in this release Xn connectivity should be available within the RNA;

- a RAN-based notification area update (RNAU) 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 or equal to a CN Tracking Area. A RAN area is specified by one RAN area ID, which consists of a TAC and optionally a RAN area Code;

- A cell broadcasts one or, in case of network sharing with multiple cell ID broadcast, more RAN area IDs in the system information.

NG-RAN may provide different RNA definitions to different UEs but not mix different definitions to the same UE at the same time. UE shall support all RNA configuration options listed above.

#### 9.2.2.4 State Transitions

##### 9.2.2.4.1 UE triggered transition from RRC\_INACTIVE to RRC\_CONNECTED

The following figure describes the UE triggered transition from RRC\_INACTIVE to RRC\_CONNECTED in case of UE context retrieval success:



Figure 9.2.2.4.1-1: UE triggered transition from RRC\_INACTIVE to RRC\_CONNECTED  
(UE context retrieval success)

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI, allocated by the last serving gNB.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context data.

3. The last serving gNB provides UE context data.

4/5. The gNB and UE completes the resumption of the RRC connection.

NOTE: User Data can also be sent in step 5 if the grant allows.

6. If loss of DL user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses.

7/8. The gNB performs path switch.

9. The gNB triggers the release of the UE resources at the last serving gNB.

After step 1 above, when the gNB decides to use a single RRC message to reject the Resume Request right away and keep the UE in RRC\_INACTIVE without any reconfiguration (e.g. as described in the two examples below), or when the gNB decides to setup a new RRC connection, SRB0 (without security) is used. Conversely, when the gNB decides to reconfigure the UE (e.g. with a new DRX cycle or RNA) or when the gNB decides to push the UE to RRC\_IDLE, SRB1 (with integrity protection and ciphering as previously configured for that SRB) shall be used.

NOTE: SRB1 can only be used once the UE Context is retrieved i.e. after step 3.

The following figure describes the UE triggered transition from RRC\_INACTIVE to RRC\_CONNECTED in case of UE context retrieval failure:



Figure 9.2.2.4.1-2: UE triggered transition from RRC\_INACTIVE to RRC\_CONNECTED  
(UE context retrieval failure)

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI, allocated by the last serving gNB.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context data.

3. The last serving gNB cannot retrieve or verify the UE context data.

4. The last serving gNB indicates the failure to the gNB.

5. The gNB performs a fallback to establish a new RRC connection by sending *RRCSetup*.

6. A new connection is setup as described in clause 9.2.1.3.

The following figure describes the rejection form the network when the UE attempts to resume a connection from RRC\_INACTIVE:



Figure 9.2.2.4.1-3: Reject from the network, UE attempts to resume a connection

1. UE attempts to resume the connection from RRC\_INACTIVE.

2. The gNB is not able to handle the procedure, for instance due to congestion.

3. The gNB sends *RRCReject* (with a wait time) to keep the UE in RRC\_INACTIVE.

##### 9.2.2.4.2 Network triggered transition from RRC\_INACTIVE to RRC\_CONNECTED

The following figure describes the network triggered transition from RRC\_INACTIVE to RRC\_CONNECTED:



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 last serving gNB or also by means of Xn RAN Paging in cells controlled by other gNBs, configured to the UE in the RAN-based Notification Area (RNA).

3. The UE is paged with the I-RNTI.

4. If the UE has been successfully reached, it attempts to resume from RRC\_INACTIVE, as described in clause 9.2.2.4.1.

#### 9.2.2.5 RNA update

The following figure describes the UE triggered RNA update procedure involving context retrieval over Xn. The procedure may be triggered when the UE moves out of the configured RNA, or periodically.



Figure 9.2.2.5-1: RNA update procedure with UE context relocation

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI allocated by the last serving gNB and appropriate cause value, e.g., RAN notification area update.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context, providing the cause value received in step 1.

3. The last serving gNB may provide the UE context (as assumed in the following). Alternatively, the last serving gNB may decide to move the UE to RRC\_IDLE (and the procedure follows steps 3 and later of figure 9.2.2.5-3) or, if the UE is still within the previously configured RNA, to keep the UE context in the last serving gNB and to keep the UE in RRC\_INACTIVE (and the procedure follows steps 3 and later of figure 9.2.2.5-2).

4. The gNB may move the UE to RRC\_CONNECTED (and the procedure follows step 4 of Figure 9.2.2.4.1-1), or send the UE back to RRC\_IDLE (in which case an *RRCRelease* message is sent by the gNB), or send the UE back to RRC\_INACTIVE as assumed in the following.

5. If loss of DL user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses.

6./7. The gNB performs path switch.

8. The gNB keeps the UE in RRC\_INACTIVE state by sending *RRCRelease* with suspend indication.

9. The gNB triggers the release of the UE resources at the last serving gNB.

The following figure describes the RNA update procedure for the case when the UE is still within the configured RNA and the last serving gNB decides not to relocate the UE context and to keep the UE in RRC\_INACTIVE:



Figure 9.2.2.5-2: Periodic RNA update procedure without UE context relocation

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI allocated by the last serving gNB and appropriate cause value, e.g., RAN notification area update.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context, providing the cause value received in step 1.

3. The last serving gNB stores received information to be used in the next resume attempt (e.g. C-RNTI and PCI related to the resumption cell), and responds to the gNB with the RETRIEVE UE CONTEXT FAILURE message including an encapsulated *RRCRelease* message. The *RRCRelease* message includes Suspend Indication.

4. The gNB forwards the *RRCRelease* message to the UE.

The following figure describes the RNA update procedure for the case when the last serving gNB decides to move the UE to RRC\_IDLE:



Figure 9.2.2.5-3: RNA update procedure with transition to RRC\_IDLE

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI allocated by the last serving gNB and appropriate cause value, e.g., RAN notification area update.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context, providing the cause value received in step 1.

3. Instead of providing the UE context, the last serving gNB provides an *RRCRelease* message to move the UE to RRC\_IDLE.

4. The last serving gNB deletes the UE context.

5. The gNB sends the *RRCRelease* which triggers the UE to move to RRC\_IDLE.

#### 9.2.2.6 Resume request responded with Release with Redirect, with UE context relocation

The following figure describes a UE triggered NAS procedure responded by the network with a release with redirect, with UE context relocation.



Figure 9.2.2.6-1: Resume request responded with Release with Redirect, with UE Context relocation

1. The UE resumes from RRC\_INACTIVE, providing the I-RNTI allocated by the last serving gNB.

2. The gNB, if able to resolve the gNB identity contained in the I-RNTI, requests the last serving gNB to provide UE Context data.

3. The last serving gNB provides the UE context.

4. The gNB may move the UE to RRC\_CONNECTED (and the procedure follows step 4 of Figure 9.2.2.4.1-1), or send the UE back to RRC\_IDLE (in which case an *RRCRelease* message is sent by the gNB), or send the UE back to RRC\_INACTIVE, including a release with redirect indication (as assumed in the following).

5. If loss of DL user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses.

6./7. The gNB performs path switch.

8. The gNB keeps the UE in RRC\_INACTIVE state by sending *RRCRelease* with suspend indication, including redirection information (frequency layer the UE performs cell selection upon entering RRC\_INACTIVE).

9. The gNB triggers the release of the UE resources at the last serving gNB.

NOTE1: Upon receiving the release with redirect, the higher layers trigger a pending procedure so the UE tries to resume again after cell selection.

### 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. Beam level mobility includes intra-cell beam level mobility and inter-cell 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 9.2.3.1-1:



Figure 9.2.3.1-1: 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 new RRC configuration as part of the HANDOVER REQUEST ACKNOWLEDGE.

3. The source gNB provides the RRC configuration to the UE by forwarding the *RRCReconfiguration* message received in the HANDOVER REQUEST ACKNOWLEDGE. The *RRCReconfiguration* 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 *RRCReconfiguration* 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 with the *RRCReconfigurationComplete*.

NOTE 1: User Data can also be sent in step 4 if the grant allows.

In case of DAPS handover, the UE continues the downlink user data reception from the source gNB until releasing the source cell and continues the uplink user data transmission to the source gNB until successful random access procedure to the target gNB.

Only source and target PCell are used during DAPS handover. CA, DC, SUL, multi-TRP, EHC, CHO, UDC, LTM, NR sidelink configurations and V2X sidelink configurations are released by the source gNB before the handover command is sent to the UE and are not configured by the target gNB until the DAPS handover has completed (i.e. at earliest in the same message that releases the source PCell).

The handover mechanism triggered by RRC requires the UE at least to reset the MAC entity and re-establish RLC, except for DAPS handover, where upon reception of the handover command, the UE:

- Creates a MAC entity for target;

- Establishes the RLC entity and an associated DTCH logical channel for target for each DRB configured with DAPS;

- For each DRB configured with DAPS, reconfigures the PDCP entity with separate security and ROHC functions for source and target and associates them with the RLC entities configured by source and target respectively;

- Retains the rest of the source configurations until release of the source.

The cell switch mechanism triggered by MAC, (i.e., LTM cell switch) requires the UE at least to reset the MAC entity. RLC and PDCP handling depends on the network configuration.

NOTE 2: Void.

NOTE 3: Void.

RRC managed handovers with and without PDCP entity re-establishment are both supported. 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, PDCP can either be re-established together with a security key change or remain as it is without a key change. For SRBs, PDCP can either remain as it is, discard its stored PDCP PDUs/SDUs without a key change or be re-established together with a security key change.

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

Timer based handover failure procedure is supported in NR. RRC connection re-establishment procedure is used for recovering from handover failure except in certain CHO, DAPS handover or LTM cell switch scenarios:

- When DAPS handover fails, the UE falls back to the source cell configuration, resumes the connection with the source cell, and reports DAPS handover failure via the source without triggering RRC connection re-establishment if the source link has not been released.

- When initial CHO execution attempt fails or HO fails, the UE performs cell selection, and if the selected cell is a CHO candidate and if network configured the UE to try CHO after handover/CHO failure, then the UE attempts CHO execution once, otherwise re-establishment is performed.

- When LTM execution attempt triggered by LTM cell switch command MAC CE fails, the UE performs cell selection and if the selected cell is an LTM candidate cell and if network configured the UE to try LTM after LTM execution failure, then the UE attempts RACH-based LTM execution once, otherwise re-establishment is performed.

NOTE: PDCP SN gap for SRB may exist upon LTM attempt toward the selected cell after LTM fails. It is up to network implementation to avoid the latency caused by the PDCP SN gap.

DAPS handover for FR2 to FR2 case is not supported in this release of the specification.

The handover of the IAB-MT in SA mode follows the same procedure as described for the UE. After the backhaul has been established, the handover of the IAB-MT is part of the intra-CU or inter-CU topology adaptation procedures defined in TS 38.401 [4]. Modifications to the configuration of BAP sublayer and higher protocol layers above the BAP sublayer are described in TS 38.401 [4].

The handover of the mobile IAB-MT follows the same procedure as described for the UE. After the backhaul has been established, the handover of the mobile IAB-MT is part of the mobile IAB-MT migration procedure defined in TS 38.401 [4].

