**3GPP TSG-RAN WG2 Meeting #109-e *draftR2-2001787***

**Electronic meeting, 24 Feb – 6 Mar 2020**

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| *CR-Form-v12.0* |
| **CHANGE REQUEST** |
|  |
|  | **36.321** | **CR** | **1466** | **rev** | **1** | **Current version:** | **15.8.0** |  |
|  |
| *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 additional enhancements for NB-IoT |
|  |  |
| ***Source to WG:*** | Ericsson |
| ***Source to TSG:*** | R2 |
|  |  |
| ***Work item code:*** | NB-IOTenh3-Core |  | ***Date:*** | 2020-03-10 |
|  |  |  |  |  |
| ***Category:*** | B |  | ***Release:*** | Rel-16 |
|  | *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-12 (Release 12)Rel-13 (Release 13)Rel-14 (Release 14)Rel-15 (Release 15)Rel-16 (Release 16)* |
|  |  |
| ***Reason for change:*** | Introduction of additional enhancements for NB-IoT in Release 16. |
|  |  |
| ***Summary of change:*** | The following features have been included:* Scheduling multiple DL/UL transport blocks
* Quality report in Msg3
* 2-bit AS RAI reporting
* Preconfigured uplink resources
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| ***Consequences if not approved:*** | Rel-16 enhancements for NB-IoT will be missing from MAC. |
|  |  |
| ***Clauses affected:*** | 3.1, 3.2, 5.3.1, 5.4.1, 5.4.2.1, 5.4.3.1, 5.4.5, 5.4.x, 5.4.x.1, 5.4.x.2, 5.4.y, 5.7, 5.9, 5.xx, 6.1.3.xx, 6.1.3.xy, 6.2.1, 7.1, 7.7 |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** | **x** |  |  Other core specifications  | TS 36.300 CR 1259TS 36.306 CR 1731TS 36.331 CR 4192 |
| ***affected:*** |  | **X** |  Test specifications |  |
| ***(show related CRs)*** |  | **X** |  O&M Specifications |  |
|  |  |
| ***Other comments:*** |  |
|  |  |
| ***This CR's revision history:*** | R2-1914099: Initial version endorsed after RAN2#107bis. R2-1915404: Version submitted to RAN2#108.R2-1916568: Version endorsed after RAN2#108.R2-2000983: Version submitted to RAN2#109-e, updated to v15.8.0, CR number 1466 rev – R2-2001787: This version.  |

First change

## 3.1 Definitions

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

**Active Time:** Time related to DRX operation, as defined in clause 5.7, during which the MAC entity monitors the PDCCH.

***mac-ContentionResolutionTimer***: Specifies the number of consecutive subframe(s) during which the MAC entity shall monitor the PDCCH after Msg3 is transmitted.

**DRX Cycle:** Specifies the periodic repetition of the On Duration followed by a possible period of inactivity (see figure 3.1-1 below).



Figure 3.1-1: DRX Cycle

***drx-InactivityTimer***: Except for NB-IoT UEs, BL UEs or UEs in enhanced coverage, it specifies the number of consecutive PDCCH-subframe(s) after the subframe in which a PDCCH indicates an initial UL, DL or SL user data transmission for this MAC entity. For NB-IoT UEs, it specifies the number of consecutive PDCCH-subframe(s) after the subframe in which the HARQ RTT timer or UL HARQ RTT timer expires. For BL UEs or UEs in enhanced coverage, it specifies the number of consecutive PDCCH-subframe(s) following the subframe containing the last repetition of the PDCCH reception that indicates an initial UL or DL user data transmission for this MAC entity.

***drx-RetransmissionTimer***: Specifies the maximum number of consecutive PDCCH-subframe(s) until a DL retransmission is received.

***drx-RetransmissionTimerShortTTI***: Specifies the maximum number of consecutive TTI(s) until a DL retransmission is received for HARQ processes scheduled using short TTI.

***drxShortCycleTimer***: Specifies the number of consecutive subframe(s) the MAC entity shall follow the Short DRX cycle.

***drxStartOffset***: Specifies the subframe where the DRX Cycle starts.

***drx-ULRetransmissionTimer***: Specifies the maximum number of consecutive PDCCH-subframe(s) until a grant for UL retransmission or the HARQ feedback is received.

***drx-ULRetransmissionTimeShortTTI***: Specifies the maximum number of consecutive TTI(s) until a grant for UL retransmission is received for HARQ processes scheduled using short TTI.

**Early Data Transmission**: Allows one uplink data transmission optionally followed by one downlink data transmission during the random access procedure as specified in TS 36.300 [20]. The S1 connection is established or resumed upon reception of the uplink data and may be released or suspended along with the transmission of the downlink data. Early data transmission refers to both CP-EDT and UP-EDT.

