**3GPP TSG-RAN WG2 Meeting #124 *R2-231xxxx***

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| **CHANGE REQUEST** |
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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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|  |
| ***Title:***  | Introduction of Network Energy Savings |
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| ***Source to WG:*** | Ericsson |
| ***Source to TSG:*** | R2 |
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| ***Work item code:*** | Netw\_Energy\_NR-Core |  | ***Date:*** | 2023-12-01 |
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| ***Category:*** | **B** |  | ***Release:*** | Rel-18 |
|  | *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-16 (Release 16)Rel-17 (Release 17)Rel-18 (Release 18)Rel-19 (Release 19)* |
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| ***Reason for change:*** | Feature addition for Network energy savings techniques  |
|  |  |
| ***Summary of change:*** | * Add new abbreviation for DTX
* Add new clause for “Cell DTX/DRX”
* Add new clause for “Conditional Handover”
* Add new clause for “Mobility in RRC\_IDLE and RRC\_INACTIVE”
* Add new clause for “Inter-band SSB-less”
* Update of clause 10.2,10.3 and 11 to account for cell DTX/DRX
* Merging of:
	+ R2-2313984 “Introduction of Network Energy Saving”
 |
|  |  |
| ***Consequences if not approved:*** | Network energy saving techniques are not clarified in stage-2 |
|  |  |
| ***Clauses affected:*** | 3.1 Abbreviations10.2 Downlink Scheduling10.3 Uplink Scheduling11 UE power saving15.4.2.x1 Cell DTX/DRX15.4.2.x2 Conditional Handover15.4.2.x3 Camping Restrictions15.4.2.x4 CA SSB-less SCell15.4.2.x5 Spatial and power domain adaptation |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** | **x** |  |  Other core specifications  | TS/TR 38.331 CR 4453  |
| ***affected:*** |  | **x** |  Test specifications | TS/TR ... CR ... |
| ***(show related CRs)*** |  | **x** |  O&M Specifications | TS/TR ... CR ... |
|  |  |
| ***Other comments:*** |  |
|  |  |
| ***This CR's revision history:*** | Updated to version 17.5.0 of 38.300Take into account agreements from RAN2#123Updated UE alignment wordingUpdated to version 17.6.0 of 38.300Updated cell DTX/DRX and spatial and power domain adaptation clausesTake into account agreements from RAN2#124 |

START OF FIRST CHANGE

# 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

A-CSI Aperiodic CSI

AGC Automatic Gain Control

AKA Authentication and Key Agreement

AMBR Aggregate Maximum Bit Rate

AMC Adaptive Modulation and Coding

AMF Access and Mobility Management Function

ARP Allocation and Retention Priority

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

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

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

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

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

DTX Discontinuous Transmission

E-CID Enhanced Cell-ID (positioning method)

EHC Ethernet Header Compression

ePWS enhancements of Public Warning System

END OF FIRST CHANGE

START OF SECOND CHANGE

## 10.2 Downlink Scheduling

In the downlink, the gNB can dynamically allocate resources to UEs via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible assignments when its downlink reception is enabled (activity governed by DRX and cell DTX when configured). When CA is configured, the same C-RNTI applies to all serving cells.

The gNB may pre-empt an ongoing PDSCH transmission to one UE with a latency-critical transmission to another UE. The gNB can configure UEs to monitor interrupted transmission indications using INT-RNTI on a PDCCH. If a UE receives the interrupted transmission indication, the UE may assume that no useful information to that UE was carried by the resource elements included in the indication, even if some of those resource elements were already scheduled to this UE.

In addition, with Semi-Persistent Scheduling (SPS), the gNB can allocate downlink resources for the initial HARQ transmissions to UEs: RRC defines the periodicity of the configured downlink assignments while PDCCH addressed to CS-RNTI can either signal and activate the configured downlink assignment, or deactivate it; i.e. a PDCCH addressed to CS-RNTI indicates that the downlink assignment can be implicitly reused according to the periodicity defined by RRC, until deactivated.

NOTE: When required, retransmissions are explicitly scheduled on PDCCH(s).

The dynamically allocated downlink reception overrides the configured downlink assignment in the same serving cell, if they overlap in time. Otherwise a downlink reception according to the configured downlink assignment is assumed, if activated.

The UE may be configured with up to 8 active configured downlink assignments for a given BWP of a serving cell. When more than one is configured:

- The network decides which of these configured downlink assignments are active at a time (including all of them); and

- Each configured downlink assignment is activated separately using a DCI command and deactivation of configured downlink assignments is done using a DCI command, which can either deactivate a single configured downlink assignment or multiple configured downlink assignments jointly.