**Beam Level Mobility** does not require explicit RRC signalling to be triggered. Beam level mobility can be within a cell, or between cells, the latter is referred to as inter-cell beam management (ICBM). For ICBM, a UE can receive or transmit UE dedicated channels/signals via a TRP associated with a PCI different from the PCI of a serving cell, while non-UE-dedicated channels/signals can only be received via a TRP associated with a PCI of the serving cell. The gNB provides via RRC signalling the UE with measurement configuration containing configurations of SSB/CSI resources and resource sets, reports and trigger states for triggering channel and interference measurements and reports. In case of ICBM, a measurement configuration includes SSB resources associated with PCIs different from the PCI of a serving cell. Beam Level Mobility is then dealt with at lower layers by means of physical layer and MAC layer control signalling, and RRC is not required to know which beam is being used at a given point in time.

SSB-based Beam Level Mobility is based on the CD-SSB associated to the initial DL BWP and can be configured for the initial DL BWPs, for DL BWPs containing the CD-SSB associated to the initial DL BWP, and if supported, for DL BWPs not containing the CD-SSB associated to the initial DL BWP. SSB-based Beam Level Mobility can be also performed based on an NCD-SSB, if configured for the active DL BWP. Beam Level Mobility can be also performed based on CSI-RS, if configured for the active DL BWP.

#### 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 *MeasurementReport* and RRM information.

3. The source gNB issues a Handover Request message to the target gNB passing a transparent RRC container with necessary information to prepare the handover at the target side. The information includes at least the target cell ID, KgNB\*, the C-RNTI of the UE in the source gNB, RRM-configuration including UE inactive time, basic AS-configuration including *antenna Info and DL Carrier Frequency*, the current QoS flow to DRB mapping rules applied to the UE, the SIB1 information from source gNB, the UE capabilities for different RATs, PDU session related information, and can include the UE reported measurement information including beam-related information if available. The PDU session related information includes the slice information and QoS flow level QoS profile(s). The source gNB may also request a DAPS handover for one or more DRBs.

NOTE 1: After issuing a Handover Request, the source gNB should not reconfigure the UE, including performing Reflective QoS flow to DRB mapping.

4. Admission Control may be performed by the target gNB. Slice-aware admission control shall be performed if the slice information is sent to the target gNB. If the PDU sessions are associated with non-supported slices the target gNB shall reject such PDU Sessions.

5. The target gNB prepares the handover with L1/L2 and sends the HANDOVER REQUEST ACKNOWLEDGE to the source gNB, which includes a transparent container to be sent to the UE as an RRC message to perform the handover. The target gNB also indicates if a DAPS handover is accepted.

NOTE 2: As soon as the source gNB receives the HANDOVER REQUEST ACKNOWLEDGE, or as soon as the transmission of the handover command is initiated in the downlink, data forwarding may be initiated.

NOTE 3: For DRBs configured with DAPS, downlink PDCP SDUs are forwarded with SN assigned by the source gNB, until SN assignment is handed over to the target gNB in step 8b, for which the normal data forwarding follows as defined in 9.2.3.2.3.

6. The source gNB triggers the Uu handover by sending an *RRCReconfiguration* message to the UE, containing the information required to access the target cell: at least the target cell ID, the new C-RNTI, the target gNB security algorithm identifiers for the selected security algorithms. It can also include a set of dedicated RACH resources, the association between RACH resources and SSB(s), the association between RACH resources and UE-specific CSI-RS configuration(s), common RACH resources, and system information of the target cell, etc.

NOTE 4: For DRBs configured with DAPS, the source gNB does not stop transmitting downlink packets until it receives the HANDOVER SUCCESS message from the target gNB in step 8a.

NOTE 4a: CHO cannot be configured simultaneously with DAPS handover.

7a. For DRBs configured with DAPS, the source gNB sends the EARLY STATUS TRANSFER message. The DL COUNT value conveyed in the EARLY STATUS TRANSFER message indicates PDCP SN and HFN of the first PDCP SDU that the source gNB forwards to the target gNB. The source gNB does not stop assigning SNs to downlink PDCP SDUs until it sends the SN STATUS TRANSFER message to the target gNB in step 8b.

7. For DRBs not configured with DAPS, the source gNB sends the SN STATUS TRANSFER message to the target gNB to convey the uplink PDCP SN receiver status and the downlink PDCP SN transmitter status of DRBs for which PDCP status preservation applies (i.e. for RLC AM). The uplink PDCP SN receiver status includes at least the PDCP SN of the first missing UL PDCP SDU and may include a bit map of the receive status of the out of sequence UL PDCP SDUs that the UE needs to retransmit in the target cell, if any. The downlink PDCP SN transmitter status indicates the next PDCP SN that the target gNB shall assign to new PDCP SDUs, not having a PDCP SN yet.

NOTE 5: In case of DAPS handover, the uplink PDCP SN receiver status and the downlink PDCP SN transmitter status for a DRB with RLC-AM and not configured with DAPS may be transferred by the SN STATUS TRANSFER message in step 8b instead of step 7.

NOTE 6: For DRBs configured with DAPS, the source gNB may additionally send the EARLY STATUS TRANSFER message(s) between step 7 and step 8b, to inform discarding of already forwarded PDCP SDUs. The target gNB does not transmit forwarded downlink PDCP SDUs to the UE, whose COUNT is less than the conveyed DL COUNT value and discards them if transmission has not been attempted already.

8. The UE synchronises to the target cell and completes the RRC handover procedure by sending *RRCReconfigurationComplete* message to target gNB. In case of DAPS handover, the UE does not detach from the source cell upon receiving the *RRCReconfiguration* message. The UE releases the source resources and configurations and stops DL/UL reception/transmission with the source upon receiving an explicit release from the target node.

NOTE 6a: From RAN point of view, the DAPS handover is considered to only be completed after the UE has released the source cell as explicitly requested from the target node. RRC suspend, a subsequent handover or inter-RAT handover cannot be initiated until the source cell has been released.

8a/b In case of DAPS handover, the target gNB sends the HANDOVER SUCCESS message to the source gNB to inform that the UE has successfully accessed the target cell. In return, the source gNB sends the SN STATUS TRANSFER message for DRBs configured with DAPS for which the description in step 7 applies, and the normal data forwarding follows as defined in 9.2.3.2.3.

NOTE 7: The uplink PDCP SN receiver status and the downlink PDCP SN transmitter status are also conveyed for DRBs with RLC-UM in the SN STATUS TRANSFER message in step 8b, if configured with DAPS.

NOTE 8: For DRBs configured with DAPS, the source gNB does not stop delivering uplink QoS flows to the UPF until it sends the SN STATUS TRANSFER message in step 8b. The target gNB does not forward QoS flows of the uplink PDCP SDUs successfully received in-sequence to the UPF until it receives the SN STATUS TRANSFER message, in which UL HFN and the first missing SN in the uplink PDCP SN receiver status indicates the start of uplink PDCP SDUs to be delivered to the UPF. The target gNB does not deliver any uplink PDCP SDUs which has an UL COUNT lower than the provided.

NOTE 9: Void.

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. The UPF sends one or more "end marker" packets on the old path to the source gNB per PDU session/tunnel and then can release any U-plane/TNL resources towards the source gNB.

11. The AMF confirms the PATH SWITCH REQUEST message with the PATH SWITCH REQUEST ACKNOWLEDGE message.

12. Upon reception of the PATH SWITCH REQUEST ACKNOWLEDGE message from the AMF, the target gNB sends the UE CONTEXT RELEASE to inform the source gNB about the success of the handover. The source gNB can then release radio and C-plane related resources associated to the UE context. Any ongoing data forwarding may continue.

The RRM configuration can include both beam measurement information (for layer 3 mobility) associated to SSB(s) and CSI-RS(s) for the reported cell(s) if both types of measurements are available. Also, if CA is configured, the RRM configuration can include the list of best cells on each frequency for which measurement information is available. And the RRM measurement information can also include the beam measurement for the listed cells that belong to the target gNB.

The common RACH configuration for beams in the target cell is only associated to the SSB(s). The network can have dedicated RACH configurations associated to the SSB(s) and/or have dedicated RACH configurations associated to CSI-RS(s) within a cell. The target gNB can only include one of the following RACH configurations in the Handover Command to enable the UE to access the target cell:

i) Common RACH configuration;

ii) Common RACH configuration + Dedicated RACH configuration associated with SSB;

iii) Common RACH configuration + Dedicated RACH configuration associated with CSI-RS.

The dedicated RACH configuration allocates RACH resource(s) together with a quality threshold to use them. When dedicated RACH resources are provided, they are prioritized by the UE and the UE shall not switch to contention-based RACH resources as long as the quality threshold of those dedicated resources is met. The order to access the dedicated RACH resources is up to UE implementation.

Upon receiving a handover command requesting DAPS handover, the UE suspends source cell SRBs, stops sending and receiving any RRC control plane signalling toward the source cell, and establishes SRBs for the target cell. The UE releases the source cell SRBs configuration upon receiving source cell release indication from the target cell after successful DAPS handover execution. When DAPS handover to the target cell fails and if the source cell link is available, then the UE reverts back to the source cell configuration and resumes source cell SRBs for control plane signalling transmission.

##### 9.2.3.2.2 U-Plane Handling

The U-plane handling during the Intra-NR-Access mobility activity for UEs in RRC\_CONNECTED takes the following principles into account to avoid data loss during HO:

- During HO preparation, U-plane tunnels can be established between the source gNB and the target gNB;

- During HO execution, user data can be forwarded from the source gNB to the target gNB;

- Forwarding should take place in order as long as packets are received at the source gNB from the UPF or the source gNB buffer has not been emptied.

- During HO completion:

- The target gNB sends a path switch request message to the AMF to inform that the UE has gained access and the AMF then triggers path switch related 5GC internal signalling and actual path switch of the source gNB to the target gNB in UPF;

- The source gNB should continue forwarding data as long as packets are received at the source gNB from the UPF or the source gNB buffer has not been emptied.

**For RLC-AM bearers**:

- For in-sequence delivery and duplication avoidance, PDCP SN is maintained on a per DRB basis and the source gNB informs the target gNB about the next DL PDCP SN to allocate to a packet which does not have a PDCP sequence number yet (either from source gNB or from the UPF).

- For security synchronisation, HFN is also maintained and the source gNB provides to the target one reference HFN for the UL and one for the DL i.e. HFN and corresponding SN.

- In both the UE and the target gNB, a window-based mechanism is used for duplication detection and reordering.

- The occurrence of duplicates over the air interface in the target gNB is minimised by means of PDCP SN based reporting at the target gNB by the UE. In uplink, the reporting is optionally configured on a per DRB basis by the gNB and the UE should first start by transmitting those reports when granted resources are in the target gNB. In downlink, the gNB is free to decide when and for which bearers a report is sent and the UE does not wait for the report to resume uplink transmission.

- The target gNB re-transmits and prioritizes all downlink data forwarded by the source gNB (i.e. the target gNB should first send all forwarded PDCP SDUs with PDCP SNs, then all forwarded downlink PDCP SDUs without SNs before sending new data from 5GC), excluding PDCP SDUs for which the reception was acknowledged through PDCP SN based reporting by the UE.

NOTE 1: Lossless delivery when a QoS flow is mapped to a different DRB at handover, requires the old DRB to be configured in the target cell. For in-order delivery in the DL, the target gNB should first transmit the forwarded PDCP SDUs on the old DRB before transmitting new data from 5GC on the new DRB. In the UL, the target gNB should not deliver data of the QoS flow from the new DRB to 5GC before receiving the end marker on the old DRB from the UE.