**HARQ information**: HARQ information for DL-SCH or for UL-SCH transmissions consists of New Data Indicator (NDI), Transport Block (TB) size. For DL-SCH transmissions and for asynchronous UL HARQ and for autonomous UL HARQ, the HARQ information also includes HARQ process ID, except for UEs in NB-IoT configured with a single HARQ process for which this information is not present. For UL-SCH transmission the HARQ information also includes Redundancy Version (RV). In case of spatial multiplexing on DL-SCH the HARQ information comprises a set of NDI and TB size for each transport block. HARQ information for SL-SCH and SL-DCH transmissions consists of TB size only.

**HARQ RTT Timer**: This parameter specifies the minimum amount of subframe(s) before a DL assignment for HARQ retransmission is expected by the MAC entity.

**Msg3**:Message transmitted on UL-SCH containing a C-RNTI MAC CE or a CCCH SDU optionally multiplexed with DTCH for the UP-EDT, submitted from upper layer and associated with the UE Contention Resolution Identity, as part of a random access procedure.

**NB-IoT**:NB-IoT allows access to network services via E-UTRA with a channel bandwidth limited to 200 kHz.

**NB-IoT UE**:A UE that uses NB-IoT.

***onDurationTimer***: Specifies the number of consecutive PDCCH-subframe(s) at the beginning of a DRX Cycle.

**PDCCH:** Refers to the PDCCH (see TS 36.211 [7]), EPDCCH (in subframes when configured), MPDCCH (see TS 36.213 [2]), for an RN with R-PDCCH configured and not suspended, to the R-PDCCH, for NB-IoT to the NPDCCH or for short TTI to SPDCCH.

**PDCCH period (pp):** Refers to the interval between the start of two consecutive PDCCH occasions and depends on the currently used PDCCH search space, as specified in TS 36.213 [2]. A PDCCH occasion is the start of a search space and is defined by subframe k0 as specified in clause 16.6 of TS 36.213 [2]. The calculation of number of PDCCH-subframes for the timer configured in units of a PDCCH period is done by multiplying the number of PDCCH periods with *npdcch-NumRepetitions-RA* when the UE uses the common search space or by *npdcch-NumRepetitions* when the UE uses the UE specific search space. When counting a timer whose length is calculated in PDCCH-subframes, the UE shall include PDCCH-subframes that will be dropped or not required to be monitored as specified in clause 16.6 of TS 36.213 [2]. The calculation of number of subframes for the timer configured in units of a PDCCH period is done by multiplying the number of PDCCH periods with duration between two consecutive PDCCH occasions.

**PDCCH-subframe:** Refers to a subframe with PDCCH. This represents the union over PDCCH-subframes for all serving cells excluding cells configured with cross carrier scheduling for both uplink and downlink, as specified in TS 36.331 [8]; except if the UE is not capable of simultaneous reception and transmission in the aggregated cells where this instead represents the PDCCH-subframes of the SpCell.

- For FDD serving cells, all subframes represent PDCCH-subframes, unless specified otherwise in this clause.

- For TDD serving cells, all downlink subframes and subframes including DwPTS of the TDD UL/DL configuration indicated by *tdd-Config*, as specified in TS 36.331 [8] of the cell represent PDCCH-subframes, unless specified otherwise in this clause.

- For serving cells operating according to Frame structure Type 3, all subframes represent PDCCH-subframes.

- For RNs with an RN subframe configuration configured and not suspended, in its communication with the E-UTRAN, all downlink subframes configured for RN communication with the E-UTRAN represent PDCCH-subframes.

- For SC-PTM reception on an FDD cell, all subframes except MBSFN subframes represent PDCCH-subframes, unless specified otherwise in this clause.

- For SC-PTM reception on a TDD cell, all downlink subframes and subframes including DwPTS of the TDD UL/DL configuration indicated by *tdd-Config*, as specified in TS 36.331 [8] of the cell except MBSFN subframes represent PDCCH-subframes, unless specified otherwise in this clause.

- For BL UE or UE in enhanced coverage, all subframes in which the UE is required to monitor MPDCCH represent PDCCH-subframes among all valid subframes regardless of whether the subframe is dropped, see clause 9.1.5 of TS 36.213 [2].

- For NB-IoT UE, all subframes that are part of the NPDCCH search space represent PDCCH-subframes among all NB-IoT downlink subframes, including those which the UE is not required to monitor as specified in clause 16.6 of TS 36.213 [2].

**PDSCH**: Refers to subframe-PDSCH/slot-PDSCH/subslot-PDSCH or for NB-IoT to NPDSCH.

**PRACH**: Refers to PRACH or for NB-IoT to NPRACH.

**PRACH Resource Index**: The index of a PRACH within a system frame, see TS 36.211 [7]

**Primary Timing Advance Group:** Timing Advance Group containing the SpCell.

**PUCCH SCell:** An SCell configured with PUCCH/SPUCCH.

**PUSCH**: Refers to subframe-PUSCH/slot-PUSCH/subslot-PUSCH or for NB-IoT to NPUSCH.

***ra-PRACH-MaskIndex*:** Defines in which PRACHs within a system frame the MAC entity can transmit a Random Access Preamble (see clause 7.3).