## 10.3 Uplink Scheduling

In the uplink, the gNB can dynamically allocate resources to UEs via the C-RNTI on PDCCH(s). A UE always monitors the PDCCH(s) in order to find possible grants for uplink transmission when its downlink reception is enabled (activity governed by DRX and cell DTX when configured). When CA is configured, the same C-RNTI applies to all serving cells.

The gNB may cancel a PUSCH transmission, or a repetition of a PUSCH transmission, or an SRS transmission of a UE for another UE with a latency-critical transmission. The gNB can configure UEs to monitor cancelled transmission indications using CI-RNTI on a PDCCH. If a UE receives the cancelled transmission indication, the UE shall cancel the PUSCH transmission from the earliest symbol overlapped with the resource or the SRS transmission overlapped with the resource indicated by cancellation (see clause 11.2A of TS 38.213 [38]).

In addition, with Configured Grants, the gNB can allocate uplink resources for the initial HARQ transmissions and HARQ retransmissions to UEs. Two types of configured uplink grants are defined:

- With Type 1, RRC directly provides the configured uplink grant (including the periodicity).

- With Type 2, RRC defines the periodicity of the configured uplink grant while PDCCH addressed to CS-RNTI can either signal and activate the configured uplink grant, or deactivate it; i.e. a PDCCH addressed to CS-RNTI indicates that the uplink grant can be implicitly reused according to the periodicity defined by RRC, until deactivated.

If the UE is not configured with enhanced intra-UE overlapping resources prioritization, the dynamically allocated uplink transmission overrides the configured uplink grant in the same serving cell, if they overlap in time. Otherwise an uplink transmission according to the configured uplink grant is assumed, if activated.

If the UE is configured with enhanced intra-UE overlapping resources prioritization, in case a configured uplink grant transmission overlaps in time with dynamically allocated uplink transmission or with another configured uplink grant transmission in the same serving cell, the UE prioritizes the transmission based on the comparison between the highest priority of the logical channels that have data to be transmitted and which are multiplexed or can be multiplexed in MAC PDUs associated with the overlapping resources. Similarly, in case a configured uplink grant transmissions or a dynamically allocated uplink transmission overlaps in time with a scheduling request transmission, the UE prioritizes the transmission based on the comparison between the priority of the logical channel which triggered the scheduling request and the highest priority of the logical channels that have data to be transmitted and which are multiplexed or can be multiplexed in MAC PDU associated with the overlapping resource. In case the MAC PDU associated with a deprioritized transmission has already been generated, the UE keeps it stored to allow the gNB to schedule a retransmission. The UE may also be configured by the gNB to transmit the stored MAC PDU as a new transmission using a subsequent resource of the same configured uplink grant configuration when an explicit retransmission grant is not provided by the gNB.

Retransmissions other than repetitions are explicitly allocated via PDCCH(s) or via configuration of a retransmission timer.

The UE may be configured with up to 12 active configured uplink grants for a given BWP of a serving cell. When more than one is configured, the network decides which of these configured uplink grants are active at a time (including all of them). Each configured uplink grant can either be of Type 1 or Type 2. For Type 2, activation and deactivation of configured uplink grants are independent among the serving cells. When more than one Type 2 configured grant is configured, each configured grant is activated separately using a DCI command and deactivation of Type 2 configured grants is done using a DCI command, which can either deactivate a single configured grant configuration or multiple configured grant configurations jointly.

When SUL is configured, the network should ensure that an active configured uplink grant on SUL does not overlap in time with another active configured uplink grant on the other UL configuration.

For both dynamic grant and configured grant, for a transport block, two or more repetitions can be in one slot, or across slot boundary in consecutive available slots with each repetition in one slot. For both dynamic grant and configured grant Type 2, the number of repetitions can be also dynamically indicated in the L1 signalling. The dynamically indicated number of repetitions shall override the RRC configured number of repetitions, if both are present.

END OF SECOND CHANGE

START OF THIRD CHANGE

# 11 UE Power Saving

The PDCCH monitoring activity of the UE in RRC connected mode is governed by DRX, BA, DCP and cell DTX (see clause 15.4.2.x1).

When DRX is configured, the UE does not have to continuously monitor PDCCH. DRX is characterized by the following:

- **on-duration**: duration that the UE waits for, after waking up, to receive PDCCHs. If the UE successfully decodes a PDCCH, the UE stays awake and starts the inactivity timer;

- **inactivity-timer**: duration that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH, failing which it can go back to sleep. The UE shall restart the inactivity timer following a single successful decoding of a PDCCH for a first transmission only (i.e. not for retransmissions);

- **retransmission-timer**: duration until a retransmission can be expected;

- **cycle**: specifies the periodic repetition of the on-duration followed by a possible period of inactivity (see figure 11-1 below);

**- active-time**: total duration that the UE monitors PDCCH. This includes the "on-duration" of the DRX cycle, the time UE is performing continuous reception while the inactivity timer has not expired, and the time when the UE is performing continuous reception while waiting for a retransmission opportunity.