- The UE re-transmits in the target gNB all uplink PDCP SDUs starting from the oldest PDCP SDU that has not been acknowledged at RLC in the source, excluding PDCP SDUs for which the reception was acknowledged through PDCP SN based reporting by the target.

- In case of handovers involving Full Configuration, the following description below for RLC-UM bearers applies for RLC-AM bearers instead. Data loss may happen.

**For RLC-UM bearers**:

- The PDCP SN and HFN are reset in the target gNB, unless the bearer is configured with DAPS handover;

- No PDCP SDUs are retransmitted in the target gNB;

- The target gNB prioritises all downlink SDAP SDUs forwarded by the source gNB over the data from the core network;

NOTE 2: To minimise losses when a QoS flow is mapped to a different DRB at handover, the old DRB needs to be configured in the target cell. For in-order delivery in the DL, the target gNB should first transmit the forwarded PDCP SDUs on the old DRB before transmitting new data from 5GC on the new DRB. In the UL, the target gNB should not deliver data of the QoS flow from the new DRB to 5GC before receiving the end marker on the old DRB from the UE.

- The UE does not retransmit any PDCP SDU in the target cell for which transmission had been completed in the source cell.

**For DAPS handover:**

A DAPS handover can be used for an RLC-AM or RLC-UM bearer. For a DRB configured with DAPS, the following principles are additionally applied.

Downlink:

- During HO preparation, a forwarding tunnel is always established.

- The source gNB is responsible for allocating downlink PDCP SNs until the SN assignment is handed over to the target gNB and data forwarding in 9.2.3.2.3 takes place. That is, the source gNB does not stop assigning PDCP SNs to downlink packets until it receives the HANDOVER SUCCESS message and sends the SN STATUS TRANSFER message to the target gNB.

- Upon allocation of downlink PDCP SNs by the source gNB, it starts scheduling downlink data on the source radio link and also starts forwarding downlink PDCP SDUs along with assigned PDCP SNs to the target gNB.

- For security synchronisation, HFN is maintained for the forwarded downlink SDUs with PDCP SNs assigned by the source gNB. The source gNB sends the EARLY STATUS TRANSFER message to convey the DL COUNT value, indicating PDCP SN and HFN of the first PDCP SDU that the source gNB forwards to the target gNB.

- HFN and PDCP SN are maintained after the SN assignment is handed over to the target gNB. The SN STATUS TRANSFER message indicates the next DL PDCP SN to allocate to a packet which does not have a PDCP sequence number yet, even for RLC-UM.

- During handover execution period, the source and target gNBs separately perform ROHC header compression, ciphering, and adding PDCP header.

- During handover execution period, the UE continues to receive downlink data from both source and target gNBs until the source gNB connection is released by an explicit release command from the target gNB.

- During handover execution period, the UE PDCP entity configured with DAPS maintains separate security and ROHC header decompression functions associated with each gNB, while maintaining common functions for reordering, duplicate detection and discard, and PDCP SDUs in-sequence delivery to upper layers. PDCP SN continuity is supported for both RLC AM and UM DRBs configured with DAPS.

Uplink:

- The UE transmits UL data to the source gNB until the random access procedure toward the target gNB has been successfully completed. Afterwards the UE switches its UL data transmission to the target gNB.

- Even after switching its UL data transmissions towards the target gNB, the UE continues to send UL layer 1 CSI feedback, HARQ feedback, layer 2 RLC feedback, ROHC feedback, HARQ data (re-)transmissions, and RLC data (re-)transmissions to the source gNB.

- During handover execution period, the UE maintains separate security context and ROHC header compressor context for uplink transmissions towards the source and target gNBs. The UE maintains common UL PDCP SN allocation. PDCP SN continuity is supported for both RLC AM and UM DRBs configured with DAPS.

- During handover execution period, the source and target gNBs maintain their own security and ROHC header decompressor contexts to process UL data received from the UE.

- The establishment of a forwarding tunnel is optional.

- HFN and PDCP SN are maintained in the target gNB. The SN STATUS TRANSFER message indicates the COUNT of the first missing PDCP SDU that the target should start delivering to the 5GC, even for RLC-UM.

##### 9.2.3.2.3 Data Forwarding

The following description depicts the data forwarding principles for intra-system handover.

The source NG-RAN node may suggest downlink data forwarding per QoS flow established for a PDU session and may provide information how it maps QoS flows to DRBs. The target NG-RAN node decides data forwarding per QoS flow established for a PDU Session.

If "lossless handover" is required and the QoS flows to DRB mapping applied at the target NG-RAN node allows applying for data forwarding the same QoS flows to DRB mapping as applied at the source NG-RAN node for a DRB and if all QoS flows mapped to that DRB are accepted for data forwarding, the target NG-RAN node establishes a downlink forwarding tunnel for that DRB.

For a DRB for which preservation of SN status applies, the target NG-RAN node may decide to establish an UL data forwarding tunnel.

The target NG-RAN node may also decide to establish a downlink forwarding tunnel for each PDU session. In this case the target NG-RAN node provides information for which QoS flows data forwarding has been accepted and corresponding UP TNL information for data forwarding tunnels to be established between the source NG-RAN node and the target NG-RAN node.

If QoS flows have been re-mapped at the source NG-RAN node and user packets along the old source mapping are still being processed at handover preparation, and if the source NG-RAN node has not yet received the SDAP end marker for certain QoS flows when providing the SN status to the target NG-RAN node, the source NG-RAN node provides the old side QoS mapping information for UL QoS flows to the target NG-RAN node for which no SDAP end marker was yet received. The target NG-RAN will receive for those QoS flows the end marker when the UE finalises to send UL user data according to the old source side mapping.

The source NG-RAN node may also propose to establish uplink forwarding tunnels for some PDU sessions in order to transfer SDAP SDUs corresponding to QoS flows for which flow re-mapping happened before the handover and the SDAP end marker has not yet been received, and for which user data was received at the source NG-RAN node via the DRB to which the QoS flow was remapped. If accepted the target NG-RAN node shall provide the corresponding UP TNL information for data forwarding tunnels to be established between the source NG-RAN node and the target NG-RAN node.

As long as data forwarding of DL user data packets takes place, the source NG-RAN node shall forward user data in the same forwarding tunnel, i.e.

- for any QoS flow accepted for data forwarding by the target NG-RAN node and for which a DRB DL forwarding tunnel was established for a DRB to which this QoS flow was mapped at the source NG-RAN node, any fresh packets of this QoS flow shall be forwarded as PDCP SDUs via the mapped DRB DL forwarding tunnel.

- for DRBs for which preservation of SN status applies, the source NG-RAN node may forward in order to the target NG-RAN node via the DRB DL forwarding tunnel all downlink PDCP SDUs with their SN corresponding to PDCP PDUs which have not been acknowledged by the UE.

NOTE: The SN of forwarded PDCP SDUs is carried in the "PDCP PDU number" field of the GTP-U extension header.

- for any QoS flow accepted for data forwarding by the target NG-RAN node for which a DL PDU session forwarding tunnel was established, the source NG-RAN node forwards SDAP SDUs as received on NG-U from the UPF.

If the data forwarding is performed and the source NG-RAN node receives SDAP SDUs with PDU Set Information Container in the GTP-U extension header on NG-U from the UPF and the target NG-RAN node supports PDU Set based handling, the source NG-RAN node forwards either the PDCP SDUs for DRB-level data forwarding or the SDAP SDUs for PDU-session-level data forwarding with the corresponding PDU Set Information Container in the GTP-U extension header to the target NG-RAN node.

For handovers involving Full Configuration, the source NG-RAN node behaviour is unchanged from the description above. In case a DRB DL forwarding tunnel was established, the target NG-RAN node may identify the PDCP SDUs for which delivery was attempted by the source NG-RAN node, by the presence of the PDCP SN in the forwarded GTP-U packet and may discard them.

As long as data forwarding of UL user data packets takes place for DRBs for which preservation of SN status applies the source NG-RAN node either:

- discards the uplink PDCP PDUs received out of sequence if the source NG-RAN node has not accepted the request from the target NG-RAN node for uplink forwarding or if the target NG-RAN node has not requested uplink forwarding for the bearer during the Handover Preparation procedure; or

- forwards to the target NG-RAN node via the corresponding DRB UL forwarding tunnel, the uplink PDCP SDUs with their SN corresponding to PDCP PDUs received out of sequence if the source NG-RAN node has accepted the request from the target NG-RAN node for uplink forwarding for the bearer during the Handover Preparation procedure, including PDCP SDUs corresponding to user data of those QoS flows, for which re-mapping happened for a QoS flow before the handover and the SDAP end marker has not yet been received at the source NG-RAN node.

As long as data forwarding of UL user data packets takes place for a PDU session, the source NG-RAN node forwards via the corresponding PDU session UL forwarding tunnel, the uplink SDAP SDUs corresponding to QoS flows for which flow re-mapping happened before the handover and the SDAP end marker has not yet been received at the source NG-RAN node, and which were received at the source NG-RAN node via the DRB to which the QoS flow was remapped.

For DRBs configured with DAPS handover, data forwarding after the source gNB receives the HANDOVER SUCCESS message from the target gNB follows the same behaviours as described above.

For DRBs configured with DAPS handover, before the source gNB receives the HANDOVER SUCCESS message:

- The source gNB may forward to the target gNB downlink PDCP SDUs with SNs assigned by the source gNB. No downlink PDCP SDU without a SN assigned or SDAP SDU is forwarded. No uplink PDCP SDU or SDAP SDU is forwarded.

- The source gNB sends the EARLY STATUS TRANSFER message to maintain HFN continuity by indicating PDCP SN and HFN of the first PDCP SDU that the source gNB forwards to the target gNB. The subsequent messages may be sent for discarding of already forwarded downlink PDCP SDUs in the target gNB.

- The source gNB does not stop transmitting downlink packets to the UE. The source gNB keeps forwarding to the 5GC the uplink SDAP SDUs successfully received in-sequence from the UE.

Handling of end marker packets:

- The source NG-RAN node receives one or several GTP-U end marker packets per PDU session from the UPF and replicates the end marker packets into each data forwarding tunnel when no more user data packets are to be forwarded over that tunnel.

- End marker packets sent via a data forwarding tunnel are applicable to all QoS flows forwarded via that tunnel. After end marker packets have been received over a forwarding tunnel, the target NG-RAN node can start taking into account the packets of QoS flows associated with that forwarding tunnel received at the target NG-RAN node from the NG-U PDU session tunnel.

#### 9.2.3.3 Re-establishment procedure

A UE in RRC\_CONNECTED may initiate the re-establishment procedure to continue the RRC connection when a failure condition occurs (e.g. radio link failure, reconfiguration failure, integrity check failure…).

The following figure describes the re-establishment procedure started by the UE:



Figure 9.2.3.3-1: Re-establishment procedure

1. The UE re-establishes the connection, providing the UE Identity (PCI+C-RNTI) to the gNB where the trigger for the re-establishment occurred.

2. If the UE Context is not locally available, the gNB, requests the last serving gNB to provide UE Context data.

3. The last serving gNB provides UE context data.

4/4a. The gNB continues the re-establishment of the RRC connection. The message is sent on SRB1.

5/5a. The gNB may perform the reconfiguration to re-establish SRB2 and DRBs when the re-establishment procedure is ongoing.

6/7. If loss of user data buffered in the last serving gNB shall be prevented, the gNB provides forwarding addresses, and the last serving gNB provides the SN status to the gNB.