**RA-RNTI:** The Random Access RNTI is used on the PDCCH when Random Access Response messages are transmitted. It unambiguously identifies which time-frequency resource was utilized by the MAC entity to transmit the Random Access preamble.

**SC Period:** Sidelink Control period, the time period consisting of transmission of SCI and its corresponding data.

**SCI:** The Sidelink Control Information contains the sidelink scheduling information such as resource block assignment, modulation and coding scheme, Group Destination ID (for sidelink communication) and PPPP (for V2X sidelink communication), see TS 36.212 [5].

**Secondary Timing Advance Group:** Timing Advance Group not containing the SpCell. A Secondary Timing Advance Group contains at least one Serving Cell with an UL configured.

**Serving Cell:** A Primary or a Secondary Cell, see TS 376.331 [8].

**Short Processing Time**: For 1 ms TTI length, the operation with short processing time in UL data transmission and DL data reception.

**Short TTI**: TTI length based on a slot or a subslot.

**Sidelink:** UE to UE interface for sidelink communication, sidelink discovery and V2X sidelink communication. The sidelink corresponds to the PC5 interface as defined in TS 23.303 [13] for sidelink communication and sidelink discovery, and as defined in TS 23.285 [14] for V2X sidelink communication.

**Sidelink communication**: AS functionality enabling ProSe Direct Communication as defined in TS 23.303 [13], between two or more nearby UEs, using E-UTRA technology but not traversing any network node.

**Sidelink Discovery Gap for Reception:** Time period during which the UE does not receive any channels in DL from any serving cell, except during random access procedure.

**Sidelink Discovery Gap for Transmission:** Time period during which the UE prioritizes transmission of sidelink discovery and associated procedures e.g. re-tuning and synchronisation over transmission of channels in UL, if they occur in the same subframe, except during random access procedure.

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

**Timing Advance Group:** A group of Serving Cells that is configured by RRC and that, for the cells with an UL configured, using the same timing reference cell and the same Timing Advance value.

**Transmission using PUR:** Allows one uplink data transmission using preconfigured uplink resource from RRC\_IDLE mode as specified in TS 36.300 [9]. Transmission using PUR refers to both CP transmission using PUR and UP transmission using PUR.

**UL HARQ RTT Timer**: This parameter specifies the minimum amount of subframe(s) before a UL HARQ retransmission grant is expected by the MAC entity.

**V2X sidelink communication**: AS functionality enabling V2X Communication as defined in TS 23.285 [14], between nearby UEs, using E-UTRA technology but not traversing any network node.

NOTE: A timer is running once it is started, until it is stopped or until it expires; otherwise it is not running. A timer can be started if it is not running or restarted if it is running. A Timer is always started or restarted from its initial value.