Figure 11-1: DRX Cycle

A SL UE can be configured with DRX, in which case, PDCCH providing SL grants can be send to the UE only during its active time.

When BA is configured, the UE only has to monitor PDCCH on the one active BWP i.e. it does not have to monitor PDCCH on the entire DL frequency of the cell. A BWP inactivity timer (independent from the DRX inactivity-timer described above) is used to switch the active BWP to the default one: the timer is restarted upon successful PDCCH decoding and the switch to the default BWP takes place when it expires.

In addition, the UE may be indicated, when configured accordingly, whether it is required to monitor or not the PDCCH during the next occurrence of the on-duration by a DCP monitored on the active BWP. If the UE does not detect a DCP on the active BWP, it does not monitor the PDCCH during the next occurrence of the on-duration, unless it is explicitly configured to do so in that case.

A UE can only be configured to monitor DCP when connected mode DRX is configured, and at occasion(s) at a configured offset before the on-duration. More than one monitoring occasion can be configured before the on-duration. The UE does not monitor DCP on occasions occurring during active-time, measurement gaps, BWP switching, or when it monitors response for a CFRA preamble transmission for beam failure recovery (see clause 9.2.6), in which case it monitors the PDCCH during the next on-duration. If no DCP is configured in the active BWP, UE follows normal DRX operation.

When CA is configured, DCP is only configured on the PCell.

One DCP can be configured to control PDCCH monitoring during on-duration for one or more UEs independently.

Power saving in RRC\_IDLE and RRC\_INACTIVE can also be achieved by UE relaxing neighbour cells RRM measurements when it meets the criteria determining it is in low mobility and/or not at cell edge.

UE power saving may be enabled by adapting the DL maximum number of MIMO layers by BWP switching.

Power saving is also enabled during active-time via cross-slot scheduling, which facilitates UE to achieve power saving with the assumption that it won't be scheduled to receive PDSCH, triggered to receive A-CSI or transmit a PUSCH scheduled by the PDCCH until the minimum scheduling offsets K0 and K2. Dynamic adaptation of the minimum scheduling offsets K0 and K2 is controlled by PDCCH.

Serving Cells of a MAC entity may be configured by RRC in two DRX groups with separate DRX parameters. When RRC does not configure a secondary DRX group, there is only one DRX group and all Serving Cells belong to that one DRX group. When two DRX groups are configured, each Serving Cell is uniquely assigned to either of the two groups. The DRX parameters that are separately configured for each DRX group are on-duration and inactivity-timer.

UE power saving in RRC\_IDLE/RRC\_INACTIVE may be achieved by providing the configuration for TRS with CSI-RS for tracking in TRS occasions. The TRS in TRS occasions may allow UEs in RRC\_IDLE/RRC\_INACTIVE to sleep longer before waking-up for its paging occasion. The TRS occasions configuration is provided in SIB17. The availability of TRS in the TRS occasions is indicated by L1 availability indication. These TRSs may also be used by the UEs configured with eDRX.

UE power saving may be achieved by UE relaxing measurements for RLM/BFD. When configured, UE determines whether it is in low mobility state and/or whether its serving cell radio link quality is better than a threshold. The configuration for low mobility and good serving cell quality criterion is provided through dedicated RRC signalling.

RLM and BFD relaxation may be enabled/disabled separately through RRC Configuration. Additionally, RLM relaxation may be enabled/disabled on per Cell Group basis while BFD relaxation may be enabled/disabled on per serving cell basis.

The UE is only allowed to perform RLM and/or BFD relaxation when relaxed measurement criterion for low mobility and/or for good serving cell quality is met. If configured to do so, the UE shall trigger reporting of its RLM and/or BFD relaxation status through UE assistance information if the UE changes its respective RLM and/or BFD relaxation status while meeting the UE minimum requirements specified in TS 38.133 [13].

UE power saving may also be achieved through PDCCH monitoring adaptation mechanisms when configured by the network, including skipping of PDCCH monitoring and Search space set group (SSSG) switching. In this case UE does not monitor PDCCH during the PDCCH skipping duration except for the cases as specified in TS 38.213 [38], or monitors PDCCH according to the search space sets applied in SSSG.

END OF THIRD CHANGE

START OF FOURTH CHANGE

## 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 neighboring 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.x1 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 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 (e.g. MPS or MCS), 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.x2 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 [x]:

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

#### 15.4.2.x3 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.

#### 15.4.2.x4 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.x5 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 [xy]. 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.

### 15.4.3 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 FOURTH CHANGE