8/9. The gNB performs path switch.

10. The gNB triggers the release of the UE resources at the last serving gNB.

The IAB-MT in SA mode follows the same re-establishment procedure as described for the UE. After the backhaul has been established, the re-establishment procedure of the IAB-MT is part of the intra-CU backhaul RLF recovery procedure for IAB-nodes defined in TS 38.401 [4]. Modifications to the configuration of BAP sublayer and higher protocol layers above the BAP sublayer are described in TS 38.401 [4].

#### 9.2.3.4 Conditional Handover

##### 9.2.3.4.1 General

A Conditional Handover (CHO) is defined as a handover that is executed by the UE when one or more handover execution conditions are met. The UE starts evaluating the execution condition(s) upon receiving the CHO configuration, and stops evaluating the execution condition(s) once a handover is executed.

The following principles apply to CHO:

- The CHO configuration contains the configuration of CHO candidate cell(s) generated by the candidate gNB(s) and execution condition(s) generated by the source gNB.

- An execution condition may consist of one or two trigger condition(s) (CHO events A3/A5, as defined in [12]). Only single RS type is supported and at most two different trigger quantities (e.g. RSRP and RSRQ, RSRP and SINR, etc.) can be configured simultaneously for the evalution of CHO execution condition of a single candidate cell.

- Before any CHO execution condition is satisfied, upon reception of HO command (without CHO configuration) or LTM cell switch command MAC CE, the UE executes the HO procedure as described in clause 9.2.3.2 or LTM cell switch procedure as described in clause 9.2.3.5, regardless of any previously received CHO configuration.

- While executing CHO, i.e. from the time when the UE starts synchronization with target cell, UE does not monitor source cell.

CHO is also supported for the IAB-MT in context of intra- and inter-donor IAB-node migration and BH RLF recovery.

CHO is not supported for NG-C based handover in this release of the specification.

##### 9.2.3.4.2 C-plane handling

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



Figure 9.2.3.4.2-1: Intra-AMF/UPF Conditional Handover

0/1. Same as step 0, 1 in Figure 9.2.3.2.1-1 of clause 9.2.3.2.1.

2. The source gNB decides to use CHO.

3. The source gNB requests CHO for one or more candidate cells belonging to one or more candidate gNBs. A CHO request message is sent for each candidate cell.

4. Same as step 4 in Figure 9.2.3.2.1-1 of clause 9.2.3.2.1.

5. The candidate gNB(s) sends CHO response (HO REQUEST ACKNOWLEDGE) including configuration of CHO candidate cell(s) to the source gNB. The CHO response message is sent for each candidate cell.

6. The source gNB sends an *RRCReconfiguration* message to the UE, containing the configuration of CHO candidate cell(s) and CHO execution condition(s).

NOTE 1: CHO configuration of candidate cells can be followed by another reconfiguration from the source gNB.

NOTE 1a: A configuration of a CHO candidate cell cannot contain a DAPS handover configuration.

7. The UE sends an *RRCReconfigurationComplete* message to the source gNB.

7a If early data forwarding is applied, the source gNB sends the EARLY STATUS TRANSFER message.

8. The UE maintains connection with the source gNB after receiving CHO configuration, and starts evaluating the CHO execution conditions for the candidate cell(s). If at least one CHO candidate cell satisfies the corresponding CHO execution condition, the UE detaches from the source gNB, applies the stored corresponding configuration for that selected candidate cell, synchronises to that candidate cell and completes the RRC handover procedure by sending *RRCReconfigurationComplete* message to the target gNB. The UE releases stored CHO configurations after successful completion of RRC handover procedure.

8a/b The target gNB sends the HANDOVER SUCCESS message to the source gNB to inform that the UE has successfully accessed the target cell. In return, the source gNB sends the SN STATUS TRANSFER message following the principles described in step 7 of Intra-AMF/UPF Handover in clause 9.2.3.2.1.

NOTE 2: Late data forwarding may be initiated as soon as the source gNB receives the HANDOVER SUCCESS message.

8c. The source gNB sends the HANDOVER CANCEL message toward the other signalling connections or other candidate target gNBs, if any, to cancel CHO for the UE.

##### 9.2.3.4.3 U-plane handling

The U-plane handling for Conditional Handover follows the same principles for DAPS handover in 9.2.3.2.2, if early data forwarding is applied, except that, in case of Full Configuration, HFN and PDCP SN are reset in the target gNB after the SN assignment is handed over to the target gNB. If late data forwarding is applied, the U-plane handling follows the RLC-AM or RLC-UM bearer principles defined in 9.2.3.2.2.

##### 9.2.3.4.4 Data Forwarding

If late data forwarding is applied, the source NG-RAN node initiates data forwarding once it knows which target NG-RAN node the UE has successfully accessed. In that case the behavior of the Conditional Handover data forwarding follows the same behavior as defined in 9.2.3.2.3 for the intra-system handover data forwarding, except the behavior for DRBs configured with DAPS handover.

If early data forwarding is applied instead, the source NG-RAN node initiates data forwarding before the UE executes the handover, to a candidate target node of interest. The behavior of early data forwarding for the Conditional Handover follows the same principles for DRBs configured with DAPS handover in the intra-system handover as defined in 9.2.3.2.3.

#### 9.2.3.5 L1/L2 Triggered Mobility

##### 9.2.3.5.1 General

LTM is a procedure in which a gNB receives L1 or L3 measurement report(s) from a UE, and on their basis the gNB may change UE serving cell by a cell switch command signalled via a MAC CE. The cell switch command indicates an LTM candidate configuration that the gNB previously prepared and provided to the UE through RRC signalling. Then the UE switches to the target configuration according to the cell switch command. The LTM procedure can be used to reduce the mobility latency as described in Annex G.

When configured by the network, it is possible to activate TCI states of one or multiple cells that are different from the current serving cell. For instance, the TCI states of the LTM candidate cells can be activated in advance before any of those cells become the serving cell. This allows the UE to be DL synchronized with those cells, thereby facilitating a faster cell switch to one of those cells when cell switch is triggered. All the activated TCI states except those received in the cell switch command are deactivated upon LTM cell switch execution.

When configured by the network, it is possible to initiate UL TA acquisition (called early TA) procedure of one or multiple cells that are different from the current serving cells. If the cell has the same NTA as the current serving cells or NTA=0, early TA acquisition procedure is not required. The network may request the UE to perform early TA acquisition of a candidate cell before a cell switch. The early TA acquisition procedure is triggered by PDCCH order as specified in clause 9.2.6 or realized through UE-based TA measurement as configured by RRC. In the former case, the gNB/gNB-DU to which the candidate cell belongs calculates the TA value and sends it to the gNB/gNB-DU to which the serving cell belongs via gNB-CU. The serving cell sends the TA value in the LTM cell switch command MAC CE when triggering LTM cell switch. In the latter case, the UE performs TA measurement for the candidate cells after being configured by RRC but the exact time the UE performs TA measurement is up to UE implementation. The UE applies the TA value measured by itself and performs RACH-less LTM upon receiving the cell switch command, if it does not include any valid TA value. The network may also send a TA value in the LTM cell switch command MAC CE without early TA acquisition.

When two TAG IDs are configured for an LTM candidate cell, the gNB-DU to which the LTM candidate cell belongs assigns the same TAG ID pointer value for each TRP to be used by the UEs.

Depending on the availability of a valid TA value, the UE performs either a RACH-less LTM or RACH-based LTM cell switch. If the valid TA value is provided in the cell switch command, the UE applies the TA value as instructed by the network. In the case where UE-based TA measurement is configured, but no valid TA value is provided in the cell switch command, the UE applies the valid TA value by itself if available. The UE performs RACH-less LTM cell switch upon receiving the cell switch command whenever a valid TA value is available. If no valid TA value is available, the UE performs RACH-based LTM cell switch.

Regardless of whether the UE is configured for UE-based TA measurement for a certain candidate cell, it will still follow the PDCCH order, which includes performing a random access procedure towards one or more candidate cells. This also applies to the candidate cells for which the UE is capable of deriving TA values by itself. Additionally, regardless of whether the UE has already performed a random access procedure towards the candidate cells, it will still follow the UE-based measurement configuration if configured by the network.

For RACH-less LTM, the UE accesses the target cell using either a configured grant or a dynamic grant. The configured grant is provided in the LTM candidate configuration, and the UE selects the configured grant occasion associated with the beam indicated in the cell switch command. Upon initiation of LTM cell switch to the target cell, the UE starts to monitor PDCCH on the target cell for dynamic scheduling. Before RACH-less LTM procedure completion, the UE shall not trigger random access procedure if it does not have a valid PUCCH resource for triggered SRs.

The following principles apply to LTM:

- Security keys are maintained upon an LTM cell switch;

- Subsequent LTM is supported.

LTM supports both intra-gNB-DU and inter-gNB-DU mobility within the same gNB-CU. LTM supports both intra-frequency and inter-frequency mobility, including mobility to inter-frequency cell that is not a current serving cell. LTM is supported only for licensed spectrum. The following scenarios are supported:

- PCell change in non-CA scenario and non-DC scenario;

- PCell and SCell(s) change in CA scenario;

- Dual connectivity scenario: including PCell and MCG SCell(s) change and intra-SN PSCell and SCG SCell(s) change without MN involvement. LTM for simultaneous PCell and PSCell change is not supported.

While the UE has stored LTM candidate configurations the UE can also execute any L3 handover except for DAPS handover. In the RRC message which the UE applies for any L3 handover (except DAPS), LTM candidate configurations can be added/modified/released by the target cell.

##### 9.2.3.5.2 C-Plane Handling

Cell switch command is conveyed in a MAC CE, which contains the necessary information to perform the LTM cell switch.

The overall procedure for LTM is shown in Figure 9.2.3.5.2-1 below. Subsequent LTM is done by repeating the early synchronization, LTM cell switch execution, and LTM cell switch completion steps without the need to release, reconfigure or add other LTM candidate configurations after each LTM cell switch completion. The general procedure over the air interface is applicable to SCG LTM. Further details of SCG LTM can be found in TS 37.340 [21].



Figure 9.2.3.5.2-1. Signalling procedure for LTM

The procedure for LTM is as follows:

1. The UE sends a *MeasurementReport* message to the gNB. The gNB decides to configure LTM and initiates LTM preparation.

2. The gNB transmits an *RRCReconfiguration* message to the UE including the LTM candidate configurations.

3. The UE stores the LTM candidate configurations and transmits an *RRCReconfigurationComplete* message to the gNB.

4a. The UE performs DL synchronization with the LTM candidate cell(s) before receiving the cell switch command. The UE may activate and deactivate TCI states of LTM candidate cell(s), as triggered by the gNB and defined in TS 38.133 [13].

4b. The UE may perform UL synchronization with LTM candidate cell(s) before receiving the cell switch command, by using UE-based TA measurement, if configured, and/or by transmitting a preamble towards the candidate cell, as triggered by the gNB. When UE-based TA measurement is configured, UE acquires the TA value(s) of the candidate cell(s) by measurement. UE performs early TA acquisition with the candidate cell(s) as requested by the network before receiving the cell switch command as specified in clause 9.2.6 and TS 38.133 [13]. This is done via CFRA triggered by a PDCCH order from the source cell, following which the UE sends preamble towards the indicated candidate cell. In order to minimize the data interruption of the source cell due to CFRA towards the candidate cell(s), the UE does not receive random access response from the network for the purpose of TA value acquisition and the TA value of the candidate cell is indicated in the cell switch command. The UE does not maintain the TA timer for the candidate cell and relies on network implementation to guarantee the TA validity.