Next Change

## 3.2 Abbreviations

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

AUL Autonomous Uplink

AS Access stratum

BL Bandwidth reduced Low complexity

BR Bandwidth Reduced

BSR Buffer Status Report

C-RNTI Cell RNTI

CBR Channel Busy Ratio

CC-RNTI Common Control RNTI

CQI Channel Quality Indicator

CRI CSI-RS Resource Indicator

CSI Channel State Information

DCQR Downlink Channel Quality Report

DRB Data Radio Bearer

EDT Early Data Transmission

eIMTA Enhanced Interference Management and Traffic Adaptation

eIMTA-RNTI Enhanced Interference Management and Traffic Adaptation - RNTI

E-UTRA Evolved UMTS Terrestrial Radio Access

E-UTRAN Evolved UMTS Terrestrial Radio Access Network

G-RNTI Group RNTI

H-SFN Hyper SFN

MAC Medium Access Control

MCG Master Cell Group

M-RNTI MBMS RNTI

MPDCCH MTC Physical Downlink Control Channel

LCG Logical Channel Group

NB-IoT Narrow Band Internet of Things

NPDCCH Narrowband Physical Downlink Control Channel

NPDSCH Narrowband Physical Downlink Shared channel

NPRACH Narrowband Physical Random Access Control Channel

NPUSCH Narrowband Physical Uplink Shared channel

PCell Primary Cell

PSCell Primary Secondary Cell

PHR Power Headroom Report

PMI Precoding Matrix Index

PPPP ProSe Per-Packet Priority

P-RNTI Paging RNTI

ProSe Proximity-based Services

pTAG Primary Timing Advance Group

PTI Precoding Type Indicator

PUR Preconfigured Uplink Resource

RA-RNTI Random Access RNTI

RAI Release Assistance Indication

RI Rank Indicator

RN Relay Node

RNTI Radio Network Temporary Identifier

SCell Secondary Cell

SC-FDM Single-Carrier Frequency Division Multiplexing

SCG Secondary Cell Group

SCI Sidelink Control Information

SC-N-RNTI Single Cell Notification RNTI

SC-PTM Single Cell Point to Multipoint

SC-RNTI Single Cell RNTI

SI-RNTI System Information RNTI

SL Sidelink

SL-RNTI Sidelink RNTI

SL-V-RNTI Sidelink V2X RNTI

SR Scheduling Request

SRS Sounding Reference Symbols

SRS-TPC-RNTI Sounding Reference Symbols-Transmit Power Control-RNTI

SpCell Special Cell

sTAG Secondary Timing Advance Group

sTTI Slot or subslot TTI

TAG Timing Advance Group

TB Transport Block

TPC-PUCCH-RNTI Transmit Power Control-Physical Uplink Control Channel-RNTI

TPC-PUSCH-RNTI Transmit Power Control-Physical Uplink Shared Channel-RNTI

V2X Vehicle-to-Everything

Next Change

### 5.3.1 DL Assignment reception

Downlink assignments transmitted on the PDCCH indicate if there is a transmission on a DL-SCH for a particular MAC entity and provide the relevant HARQ information.

When the MAC entity has a C-RNTI, Semi-Persistent Scheduling C-RNTI, Preconfigured Uplink Resource C-RNTI or Temporary C-RNTI, the MAC entity shall for each TTI during which it monitors PDCCH and for each Serving Cell:

- if a downlink assignment for this TTI and this Serving Cell has been received on the PDCCH for the MAC entity's C-RNTI, Preconfigured Uplink Resource C-RNTI, or Temporary C‑RNTI:

- if this is the first downlink assignment for this Temporary C-RNTI; or

- if this is the first downlink assignment corresponding to uplink transmission using previous preconfigured uplink grant for this Preconfigured Uplinkg Resource C-RNTI:

- consider the NDI to have been toggled.

- if the downlink assignment is for the MAC entity's C-RNTI and if the previous downlink assignment indicated to the HARQ entity of the same HARQ process was either a downlink assignment received for the MAC entity's Semi-Persistent Scheduling C-RNTI or a configured downlink assignment:

- consider the NDI to have been toggled regardless of the value of the NDI.

- indicate the presence of a downlink assignment and deliver the associated HARQ information to the HARQ entity for this TTI.

- else, if a downlink assignment for this TTI has been received for this Serving Cell on the PDCCH for the MAC entity's Semi-Persistent Scheduling C-RNTI:

- if the NDI in the received HARQ information is 1:

- consider the NDI not to have been toggled;

- indicate the presence of a downlink assignment and deliver the associated HARQ information to the HARQ entity for this TTI.

- else, if the NDI in the received HARQ information is 0:

- if PDCCH contents indicate SPS release:

- clear the configured downlink assignment (if any);

- if the *timeAlignmentTimer*, associated with the TAG containing the serving cell on which the acknowledgement for the downlink SPS release is to be transmitted, is running:

- indicate a positive acknowledgement for the downlink SPS release to the physical layer.

- else:

- store the downlink assignment and the associated HARQ information as configured downlink assignment;

- initialise (if not active) or re-initialise (if already active) the configured downlink assignment to start in this TTI, or in TTI according to N=0 in clause 5.10.1 for short TTI, and to recur according to rules in clause 5.10.1;

- set the HARQ Process ID to the HARQ Process ID associated with this TTI;

- consider the NDI bit to have been toggled;

- indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.

- else, if a downlink assignment for this TTI has been configured for this Serving Cell and there is no measurement gap in this TTI and there is no Sidelink Discovery Gap for Reception in this TTI; and

- if this TTI is not an MBSFN subframe or the MAC entity is configured with transmission mode *tm9* or *tm10*:

- instruct the physical layer to receive, in this TTI, transport block on the DL-SCH according to the configured downlink assignment and to deliver it to the HARQ entity;

- set the HARQ Process ID to the HARQ Process ID associated with this TTI;

- consider the NDI bit to have been toggled;

- indicate the presence of a configured downlink assignment and deliver the stored HARQ information to the HARQ entity for this TTI.

- if the MAC entity is configured with *rach-Skip* or *rach-SkipSCG* and a UE Contention Resolution Identity MAC control element for this TTI has been received on the PDSCH indicated by the PDCCH of the SpCell addressed to the C-RNTI:

- indicate to upper layer the successful reception of a PDCCH transmission addressed to the C-RNTI.

For configured downlink assignments, the HARQ Process ID associated with this TTI is derived from the following equation:

- if the TTI is a subframe TTI:

- HARQ Process ID = [floor(CURRENT\_TTI/*semiPersistSchedIntervalDL*)] modulo *numberOfConfSPS-Processes*,

where CURRENT\_TTI=[(SFN \* 10) + subframe number].

- else:

- HARQ Process ID = [floor(C*URRENT\_TTI/semiPersistSchedIntervalDL-sTTI*)] modulo *numberOfConfSPS-Processes-sTTI*,

where CURRENT\_TTI = [(SFN \* 10 \* sTTI\_Number\_Per\_Subframe) + subframe number \* sTTI\_Number\_Per\_Subframe + sTTI\_number]. Refer to 5.10.1 for sTTI\_Number\_Per\_Subframe and sTTI\_number.

