**3GPP TSG-RAN2 Meeting #131 *R2-250xxxx***

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

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| *CR-Form-v12.3* |
| **CHANGE REQUEST** |
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|  | **38.300** | **CR** | **1013** | **rev** | **1** | **Current version:** | **18.6.0** |  |
|  |
| *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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|  |
| ***Title:***  | Introduction of Network Energy Savings Enhancements  |
|  |  |
| ***Source to WG:*** | Huawei, HiSilicon  |
| ***Source to TSG:*** | R2 |
|  |  |
| ***Work item code:*** | Netw\_Energy\_NR\_enh-Core |  | ***Date:*** | 2025-09-09 |
|  |  |  |  |  |
| ***Category:*** | **B** |  | ***Release:*** | Rel-19 |
|  | *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 canbe 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, including the support for:* On-demand SSB SCell operation
* On-demand SIB1 for UEs in idle/inactive mode
* Adaptation of common signal/channel transmissions
 |
|  |  |
| ***Consequences if not approved:*** | No support for Release-19 Network Energy Savings Enhancements.  |
|  |  |
| ***Clauses affected:*** | 3.1, 5.2.5.5, 7.3.1, 7.3.2, 9.2.4, 9.2.5, 9.2.6, 15.4.2.5, 15.4.2 |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** | **X** |  |  Other core specifications  | TS 38.304 CR 0442TS 38.306 CR 1321TS 38.321 CR 2110TS 38.331 CR 5428TS 38.331 CR 5403TS 38.423 CR 1436TS 38.401 CR 0480TS 38.420 CR 0049 |
| ***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

HSDN High Speed Dedicated Network

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

TN Terrestrial Network

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

*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*

### 9.2.4 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 SSB frequency configured in the measurement object associated with 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 SSB frequency configured in the measurement object associated with 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.

NOTE 2b: The above measurement object associated with the serving cell refers to the serving cell measurement object for OD-SSB when OD-SSB is activated, otherwise it refers to the serving cell measurement object for SSB.

- 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:

- If the serving cell is associated with SSB, 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;

- If the serving cell is not associated with SSB (i.e. SSB-less SCell), if the initial BWP or any of the UE configured BWPs do not contain the SSB frequency configured in the measurement object associated with the serving cell, 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 RRC\_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*

## 15.4 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].

#### 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 as specified in TS 38.331 [12].

A gNB may request neighbour gNB(s) over the Xn interface to transmit or stop transmitting the OD-SIB1 configuration for a cell supporting OD-SIB1. The neighbour gNB(s) deciding to stop the OD-SIB1 configuration transmission informs the requesting gNB over Xn. The inter-gNB coordination procedures are defined in TS 38.401 [4].

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

For adaptation of paging in time domain, the value range for parameter N, which is the number of paging frames in one paging cycle, 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 via DCI 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*