5. The UE performs L1 measurements on the configured LTM candidate cell(s) and transmits L1 measurement reports to the gNB. L1 measurement should be performed as long as RRC reconfiguration (step 2) is applicable. The UE can also perform L3 measurement reporting to the gNB, including beam level measurement results on cell(s) which are configured as LTM candidate cell(s) according to the received network configuration.

6. The gNB decides to execute cell switch to a target cell and transmits an LTM cell switch command MAC CE triggering cell switch by including a target configuration ID which indicates the index of the candidate configuration of the target cell, a beam indicated with a TCI state or beams indicated with DL and UL TCI states, and a timing advance command for the target cell, if available. The UE switches to the target cell and applies the candidate configuration indicated by the target configuration ID.

7. The UE performs the random access procedure towards the target cell, if UE does not have valid TA of the target cell as specified in clause 5.18.35 of TS 38.321[6].

8. The UE completes the LTM cell switch procedure by sending *RRCReconfigurationComplete* message to target cell. If the UE has performed a RA procedure in step 7 the UE considers that LTM cell switch execution is successfully completed when the random access procedure is successfully completed. For RACH-less LTM, the UE considers that LTM cell switch execution is successfully completed when the UE determines that the network has successfully received its first UL data.

The steps 4-8 can be performed multiple times for subsequent LTM cell switch executions using the LTM candidate configuration(s) provided in step 2.

The procedure over the air interface described in Figure 9.2.3.5.2-1 is applicable to both intra-gNB-DU LTM and inter-gNB-DU LTM. The overall LTM procedures over F1-C interface are captured in TS 38.401[4].

##### 9.2.3.5.3 U-Plane Handling

After receiving an LTM cell switch command MAC CE, the UE performs MAC reset. Whether the UE performs RLC re-establishment and PDCP data recovery during cell switch is explicitly controlled by the network through RRC signalling.

#### 9.2.3.6 RACH-less handover

During intra-gNB HO procedure, RACH-less handover can be configured for a UE. The RACH-less handover procedure applies the following functionality:

- The UE uses the same timing advance value (i.e., NTA value) at the target cell as in the source cell or timing advance value (i.e., NTA value) of 0.

- The handover command for the UE may contain a beam identifier for the beam to be used by the UE at the target cell. The beam may be determined based on a UE measurement report and/or left up to gNB implementation, e.g., using the target cell's knowledge about the beam(s) used by the UE at the co-located source cell.

- The handover command may include a configured UL grant. UE can fallback to RACH when there is no valid configured uplink grant. Alternatively, an UL grant is dynamically signalled by the target cell.

- The UE transmits the *RRCReconfigurationComplete* message using the configured or dynamically signalled UL grant. Successful UL data reception on the target cell terminates the RACH-less handover execution.

### 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. 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.

The corresponding high-level measurement model is described below:



Figure 9.2.4-1: Measurement Model

NOTE 1: K beams correspond to the measurements on SSB 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**: measurements (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. 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 TS 38.133 [13]. Layer 3 filtering for cell quality and related parameters used are specified in TS 38.331 [12] and do 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 TS 38.331 [12] and do not introduce any delay in the sample availability between A1 and E.

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;

- The number of non-serving cells to be reported can be limited through configuration by the network;

- Cells belonging to an exclude-list configured by the network are not used in event evaluation and reporting, and conversely when an allow-list is configured by the network, only the cells belonging to the allow-list 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).

Intra-frequency neighbour (cell) measurements and inter-frequency neighbour (cell) measurements are defined as follows:

- SSB based intra-frequency measurement: a measurement is defined as an SSB based intra-frequency measurement provided the center frequency of the SSB of the serving cell and the center frequency of the SSB of the neighbour cell are the same, and the subcarrier spacing of the two SSBs is also the same.

- SSB based inter-frequency measurement: a measurement is defined as an SSB based inter-frequency measurement provided the center frequency of the SSB of the serving cell and the center frequency of the SSB of the neighbour cell are different, or the subcarrier spacing of the two SSBs is different.

NOTE 2: For SSB based measurements, one measurement object corresponds to one SSB and the UE considers different SSBs as different cells.

NOTE 2a: If a UE is configured to perform serving cell measurements based on an NCD-SSB configured in its active BWP, this NCD-SSB is considered as the SSB of the serving cell in the definition of intra-frequency and inter-frequency measurements as above.

- CSI-RS based intra-frequency measurement: a measurement is defined as a CSI-RS based intra-frequency measurement provided that:

- The subcarrier spacing of CSI-RS resources on the neighbour cell configured for measurement is the same as the SCS of CSI-RS resources on the serving cell indicated for measurement; and

- For 60kHz subcarrier spacing, the CP type of CSI-RS resources on the neighbour cell configured for measurement is the same as the CP type of CSI-RS resources on the serving cell indicated for measurement; and

- The centre frequency of CSI-RS resources on the neighbour cell configured for measurement is the same as the centre frequency of CSI-RS resource on the serving cell indicated for measurement.

- CSI-RS based inter-frequency measurement: a measurement is defined as a CSI-RS based inter-frequency measurement if it is not a CSI-RS based intra-frequency measurement.

NOTE 3: Extended CP for CSI-RS based measurement is not supported in this release.

Whether a measurement is non-gap-assisted or gap-assisted depends on the capability of the UE, the active BWP of the UE and the current operating frequency:

- For SSB based inter-frequency measurement, if the measurement gap requirement information is reported by the UE, a measurement gap configuration may be provided according to the information. Otherwise, a measurement gap configuration is always provided in the following cases:

- If the UE only supports per-UE measurement gaps;

- If the UE supports per-FR measurement gaps and any of the serving cells are in the same frequency range of the measurement object.

- For SSB based intra-frequency measurement, if the measurement gap requirement information is reported by the UE, a measurement gap configuration may be provided according to the information. Otherwise, a measurement gap configuration is always provided in the following case:

- Other than the initial BWP, if any of the UE configured BWPs do not contain the frequency domain resources of the SSB associated to the initial DL BWP, and are not configured with NCD-SSB for serving cell measurement.

- For CSI-RS based intra-frequency measurement, no measurement gap is needed;

- For CSI-RS based inter-frequency measurement, a measurement gap configuration is always provided in the following cases:

- If the UE only supports per-UE measurement gaps;

- If the UE supports per-FR measurement gaps and any of the serving cells are in the same frequency range of the measurement object.

In non-gap-assisted scenarios, the UE shall be able to carry out such measurements without measurement gaps. In gap-assisted scenarios, the UE cannot be assumed to be able to carry out such measurements without measurement gaps.

Network may request the UE to measure NR and/or E-UTRA carriers in RRC\_IDLE or RRC\_INACTIVE via system information or via dedicated measurement configuration in *RRCRelease*. If the UE was configured to perform measurements of NR and/or E-UTRA carriers while in RRC\_IDLE or in RRC\_INACTIVE, it may provide an indication of the availability of corresponding measurement results to the gNB in the *RRCSetupComplete* message. The network may request the UE to report those measurements after security activation. The request for the measurements can be sent by the network immediately after transmitting the Security Mode Command (i.e. before the reception of the Security Mode Complete from the UE).

If the UE was configured to perform measurements of NR and/or E-UTRA carriers while in RRC\_INACTIVE, the gNB can request the UE to provide corresponding measurement results in the *RRCResume* message and then the UE can include the available measurement results in the *RRCResumeComplete* message. Alternatively, the UE may provide an indication of the availability of the measurement results to the gNB in the *RRCResumeComplete* message and the gNB can then request the UE to provide these measurement results.

### 9.2.5 Paging

Paging allows the network to reach UEs in RRC\_IDLE and in RRC\_INACTIVE state through *Paging* messages, and to notify UEs in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED state of system information change (see clause 7.3.3) and ETWS/CMAS indications (see clause 16.4) through *Short Messages*. Both *Paging* messages and *Short Messages* are addressed with P-RNTI on PDCCH, but while the former is sent on PCCH, the latter is sent over PDCCH directly (see clause 6.5 of TS 38.331 [12]).

While in RRC\_IDLE the UE monitors the paging channels for CN-initiated paging. While in RRC\_INACTIVE with no ongoing SDT procedure (see clause 18.0) the UE monitors paging channels for RAN-initiated paging and CN-initiated paging. A UE need not monitor paging channels continuously though; Paging DRX is defined where the UE in RRC\_IDLE or RRC\_INACTIVE is only required to monitor paging channels during one Paging Occasion (PO) per DRX cycle (see TS 38.304 [10]). The Paging DRX cycles are configured by the network:

1) For CN-initiated paging, a default cycle is broadcast in system information;

2) For CN-initiated paging, a UE specific cycle can be configured via NAS signalling;

3) For RAN-initiated paging, a UE-specific cycle is configured via RRC signalling;

- The UE uses the shortest of the DRX cycles applicable i.e. a UE in RRC\_IDLE uses the shortest of the first two cycles above, while a UE in RRC\_INACTIVE uses the shortest of the three.

The POs of a UE for CN-initiated and RAN-initiated paging are based on the same UE ID, resulting in overlapping POs for both. The number of different POs in a DRX cycle is configurable via system information and a network may distribute UEs to those POs based on their IDs.

While in RRC\_CONNECTED and while in RRC\_INACTIVE with ongoing SDT procedure, the UE monitors the paging channels in any PO signalled in system information for SI change indication and PWS notification. In case of BA, a UE in RRC\_CONNECTED only monitors paging channels on the active BWP with common search space configured.

For operation with shared spectrum channel access, a UE can be configured for an additional number of PDCCH monitoring occasions in its PO to monitor for paging. However, when the UE detects a PDCCH transmission within the UE's PO addressed with P-RNTI, the UE is not required to monitor the subsequent PDCCH monitoring occasions within this PO.

If Paging Cause is included in the Paging message, a UE in RRC\_IDLE or RRC\_INACTIVE state may use the Paging Cause as per TS 23.501[3].

**Paging optimization for UEs in CM\_IDLE**: at UE context release, the NG-RAN node may provide the AMF with a list of recommended cells and NG-RAN nodes as assistance info for subsequent paging. The AMF may also provide Paging Attempt Information consisting of a Paging Attempt Count and the Intended Number of Paging Attempts and may include the Next Paging Area Scope. If Paging Attempt Information is included in the Paging message, each paged NG-RAN node receives the same information during a paging attempt. The Paging Attempt Count shall be increased by one at each new paging attempt. The Next Paging Area Scope, when present, indicates whether the AMF plans to modify the paging area currently selected at next paging attempt. If the UE has changed its state to CM CONNECTED the Paging Attempt Count is reset.

**Paging optimization for UEs in RRC\_INACTIVE**: at RAN Paging, the serving NG-RAN node provides RAN Paging area information. The serving NG-RAN node may also provide RAN Paging attempt information. Each paged NG-RAN node receives the same RAN Paging attempt information during a paging attempt with the following content: Paging Attempt Count, the intended number of paging attempts and the Next Paging Area Scope. The Paging Attempt Count shall be increased by one at each new paging attempt. The Next Paging Area Scope, when present, indicates whether the serving NG\_RAN node plans to modify the RAN Paging Area currently selected at next paging attempt. If the UE leaves RRC\_INACTIVE state the Paging Attempt Count is reset.