For BL UEs or UEs in enhanced coverage, CURRENT\_TTI refers to the TTI where first transmission of repetition bundle takes place.

When the MAC entity needs to read BCCH or BR-BCCH, the MAC entity may, based on the scheduling information from RRC:

- if the UE is a BL UE or a UE in enhanced coverage:

- the redundancy version of the received downlink assignment for this TTI is determined by *RVK* = ceiling(3/2\**k*) modulo 4, where *k* depends on the type of system information message.

- for *SystemInformationBlockType1-BR*

- if number of repetitions for PDSCH carrying *SystemInformationBlockType1-BR* is 4, *k* = floor(SFN/2) modulo 4, where SFN is the system frame number.

- else if number of repetitions for PDSCH carrying *SystemInformationBlockType1-BR* is 8, *k* = SFN modulo 4, where SFN is the system frame number.

- else if number of repetitions for PDSCH carrying *SystemInformationBlockType1-BR* is 16, *k* = (SFN\*10+i) modulo 4, where SFN is the system frame number, and *i* denotes the subframe within the SFN.

NOTE: the set of subframes for *SystemInformationBlockType1-BR* when number of repetitions for PDSCH is 16 are given by Table 6.4.1-2 in TS 36.211 [7].

- for *SystemInformation-BR* messages, *k*=*i* modulo 4, *i* =0,1,…, *nsw*–1, where *i* denotes the subframe number within the SI window *nsw*;

- indicate a downlink assignment and redundancy version for the dedicated broadcast HARQ process to the HARQ entity for this TTI.

- else if a downlink assignment for this TTI has been received on the PDCCH for the SI-RNTI, except for NB-IoT;

- if the redundancy version is not defined in the PDCCH format:

- the redundancy version of the received downlink assignment for this TTI is determined by *RVK* = ceiling(3/2\**k*) modulo 4, where *k* depends on the type of system information message: for *SystemInformationBlockType1* message, *k* = (SFN/2) modulo 4, where SFN is the system frame number; for *SystemInformation* messages, *k*=*i* modulo 4, *i* =0,1,…, *nsw*–1, where *i* denotes the subframe number within the SI window *nsw*;

- indicate a downlink assignment and redundancy version for the dedicated broadcast HARQ process to the HARQ entity for this TTI.

When the MAC entity has SC-RNTI and/or G-RNTI, the MAC entity shall for each TTI during which it monitors PDCCH for SC-RNTI as specified in TS 36.331 [8] for UEs other than NB-IoT UEs, BL UEs or UEs in enhanced coverage and in clause 5.7a for NB-IoT UEs, BL UEs or UEs in enhanced coverage and for G-RNTI as specified in clause 5.7a and for each Serving Cell and cell that may be additionally configured as a Serving Cell according to the UE capabilities:

- if a downlink assignment for this TTI and this Serving Cell has been received on the PDCCH for the MAC entity's SC-RNTI or G-RNTI:

- attempt to decode the received data.

- if the data which the MAC entity attempted to decode was successfully decoded for this TB:

- deliver the decoded MAC PDU to the disassembly and demultiplexing entity.

Next Change

### 5.4.1 UL Grant reception

In order to transmit on the UL-SCH the MAC entity must have a valid uplink grant (except for non-adaptive HARQ retransmissions) which it may receive dynamically on the PDCCH or in a Random Access Response or which may be configured semi-persistently or preallocated by RRC or preconfigured for PUR (see clause 5.4.x). To perform requested transmissions, the MAC layer receives HARQ information from lower layers. When the physical layer is configured for uplink spatial multiplexing, the MAC layer can receive up to two grants (one per HARQ process) for the same TTI from lower layers.

If the MAC entity has a C-RNTI, a Semi-Persistent Scheduling C-RNTI, a UL Semi-Persistent Scheduling V-RNTI, a AUL C-RNTI, or a Temporary C-RNTI, the MAC entity shall for each TTI and for each Serving Cell belonging to a TAG that has a running *timeAlignmentTimer* and for each grant received for this TTI and for each SPS configuration that is indicated by the PDCCH addressed to UL Semi-Persistent Scheduling V-RNTI; or if the MAC entity has Preconfigured Uplink Resource C-RNTI, the MAC entity shall for each TTI and for each grant received for this TTI:

- if an uplink grant for this TTI and this Serving Cell has been received on the PDCCH for the MAC entity's C-RNTI, Preconfigured Uplink Resource C-RNTI or Temporary C-RNTI; or

- if an uplink grant for this TTI has been received in a Random Access Response:

- if the uplink grant is for MAC entity's C-RNTI and if the previous uplink grant delivered to the HARQ entity for the same HARQ process was either an uplink grant received for the MAC entity's Semi-Persistent Scheduling C-RNTI, for the MAC entity's UL Semi-Persistent Scheduling V-RNTI, or a configured uplink grant for which the UL HARQ operation was not autonomous:

- consider the NDI to have been toggled for the corresponding HARQ process regardless of the value of the NDI.

- deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.

- else, if an uplink grant for this TTI has been received for this Serving Cell on the PDCCH for the MAC entity's Semi-Persistent Scheduling C-RNTI or for the MAC entity's UL Semi-Persistent Scheduling V-RNTI; or if an uplink grant for this TTI has been received for this Serving Cell on the PDCCH for the MAC entity's AUL C-RNTI:

- if the NDI in the received HARQ information is 1:

- consider the NDI for the corresponding HARQ process not to have been toggled;

- deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.

- else if the NDI in the received HARQ information is 0:

- if PDCCH contents indicate AUL release:

- trigger an AUL confirmation;

- if an uplink grant for this TTI has been configured:

- consider the NDI bit for the corresponding HARQ process to have been toggled;

- deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI;

- else if PDCCH contents indicate AUL activation:

- trigger an AUL confirmation;

- store the uplink grant and the associated HARQ information as configured uplink grant;

- initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI and to recur according to rules in clause 5.23;

- consider the NDI bit for the corresponding HARQ process to have been toggled;

- deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI.

- else if PDCCH contents indicate SPS release:

- if the MAC entity is configured with *skipUplinkTxSPS*:

- trigger an SPS confirmation;

- if an uplink grant for this TTI has been configured:

- consider the NDI bit for the corresponding HARQ process to have been toggled;

- deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI;

- else:

- clear the corresponding configured uplink grant (if any).

- else:

- if the MAC entity is configured with *skipUplinkTxSPS*:

- trigger an SPS confirmation;

- store the uplink grant and the associated HARQ information as configured uplink grant;

- initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI, or in TTI according to N=0 in clause 5.10.2 for short TTI, and to recur according to rules in clause 5.10.2;

- if UL HARQ operation is asynchronous, set the HARQ Process ID to the HARQ Process ID associated with this TTI;

- consider the NDI bit for the corresponding HARQ process to have been toggled;

- deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI.

- else, if an uplink grant for this TTI has been configured for the Serving Cell and if UL HARQ operation is autonomous for the corresponding HARQ process:

- if the HARQ\_FEEDBACK is set to ACK for the corresponding HARQ process or if there is no uplink grant previously delivered to the HARQ entity for the same HARQ process:

- consider the NDI bit for the corresponding HARQ process to have been toggled.

- if the *aul-RetransmissionTimer* is not running:

- if there is no uplink grant previously delivered to the HARQ entity for the same HARQ process; or

- if the previous uplink grant delivered to the HARQ entity for the same HARQ process was not an uplink grant received for the MAC entity's C-RNTI; or

- if the HARQ\_FEEDBACK is set to ACK for the corresponding HARQ process:

- deliver the configured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

- else:

- if this Serving Cell is the SpCell and an uplink grant for this TTI has been preallocated for the SpCell; or

- except for preconfigured uplink grant for PUR, if an uplink grant for this TTI has been configured for this Serving Cell:

- if UL HARQ operation is asynchronous, set the HARQ Process ID to the HARQ Process ID associated with this TTI;

- consider the NDI bit for the corresponding HARQ process to have been toggled;

- deliver the configured or preallocated uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

NOTE 1: The period of configured uplink grants is expressed in TTIs.

NOTE 2: If the MAC entity receives both a grant in a Random Access Response and a grant for its C-RNTI or Semi persistent scheduling C-RNTI requiring transmissions on the SpCell in the same UL subframe, the MAC entity may choose to continue with either the grant for its RA-RNTI or the grant for its C-RNTI or Semi persistent scheduling C-RNTI.

NOTE 3: When a configured uplink grant is indicated during a measurement gap and indicates an UL-SCH transmission during a measurement gap, the MAC entity processes the grant but does not transmit on UL-SCH. When a configured uplink grant is indicated during a Sidelink Discovery gap for reception and indicates an UL-SCH transmission during a Sidelink Discovery gap for transmission with a SL-DCH transmission, the MAC entity processes the grant but does not transmit on UL-SCH. When a configured uplink grant indicates an UL-SCH transmission during a V2X sidelink communication transmission and transmission of V2X sidelink communication is prioritized as described in clause 5.14.1.2.2, the MAC entity processes the grant but does not transmit on UL-SCH.

NOTE 4: The NDI transmitted in the PDCCH for the MAC entity's AUL C-RNTI is set to '0' (TS 36.212 [5]).

Except for NB-IoT, for configured uplink grants without *harq-ProcID-offset*, if UL HARQ operation is not autonomous, the HARQ Process ID associated with this TTI is derived from the following equation for asynchronous UL HARQ operation:

- if the TTI is a subframe TTI:

- HARQ Process ID = [floor(CURRENT\_TTI/semiPersistSchedIntervalUL)] modulo numberOfConfUlSPS-Processes,

where CURRENT\_TTI=[(SFN \* 10) + subframe number] and it refers to the subframe where the first transmission of a bundle takes place.