**UE power saving for paging monitoring:** in order to reduce UE power consumption due to false paging alarms, the group of UEs monitoring the same PO can be further divided into multiple subgroups. With subgrouping, a UE shall monitor PDCCH in its PO for paging if the subgroup to which the UE belongs is paged as indicated via associated PEI. If a UE cannot find its subgroup ID with the PEI configurations in a cell or if the UE is unable to monitor the associated PEI occasion corresponding to its PO, it shall monitor the paging in its PO.

These subgroups have the following characteristics:

- They are formed based on either CN controlled subgrouping or UE ID based subgrouping;

- If CN controlled subgroup ID is not provided from AMF, UE ID based subgrouping is used if supported by the UE and network;

- The RRC state (RRC\_IDLE or RRC\_INACTIVE state) does not impact which subgroup the UE belongs to;

- Subgrouping support for a cell is broadcast in the system information as one of the following: Only CN controlled subgrouping supported, only UE ID based subgrouping supported, or both CN controlled subgrouping and UE ID based subgrouping supported;

- Total number of subgroups allowed in a cell is up to 8 and represents the sum of CN controlled and UE ID based subgrouping configured by the network;

- A UE configured with CN controlled subgroup ID applies CN controlled subgroup ID if the cell supports CN controlled subgrouping; otherwise, it derives UE ID based subgroup ID if the cell supports only UE ID based subgrouping.

PEI associated with subgroups has the following characteristics:

- If the PEI is supported by the UE, it shall at least support UE ID based subgrouping method;

- PEI monitoring can be limited via system information to the last used cell (i.e., the cell in which the UE most recently received *RRCRelease* without indicating that the last used cell for PEI shall not be updated);

- A PEI-capable UE shall store its last used cell information;

- gNBs supporting the PEI monitoring to the last used cell function provide the UE's last used cell information to the AMF in the NG-AP UE Context Release Complete message for PEI capable UEs, as described in TS 38.413 [26];

- UE that expects MBS group notification shall ignore the PEI and shall monitor paging in its PO.

**CN controlled subgrouping:** For CN controlled subgrouping, AMF is responsible for assigning subgroup ID to the UE. The total number of subgroups for CN controlled subgrouping which can be configured, e.g. by OAM is up to 8. It is assumed that CN controlled subgrouping support is homogeneous within an RNA.

The following figure describes the procedure for CN controlled subgrouping:



Figure 9.2.5-1: Procedure for CN controlled subgrouping

1. The UE indicates its support of CN controlled subgrouping via NAS signalling.

2. If the UE supports CN controlled subgrouping, the AMF determines the subgroup ID assignment for the UE.

3. The AMF sends subgroup ID to the UE via NAS signalling.

4. The AMF informs the gNB about the CN assigned subgroup ID for paging the UE in RRC\_IDLE/ RRC\_INACTIVE state.

5. When the paging message for the UE is received from the CN or is generated by the gNB, the gNB determines the PO and the associated PEI occasion for the UE.

6. Before the UE is paged in the PO, the gNB transmits the associated PEI and indicates the corresponding CN controlled subgroup of the UE that is to be paged in the PEI.

**UE ID based subgrouping:** For UE ID based subgrouping, the gNB and UE can determine the subgroup ID based on the UE ID and the total number of subgroups for UE ID based subgrouping in the cell. The total number of subgroups for UE ID based subgrouping is decided by the gNB for each cell and can be different in different cells. The following figure describes the procedure for UE ID based subgrouping:



Figure 9.2.5-2: Procedure for UE ID based subgrouping

1. The gNB determines the total number of subgroups for UE ID based subgrouping in a cell.

2. The gNB broadcasts the total number of subgroups for UE ID based subgrouping in a cell.

3. UE determines its subgroup in a cell.

4. When paging message for the PEI capable UE is received from the CN at the gNB or is generated by the gNB, the gNB determines the PO and the associated PEI occasion for the UE.

5. Before the UE is paged in the PO, the gNB transmits the associated PEI and indicates the corresponding subgroup derived based on UE ID of the UE that is paged in the PEI.

**Paging adaptation for network energy saving** **for UEs in CM\_IDLE and RRC\_INACTIVE**: in order to increase gNB sleeping time, the value of N and Ns are extended to increase the number of POs per PF with sparser PFs. The UE supporting paging adaptation shall monitor PDCCH in POs separately signalled for paging adaptation, if configured. The UE supporting paging adaptation and PEI can monitor PEIs separately signalled for paging adaptation, if configured.

### 9.2.6 Random Access Procedure

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

- Initial access from RRC\_IDLE;

- RRC Connection Re-establishment procedure;

- DL or UL data arrival, during RRC\_CONNECTED or during RRC\_INACTIVE while SDT procedure (see clause 18.0) is ongoing, when UL synchronisation status is "non-synchronised";

- UL data arrival, during RRC\_CONNECTED or during RRC\_INACTIVE while SDT procedure is ongoing, when there are no PUCCH resources for SR available;

- Handover, except for when RACH-less HO is configured;

- SR failure;

- Explicit request by RRC upon synchronous reconfiguration;

- RRC Connection Resume procedure from RRC\_INACTIVE;

- To establish time alignment for a primary or a secondary TAG;

- Request for Other SI (see clause 7.3);

- Request for OD-SIB1 (see clause 7.3);

- Beam failure recovery;

- Consistent UL LBT failure on SpCell;

- SDT in RRC\_INACTIVE (see clause 18);

- Positioning purpose during RRC\_CONNECTED requiring random access procedure, e.g., when timing advance is needed for UE positioning;

- Early UL synchronization with an LTM candidate cell;

- RACH-based LTM cell switch.

Two types of random access procedure are supported: 4-step RA type with MSG1 and 2-step RA type with MSGA. Both types of RA procedure support contention-based random access (CBRA) and contention-free random access (CFRA) as shown on Figure 9.2.6-1 below.

The UE selects the type of random access at initiation of the random access procedure based on network configuration:

- when CFRA resources are not configured, an RSRP threshold is used by the UE to select between 2-step RA type and 4-step RA type;

- when CFRA resources for 4-step RA type are configured, UE performs random access with 4-step RA type;

- when CFRA resources for 2-step RA type are configured, UE performs random access with 2-step RA type.

The network does not configure CFRA resources for 4-step and 2-step RA types at the same time for a Bandwidth Part (BWP). CFRA with 2-step RA type is only supported for handover.

The MSG1 of the 4-step RA type consists of a preamble on PRACH. After MSG1 transmission, the UE monitors for a response from the network within a configured window. For CFRA, dedicated preamble for MSG1 transmission is assigned by the network and upon receiving random access response from the network, the UE ends the random access procedure as shown in Figure 9.2.6-1(c). For CBRA, upon reception of the random access response, the UE sends MSG3 using the UL grant scheduled in the response and monitors contention resolution as shown in Figure 9.2.6-1(a). If contention resolution is not successful after MSG3 (re)transmission(s), the UE goes back to MSG1 transmission.

The MSGA of the 2-step RA type includes a preamble on PRACH and a payload on PUSCH. After MSGA transmission, the UE monitors for a response from the network within a configured window. For CFRA, dedicated preamble and PUSCH resource are configured for MSGA transmission and upon receiving the network response, the UE ends the random access procedure as shown in Figure 9.2.6-1(d). For CBRA, if contention resolution is successful upon receiving the network response, the UE ends the random access procedure as shown in Figure 9.2.6-1(b); while if fallback indication is received in MSGB, the UE performs MSG3 transmission using the UL grant scheduled in the fallback indication and monitors contention resolution as shown in Figure 9.2.6-2. If contention resolution is not successful after MSG3 (re)transmission(s), the UE goes back to MSGA transmission.

If the random access procedure with 2-step RA type is not completed after a number of MSGA transmissions, the UE can be configured to switch to CBRA with 4-step RA type.

For the random access procedure towards an LTM candidate cell for early UL TA acquisition, CFRA triggered by a PDCCH order is used. The UE sends MSG1 towards the cell without monitoring for a response from it as shown in Figure 9.2.6-1 (e). To support UE power ramping, the UE may perform MSG1 retransmission as indicated by the network.

 

(a) CBRA with 4-step RA type (b) CBRA with 2-step RA type

 

(c) CFRA with 4-step RA type (d) CFRA with 2-step RA type



(e) CFRA without network response with 4-step RA type

Figure 9.2.6-1: Random Access Procedures



Figure 9.2.6-2: Fallback for CBRA with 2-step RA type

For random access in a cell configured with SUL, the network can explicitly signal which carrier to use (UL or SUL). Otherwise, the UE selects the SUL carrier if and only if the measured quality of the DL is lower than a broadcast threshold. UE performs carrier selection before selecting between 2-step and 4-step RA type. The RSRP threshold for selecting between 2-step and 4-step RA type can be configured separately for UL and SUL. Once started, all uplink transmissions of the random access procedure remain on the selected carrier.

The network can associate a set of RACH resources with feature(s) applicable to a Random Access procedure: Network Slicing (see clause 16.3), (e)RedCap (see clause 16.13), SDT (see clause 18), and NR coverage enhancement (see clause 19). A set of RACH resources associated with a feature is only valid for random access procedures applicable to at least that feature; and a set of RACH resources associated with several features is only valid for random access procedures having at least all of these features. The UE selects the set(s) of applicable RACH resources, after uplink carrier (i.e. NUL or SUL) and BWP selection and before selecting the RA type.

When CA is configured, random access procedure with 2-step RA type is only performed on SpCell while contention resolution can be cross-scheduled by the SpCell.

When CA is configured, for random access procedure with 4-step RA type, the first three steps of CBRA always occur on the SpCell while contention resolution (step 4) can be cross-scheduled by the SpCell. The three steps of a CFRA started on the SpCell remain on the SpCell. CFRA on SCell can only be initiated by the gNB to establish timing advance for a secondary TAG: the procedure is initiated by the gNB with a PDCCH order (step 0) that is sent on an activated SCell of the secondary TAG, preamble transmission (step 1) takes place on the SCell, and Random Access Response (step 2) takes place on SpCell.

When two TAG IDs are configured for the serving cell, the TAG for which the TA command is applied is indicated in Random Access Response message or in MSGB. To establish timing advance for the other PTAG, CFRA is initiated by the gNB with a PDCCH order.

### 9.2.7 Radio Link Failure

In RRC\_CONNECTED, the UE performs Radio Link Monitoring (RLM) in the active BWP based on reference signals (SSB/CSI-RS) and signal quality thresholds configured by the network. SSB-based RLM is based on the CD-SSB associated to the initial DL BWP and can be configured for the initial DL BWP, for DL BWPs containing the CD-SSB associated to the initial DL BWP, and, if supported, for DL BWPs not containing the CD-SSB associated to the initial DL BWP. Besides, SSB-based RLM can be also performed based on a non-cell defining SSB, if configured for the active DL BWP. RLM can be also performed based on CSI-RS, if configured for the active DL BWP. In case of DAPS handover, the UE continues the detection of radio link failure at the source cell until the successful completion of the random access procedure to the target cell.

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

- Expiry of a radio problem timer started after indication of radio problems from the physical layer (if radio problems are recovered before the timer is expired, the UE stops the timer); or

- Expiry of a timer started upon triggering a measurement report for a measurement identity for which the timer has been configured while another radio problem timer is running; or

- Random access procedure failure; or

- RLC failure; or

- Detection of consistent uplink LBT failures for operation with shared spectrum channel access as described in 5.6.1; or

- For IAB-MT, the reception of a BH RLF indication received from its parent node.