- else:

- HARQ Process ID = [floor(CURRENT\_TTI/*semiPersistSchedIntervalUL-sTTI*)] modulo *numberOfConfUlSPS-Processes-sTTI*,

where CURRENT\_TTI = [(SFN \* 10 \* sTTI\_Number\_Per\_Subframe) + subframe number \* sTTI\_Number\_Per\_Subframe + sTTI\_number] and it refers to the short TTI occasion where the first transmission of a bundle takes place. Refer to 5.10.2 for sTTI\_Number\_Per\_Subframe and sTTI\_number.

For preallocated uplink grants the HARQ Process ID associated with this TTI is derived from the following equation for asynchronous UL HARQ operation:

HARQ Process ID = [floor(CURRENT\_TTI/*ul-SchedInterval*)] modulo *numberOfConfUL-Processes*,

where CURRENT\_TTI=subframe number and it refers to the subframe where the first transmission of a bundle takes place.

For configured uplink grants, if UL HARQ operation is autonomous, the HARQ Process ID associated with this TTI for transmission on this Serving Cell is selected by the UE implementation from the HARQ process IDs that are configured for autonomous UL HARQ operation by upper layers in *aul-HARQ-Processes* (TS 36.331 [8]).

For configured uplink grants with *harq-ProcID-offset*, the HARQ Process ID associated with this TTI is derived from the following equation for asynchronous UL HARQ operation:

- if the TTI is a subframe TTI:

- HARQ Process ID = [floor(CURRENT\_TTI/*semiPersistSchedIntervalUL*)] modulo *numberOfConfUlSPS-Processes* + *harq-ProcID-offset*,

where CURRENT\_TTI = [(SFN \* 10) + subframe number] and it refers to the subframe where the first transmission of a bundle takes place.

- else:

- HARQ Process ID = [floor(CURRENT\_TTI/*semiPersistSchedIntervalUL-sTTI*)] modulo *numberOfConfUlSPS-Processes-sTTI* + harq-ProcID-offset,

where CURRENT\_TTI = [(SFN \* 10 \* sTTI\_Number\_Per\_Subframe) + subframe number \* sTTI\_Number\_Per\_Subframe + sTTI\_number] and it refers to the short TTI occasion where the first transmission of a bundle takes place. Refer to 5.10.2 for sTTI\_Number\_Per\_Subframe and sTTI\_number. For NB-IoT, for configured uplink grants for BSR, the HARQ Process ID is set to 0.

If the MAC entity is configured with Short Processing Time or short TTI and if current\_TTI is a subframe TTI, the HARQ Process ID associated with this TTI is derived from the following equation for synchronous UL HARQ operation:

HARQ Process ID = [SFN \* number\_of\_UL\_PUSCH\_SFs\_per\_radio\_frame + index\_of\_UL\_PUSCH\_SF] modulo number\_of\_UL\_HARQ\_processes.

where number\_of\_UL\_PUSCH\_SFs\_per\_radio\_frame is the number of subframes that can be used for PUSCH (UL PUSCH subframe) per radio frame:

- For FDD serving cells and serving cells operating according to Frame structure Type 3, all 10 subframes in a radio frame represent UL PUSCH subframes;

- For TDD serving cells, all uplink subframes of the TDD UL/DL configuration indicated by *tdd-Config*, as specified in TS 36.331 [8] of the cell represent UL PUSCH subframes and additionally the subframes including UpPTS if the cell is configured with *symPUSCH-UpPts-r14*;

and index\_of\_UL\_PUSCH\_SF is the index of a subframe that can be used for PUSCH within the radio frame, and number\_of\_UL\_HARQ\_processes is the number of parallel HARQ processes per HARQ entity for subframe TTI as specified in TS 36.213 [2], clause 8.

Next Change

#### 5.4.2.1 HARQ entity

There is one HARQ entity at the MAC entity for each Serving Cell with configured uplink, which maintains a number of parallel HARQ processes allowing transmissions to take place continuously while waiting for the HARQ feedback on the successful or unsuccessful reception of previous transmissions.

The number of parallel HARQ processes per HARQ entity is specified in TS 36.213 [2], clause 8. NB-IoT has one or two UL HARQ processes.

When the physical layer is configured for uplink spatial multiplexing, as specified in TS 36.213 [2], there are two HARQ processes associated with a given TTI. Otherwise there is one HARQ process associated with a given TTI.

At a given TTI, if an uplink grant is indicated for the TTI, the HARQ entity identifies the HARQ process(es) for which a transmission should take place. It also routes the received HARQ feedback (ACK/NACK information), MCS and resource, relayed by the physical layer, to the appropriate HARQ process(es).