After RLF is declared, the UE:

- stays in RRC\_CONNECTED;

- in case of DAPS handover, for RLF in the source cell:

- stops any data transmission or reception via the source link and releases the source link, but maintains the source RRC configuration;

- if handover failure is then declared at the target cell, the UE:

- selects a suitable cell and then initiates RRC re-establishment;

- enters RRC\_IDLE if a suitable cell was not found within a certain time after handover failure was declared.

- in case of CHO, for RLF in the source cell:

- selects a suitable cell and if the selected cell is a CHO candidate and if network configured the UE to try CHO after RLF then the UE attempts CHO execution once, otherwise re-establishment is performed;

- enters RRC\_IDLE if a suitable cell was not found within a certain time after RLF was declared.

- in case of MCG LTM, for RLF in the source cell:

- selects a suitable cell and if the selected cell is an LTM candidate cell and if network configured the UE to try LTM after RLF then the UE attempts RACH-based LTM execution once, otherwise re-establishment is performed;

- enters RRC\_IDLE if a suitable cell was not found within a certain time after RLF was declared.

- otherwise, for RLF in the serving cell or in case of DAPS handover, for RLF in the target cell before releasing the source cell:

- selects a suitable cell and then initiates RRC re-establishment;

- enters RRC\_IDLE if a suitable cell was not found within a certain time after RLF was declared.

When RLF occurs at the IAB BH link, the same mechanisms and procedures are applied as for the access link. This includes BH RLF detection and RLF recovery.

The IAB-DU can transmit a BH RLF detection indication to its child nodes in the following cases:

- The collocated IAB-MT initiates RRC re-establishment;

- The collocated IAB-MT is dual-connected, detects BH RLF on a BH link, and cannot perform UL re-routing for any traffic. This includes the scenario of an IAB-node operating in EN-DC or NR-DC, which uses only one link for backhauling and has BH RLF on this BH link;

- The collocated IAB-MT has received a BH RLF detection indication from a parent node, and there is no remaining backhaul link that is unaffected by the BH RLF condition indicated.

Upon reception of the BH RLF detection indication, the child node may perform local rerouting for upstream traffic, if possible, over an available BH link.

If the IAB-DU has transmitted a BH RLF detection indication to a child node due to an RLF condition on the collocated IAB-MT's parent link, and the collocated IAB-MT's subsequent RLF recovery is successful, the IAB-DU may transmit a BH RLF recovery indication to this child node.

If the IAB-DU has transmitted a BH RLF detection indication to a child node due to the reception of a BH RLF detection indication by the collocated IAB-MT, and the collocated IAB-MT receives a BH RLF recovery indication, the IAB-DU may also transmit a BH RLF recovery indication to this child node.

Upon reception of the BH RLF recovery indication, the child node reverts the actions triggered by the reception of the previous BH RLF detection indication.

In case the RRC re-establishment procedure fails, the IAB-node may transmit a BH RLF indication to its child nodes. The BH RLF detection indication, BH RLF recovery indication and BH RLF indication are transmitted as BAP Control PDUs.

*Unchanged Text is omitted*

# 15 Self-Configuration and Self-Optimisation

## 15.1 Definitions

Void.

## 15.2 Void

## 15.3 Self-configuration

### 15.3.1 Dynamic configuration of the NG-C interface

#### 15.3.1.1 Prerequisites

The following prerequisites are assumed:

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

#### 15.3.1.2 SCTP initialization

NG-RAN establishes the first SCTP (IETF RFC 4960 [23]) using a configured IP address.

NOTE: The NG-RAN node may use different source and/or destination IP end point(s) if the SCTP establishment towards one IP end point fails. How the NG-RAN node gets the remote IP end point(s) and its own IP address are outside the scope of this specification.

#### 15.3.1.3 Application layer initialization

Once SCTP connectivity has been established, the NG-RAN node and the AMF shall exchange application level configuration data over NGAP with the NG Setup procedure, which is needed for these two nodes to interwork correctly on the NG interface:

- The NG-RAN node 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 NG-RAN node, 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.

After the application layer initialization is successfully completed, the AMF may add or update or remove SCTP endpoints to be used for NG-C signalling between the AMF and the NG-RAN node pair as specified in TS 23.501 [3].

### 15.3.2 Dynamic Configuration of the Xn interface

#### 15.3.2.1 Prerequisites

The following prerequisites are necessary:

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

#### 15.3.2.2 SCTP initialization

NG-RAN establishes the first SCTP (IETF RFC 4960 [23]) using a configured IP address.

NOTE: The NG-RAN node may use different source and/or destination IP end point(s) if the SCTP establishment towards one IP end point fails.

#### 15.3.2.3 Application layer initialization

Once SCTP connectivity has been established, the NG-RAN node and its candidate peer NG-RAN node are in a position to exchange application level configuration data over XnAP needed for the two nodes to interwork correctly on the Xn interface:

- The NG-RAN node provides the relevant configuration information to the candidate NG-RAN node, which includes served cell information;

- The candidate NG-RAN node provides the relevant configuration information to the initiating NG-RAN node, which includes served cell information;

- When the application layer initialization is successfully concluded, the dynamic configuration procedure is completed and the Xn interface is operational;

- The NG-RAN node shall keep neighbouring NG-RAN nodes updated with the complete list of served cells, or, if requested by the peer NG-RAN node, by a limited list of served cells, while the Xn interface is operational.

### 15.3.3 Automatic Neighbour Cell Relation Function

#### 15.3.3.1 General

The purpose of ANR function is to relieve the operator from the burden of manually managing NCRs. Figure 15.3.3.1-1 shows ANR and its environment:



Figure 15.3.3.1-1: Interaction between gNB and OAM due to ANR

The ANR function resides in the gNB and manages the Neighbour Cell Relation Table (NCRT). Located within ANR, the Neighbour Detection Function finds new neighbours and adds them to the NCRT. ANR also contains the Neighbour Removal Function which removes outdated NCRs. The Neighbour Detection Function and the Neighbour Removal Function are implementation specific.

An existing NCR from a source cell to a target cell means that gNB controlling the source cell:

a) Knows the global and physical IDs (e.g. NR CGI/NR PCI, ECGI/PCI) of the target cell; and

b) Has an entry in the NCRT for the source cell identifying the target cell; and

c) Has the attributes in this NCRT entry defined, either by OAM or set to default values.

NCRs are cell-to-cell relations, while an Xn link is set up between two gNBs. Neighbour Cell Relations are unidirectional, while an Xn link is bidirectional.

NOTE: The neighbour information exchange, which occurs during the Xn Setup procedure or in the gNB Configuration Update procedure, may be used for ANR purpose.

The ANR function also allows OAM to manage the NCRT. OAM can add and delete NCRs. It can also change the attributes of the NCRT. The OAM system is informed about changes in the NCRT.

#### 15.3.3.2 Intra-system Automatic Neighbour Cell Relation Function

ANR relies on NCGI (see clause 8.2) and ANR reporting of E-UTRA cells as specified in TS 36.300 [2].



Figure 15.3.3.2-1: Automatic Neighbour Relation Function

Figure 15.3.3.2-1 depicts an example where the NG-RAN node serving cell A has an ANR function. In RRC\_CONNECTED, the NG-RAN node instructs each UE to perform measurements on neighbour cells. The NG-RAN node may use different policies for instructing the UE to do measurements, and when to report them to the NG-RAN node. This measurement procedure is as specified in TS 38.331[12] and TS 36.331 [29].

1. The UE sends a measurement report regarding cell B. This report contains Cell B's PCI, but not its NCGI/ECGI.

When the NG-RAN node receives a UE measurement report containing the PCI, the following sequence may be used.

2. The NG-RAN node instructs the UE, using the newly discovered PCI as parameter, to read all the broadcast NCGI(s) /ECGI(s), TAC(s), RANAC(s), PLMN ID(s) and, for neighbour NR cells, NR frequency band(s) and the gNB ID length(s). To do so, the NG-RAN node may need to schedule appropriate idle periods to allow the UE to read the NCGI/ECGI from the broadcast channel of the detected neighbour cell. How the UE reads the NCGI/ECGI is specified in TS 38.331 [12] and TS 36.331 [29].

3. When the UE has found out the new cell's NCGI(s) /ECGI(s), the UE reports all the broadcast NCGI(s)/ECGI(s) to the serving cell NG-RAN node. In addition, the UE reports all the tracking area code(s), RANAC(s), PLMN IDs and, for neighbour NR cells, NR frequency band(s), and the gNB ID length(s) that have been read by the UE. In case the detected NR cell does not broadcast SIB1, the UE may report *noSIB1* indication as specified in TS 38.331 [12].

4. The NG-RAN node decides to add this neighbour relation, and can use PCI and NCGI(s)/ECGI(s) to:

a. Lookup a transport layer address to the new NG-RAN node;

b. Update the Neighbour Cell Relation List;

c. If needed, setup a new Xn interface towards this NG-RAN node.

#### 15.3.3.3 Void

#### 15.3.3.4 Void

#### 15.3.3.5 Inter-system Automatic Neighbour Cell Relation Function

For Inter-system ANR, each cell contains an Inter Frequency Search list. This list contains all frequencies that shall be searched. Figure 15.3.3.5-1 depicts an example where the NG-RAN node serving cell A has an ANR function.



Figure 15.3.3.5-1: Automatic Neighbour Relation Function in case of E-UTRAN detected cell

In RRC\_CONNECTED, the NG-RAN node instructs a UE to perform measurements and detect E-UTRA cells connected to EPC.:

1 The NG-RAN node instructs a UE to look for neighbour cells in the target system. To do so the NG-RAN node may need to schedule appropriate idle periods to allow the UE to scan all cells in the target system.

2 The UE reports the PCI and carrier frequency of the detected cells in the target system.

NOTE: The NG-RAN node may use different policies for instructing the UE to do measurements, and when to report them to the NG-RAN node.

When the NG-RAN node receives the UE reports containing PCIs of cell(s), the following sequence may be used:

3 The NG-RAN node instructs the UE, using the newly discovered PCI as parameter, to read the ECGI, the TAC and all available PLMN ID(s) of the newly detected cell in case of E-UTRA detected cells. The UE ignores transmissions from the serving cell while finding the requested information transmitted in the broadcast channel of the detected inter-system/inter-frequency neighbour cell. To do so, the NG-RAN node may need to schedule appropriate idle periods to allow the UE to read the requested information from the broadcast channel of the detected inter-system neighbour cell.

4 After the UE has read the requested information in the new cell, it reports the detected ECGI, TAC, and available PLMN ID(s) to the serving cell NG-RAN node.

5 The NG-RAN node updates its inter-system NCRT.

### 15.3.4 Xn-C TNL address discovery

If the NG-RAN node is aware of the RAN node ID of the candidate NG-RAN node (e.g. via the ANR function) but not of a TNL address suitable for SCTP connectivity, then the NG-RAN node can utilize the 5GC (an AMF it is connected to) to determine the TNL address as follows:

- The NG-RAN node sends the UPLINK RAN CONFIGURATION TRANSFER message to the AMF to request the TNL address of the candidate NG-RAN node, and includes relevant information such as the source and target RAN node ID;

- The AMF relays the request by sending the DOWNLINK RAN CONFIGURATION TRANSFER message to the candidate NG-RAN node identified by the target RAN node ID;

- The candidate NG-RAN node responds by sending the UPLINK RAN CONFIGURATION TRANSFER message containing one or more TNL addresses to be used for SCTP connectivity with the initiating NG-RAN node, and includes other relevant information such as the source and target RAN node ID;

- The AMF relays the response by sending the DOWNLINK CONFIGURATION TRANSFER message to the initiating NG-RAN node identified by the target RAN node ID.

NOTE: Void.

The NG-RAN node may determine the gNB ID length of the candidate gNB based on, e.g. OAM configuration or UE reporting in ANR function. If the NG-RAN node is not able to make this determination, it may include the NR cell identifier in the UPLINK RAN CONFIGURATION TRANSFER message to the AMF. The AMF may, if supported, determine the target gNB ID by matching the NR cell identifier with a gNB ID of a gNB it connects to.

## 15.4 Support for Energy Saving

### 15.4.1 General

The aim of this function is to reduce operational expenses through energy savings.

The function allows, for example in a deployment where capacity boosters can be distinguished from cells providing basic coverage, to optimize energy consumption enabling the possibility for an E-UTRA or NR cell providing additional capacity via single or dual connectivity, to be switched off when its capacity is no longer needed and to be re-activated on a need basis, or to support various adaptation techniques in time, frequency, spatial and power domains.

### 15.4.2 Solution description

#### 15.4.2.1 Intra-system energy saving

The solution builds upon the possibility for the NG-RAN node owning a capacity booster cell to autonomously decide to switch-off such cell to lower energy consumption (inactive state). The decision is typically based on cell load information, consistently with configured information. The switch-off decision may also be taken by O&M.

The NG-RAN node may initiate handover actions in order to off-load the cell being switched off and may indicate the reason for handover with an appropriate cause value to support the target node in taking subsequent actions, e.g. when selecting the target cell for subsequent handovers.

All neighbour NG-RAN nodes are informed by the NG-RAN node owning the concerned cell about the switch-off actions over the Xn interface, by means of the NG-RAN node Configuration Update procedure.

All informed nodes maintain the cell configuration data, e.g., neighbour relationship configuration, also when a certain cell is inactive. If basic coverage is ensured by NG-RAN node cells, NG-RAN node owning non-capacity boosting cells may request a re-activation over the Xn interface if capacity needs in such cells demand to do so. This is achieved via the Cell Activation procedure. During switch off time period of the boost cell, the NG-RAN node may prevent idle mode UEs from camping on this cell and may prevent incoming handovers to the same cell.

The NG-RAN node receiving a request should act accordingly. The switch-on decision may also be taken by O&M. All peer NG-RAN nodes are informed by the NG-RAN node owning the concerned cell about the re-activation by an indication on the Xn interface.

The solution also builds upon the possibility for the NG-RAN node owning a coverage cell to request neighbouring NG-RAN node(s) owning a capacity booster cell to switch on some SSB beams within the cell which are deactivated. The receiving NG-RAN node should act accordingly.

The solution also builds upon the possibility for an NG-RAN node to page certain UEs (e.g., stationary UEs) in RRC\_INACTIVE state on a limited set of beams, instead of paging on all the beams within the cell. It is up to the gNB's implementation to select the UEs in RRC\_INACTIVE for which paging in limited set of beams applies. If the paging over the limited set of beams fails, the gNB performs subsequent paging by implementation, e.g., by ensuring the same paging message is repeated in all the transmitted SSB beams.

#### 15.4.2.2 Inter-system energy saving

The solution builds upon the possibility for the NG-RAN node owning a capacity booster cell to autonomously decide to switch-off such cell to dormant state. The decision is typically based on cell load information, consistently with configured information. The switch-off decision may also be taken by O&M. The NG-RAN node indicates the switch-off action to the eNB over NG interface and S1 interface. The NG-RAN node could also indicate the switch-on action to the eNB over NG interface and S1 interface.

The eNB providing basic coverage may request a NG-RAN node's cell re-activation based on its own cell load information or neighbour cell load information, the switch-on decision may also be taken by O&M. The eNB requests a NG-RAN node's cell re-activation and receives the NG-RAN node's cell re-activation reply from the NG-RAN node over the S1 interface and NG interface. Upon reception of the re-activation request, the NG-RAN node's cell should remain switched on at least until expiration of the minimum activation time. The minimum activation time may be configured by O&M or be left to the NG-RAN node's implementation.

#### 15.4.2.3 Cell DTX/DRX

To facilitate reducing gNB downlink transmission/uplink reception active time, UE can be configured with a periodic cell DTX/DRX pattern (i.e. active and non-active periods). The pattern configuration for cell DTX/DRX is common for the UEs configured with this feature in the cell. The cell DTX and cell DRX patterns can be configured and activated separately. A maximum of two cell DTX/DRX patterns can be configured per MAC entity for different serving cells. When cell DTX is configured and activated for the concerned cell, the UE may not monitor PDCCH in selected cases or does not monitor SPS occasions during cell DTX non-active duration. When cell DRX is configured and activated for the concerned cell, the UE does not transmit on CG resources or does not transmit a SR during cell DRX non-active duration. This feature is only applicable to UEs in RRC\_CONNECTED state and it does not impact Random Access procedure, SSB transmission, paging, and system information broadcasting. Cell DTX/DRX operation is only supported for single TRP scenario. Cell DTX/DRX can be activated/deactivated by RRC signalling or L1 group common signalling. Cell DTX/DRX is characterized by the following:

- **active duration**: duration that the UE waits for to receive PDCCHs or SPS occasions, and transmit SR or CG. In this duration, the gNB transmission/reception of PDCCH, SPS, SR, CG, periodic and semi-persistent CSI report are not impacted for the purpose of network energy saving;

- **cycle**: specifies the periodic repetition of the active-duration followed by a period of non-active duration.

Active duration and cycle parameters are common between cell DTX and cell DRX, when both are configured;

Once the gNB recognizes there is an emergency call or public safety related service, the network should ensure that there is no impact to that service (e.g. it may release or deactivate cell DTX/DRX configuration). The network should also ensure that there is at least partial overlapping between UE's connected mode DRX on-duration and cell DTX/DRX active duration, i.e. the UE's connected mode DRX periodicity is a multiple of cell DTX/DRX periodicity or vice versa.

#### 15.4.2.4 Conditional Handover

The same principle as described in 9.2.3.4 applies to conditional handover in case the source cell is using a network energy saving solution (e.g., the cell is activating cell DTX/DRX or turning off), unless hereunder specified. In this case, the following additional triggering conditions are supported, upon which UE may use NES-specific CHO event for executing CHO to a candidate cell, as defined in TS 38.331 [12]:

- The UE may be notified via DCI to enable CHO conditions(s) configured with NES event indication.

#### 15.4.2.5 Camping Restrictions

If a cell is activating or going to activate NES cell DTX/DRX, the cell can allow the access of UEs capable of NES cell DTX/DRX via a single bit in SIB1 but prevent the access of UEs not capable of cell DTX/DRX using barring mechanisms described in clause 7.4.

If a cell provides on-demand SIB1, the cell can allow the access of UEs supporting OD-SIB1 but prevent the access of UEs not supporting OD-SIB1 based on no SIB1 indication in MIB as described in clause 7.3.1.

#### 15.4.2.6 SSB-less SCell

For an intra-band or inter-band CA SCell, a UE may obtain timing reference and AGC source from another serving cell in case the UE is not provided with SSB nor SMTC configuration for this SCell, as described in TS 38.331 [12].

#### 15.4.2.7 Spatial and power domain adaptation

To assist the gNB on muting transceivers and/or adapting transmission power, the UE can be configured to report multiple CSI entries in a CSI report based on two or more sub-configurations, as specified in clause 5.2.1.6 in TS 38.214 [56]. Each sub-configuration corresponds to a spatial domain adaptation pattern (subsets of available spatial elements) and/or a power offset between PDSCH and CSI-RS.

#### 15.4.2.x1 On-demand SSB SCell

On-demand SSB-based SCell operations are supported for UEs in RRC\_CONNECTED configured with carrier aggregation (CA), applicable to both intra-band and inter-band CA configurations for FR1 and FR2 in non-shared spectrum. The OD-SSB transmission activation/deactivation command can only be transmitted to a UE configured with an SCell prior to or when receiving the SCell activation command. Both RRC and MAC-CE can be used for signalling the activation/deactivation state of OD-SSB transmissions. Additionally, the same MAC-CE can also update the transmission parameter of an activated OD-SSB after the SCell activation completion. The OD-SSB transmission deactivation can also be achieved implicitly based on the number of OD-SSB bursts to be transmitted configured by RRC. When there is no SSB on the SCell, the OD-SSB transmission is maintained while the SCell is activated. When SSB and OD-SSB have different centre frequencies in the SCell, only a single OD-SSB on a different centre frequency is supported. L3 measurement on OD-SSB is supported as specified in TS 38.331 [12].

Editor’s note: FFS whether to merge OD-SSB and SSB adaptation into one section.

#### 15.4.2.x2 On-demand SIB1

To facilitate reducing gNB downlink transmissions, instead of always periodically transmitting SIB1, the gNB can provide on-demand SIB1, i.e., upon receiving an OD-SIB1 request from a UE supporting OD-SIB1. OD-SIB1 is supported for UEs in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED when T311 is running. A request for SIB1 triggers a random access procedure, where MSG1 is used for indicating OD-SIB1 request and the gNB acknowledges the request in MSG2. OD-SIB1 request configurations of one or more cells which support OD-SIB1 are included in SIBxx, which can be broadcasted in any cell, including cell’s own OD-SIB1 request configuration. UE may request SIB1 based on the OD-SIB1 request configuration from SIBxx in order to determine the suitability of a cell during and after cell reselection.

#### 15.4.2.x3 Common signal/channel transmissions adaptation

For adaptation of paging in time domain, the value range for parameter N is extended to make it possible to have increased interval between PFs. The value range for Ns, which is the number of paging occasions within one paging frame, is increased to compensate the decrease in the number of PFs. UEs supporting paging adaption and PEI can monitor PEI according to the additional PEI configuration, if configured.

Adaptation of SSB in time domain is supported for SCells for UEs in RRC\_CONNECTED configured with carrier aggregation (CA). SSB adaptation is indicated via DCI. Multiple SMTC configurations can be configured to the UE, and the UE selects one SMTC based on the SSB adaptation indication.

Adaptation of PRACH configurations in time domain is supported for 4-step RACH CBRA. Furthermore, additional PRACH resource 1-bit indication in PDCCH-order applies to both CFRA and CBRA in the serving cell. Additional RACH resources are configured together with the common RACH resources in the same set of RACH resources, and the network can indicate whether the additional RACH resources are available as specified in section 8.1 of TS 38.213 [38].

### 15.4.3 O&M requirements

Operators should be able to configure the energy saving function.

The configured information should include:

- The ability of an NG-RAN node to perform autonomous cell switch-off;

- The ability of an NG-RAN node to request the re-activation of a configured list of inactive cells owned by a peer NG-RAN node.

O&M may also configure:

- policies used by the NG-RAN node for cell switch-off decision;

- policies used by peer NG-RAN nodes for requesting the re-activation of an inactive cell;

- The minimum time an NG-RAN node's cell should remain activated upon reception of a re-activation request from an eNB.

*End of changes*