In asynchronous HARQ operation, a HARQ process is associated with a TTI based on the received UL grant except for UL grant in RAR. Except for NB-IoT UE configured with a single HARQ process, each asynchronous HARQ process is associated with a HARQ process identifier. For UL transmission with UL grant in RAR, HARQ process identifier 0 is used. HARQ feedback is not applicable for asynchronous UL HARQ except if *mpdcch-UL-HARQ-ACK-FeedbackConfig* is configured.

In autonomous HARQ operation, HARQ feedback is applicable.

When TTI bundling is configured, the parameter TTI\_BUNDLE\_SIZE provides the number of TTIs of a TTI bundle. TTI bundling operation relies on the HARQ entity for invoking the same HARQ process for each transmission that is part of the same bundle. Within a bundle HARQ retransmissions are non-adaptive and triggered without waiting for feedback from previous transmissions according to TTI\_BUNDLE\_SIZE. The HARQ feedback of a bundle is only received for the last TTI of the bundle (i.e the TTI corresponding to TTI\_BUNDLE\_SIZE), regardless of whether a transmission in that TTI takes place or not (e.g. when a measurement gap occurs). A retransmission of a TTI bundle is also a TTI bundle. TTI bundling is not supported when the MAC entity is configured with one or more SCells with configured uplink.

Uplink HARQ operation is asynchronous for NB-IoT UEs, BL UEs or UEs in enhanced coverage except for the repetitions within a bundle, in serving cells configured with *pusch-EnhancementsConfig*, serving cells operating according to Frame Structure Type 3, for HARQ processes scheduled using short TTI, for HARQ processes scheduled using Short Processing Time, and for HARQ processes associated with an SPS configuration with *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* exceptfor the repetitions within a bundle.

For serving cells configured with *pusch-EnhancementsConfig*, NB-IoT UEs, BL UEs or UEs in enhanced coverage, the parameter UL\_REPETITION\_NUMBER provides the number of transmission repetitions within a bundle. For each bundle, UL\_REPETITION\_NUMBER is set to a value provided by lower layers. Bundling operation relies on the HARQ entity for invoking the same HARQ process for each transmission that is part of the same bundle. Within a bundle HARQ retransmissions are non-adaptive and are triggered without waiting for feedback from previous transmissions according to UL\_REPETITION\_NUMBER. An uplink grant corresponding to a new transmission of the bundle is only received after the last repetiton of the bundle if *mpdcch-UL-HARQ-ACK-FeedbackConfig* is not configured. An uplink grant corresponding to a retransmission of the bundle is only received after the last repetition of the bundle. For UEs configured with *mpdcch-UL-HARQ-ACK-FeedbackConfig*, repetitions within a bundle are stopped if an UL HARQ-ACK feedback or an uplink grant corresponding to a new transmission of the bundle is received on PDCCH during the bundle transmission. A retransmission of a bundle is also a bundle.

For a SPS configuration with *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* (TS 36.331 [8]), the parameter *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* provides the number of transmission repetitions within a configured grant bundle. Bundling operation relies on the HARQ entity invoking the same HARQ process for each transmission that is part of the same bundle. Within a bundle HARQ retransmissions are non-adaptive and are triggered without waiting for feedback from previous transmissions.

TTI bundling is not supported for RN communication with the E-UTRAN in combination with an RN subframe configuration.

For transmission of Msg3 during Random Access (see clause 5.1.5) TTI bundling does not apply. For UEs configured with *pusch-EnhancementsConfig* performing contention free Random Access, NB-IoT UEs, BL UEs or UEs in enhanced coverage, uplink repetition bundling is used for transmission of Msg3.

For each TTI, the HARQ entity shall:

- identify the HARQ process(es) associated with this TTI, and for each identified HARQ process:

- if an uplink grant has been indicated for this process and this TTI:

- if the received grant was not addressed to a Temporary C-RNTI on PDCCH and if the NDI provided in the associated HARQ information has been toggled compared to the value in the previous transmission of this HARQ process; or

- if the uplink grant was received on PDCCH for the C-RNTI and the HARQ buffer of the identified process is empty; or

- if the uplink grant was received in a Random Access Response:

- if there is a MAC PDU in the Msg3 buffer and the uplink grant was received in a Random Access Response:

- if the MAC PDU in the Msg3 buffer contains the Data Volume and Power Headroom Report MAC control element:

- the MAC entity shall update the Data Volume and Power Headroom Report MAC control element in the MAC PDU in the Msg3 buffer.

 - if the UE is an NB-IoT UE and *cqi-Reporting* is configured by upper layers:

- the MAC entity shall update the MAC PDU in the Msg3 buffer in accordance with the DL channel quality measurement result.

- obtain the MAC PDU to transmit from the Msg3 buffer.

- else if the uplink grant is a configured grant with *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* and if a retransmission within a bundle is triggered for another configured grant with *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* in this TTI:

- ignore the uplink grant.

- else if the MAC entity is configured with *semiPersistSchedIntervalUL* shorter than 10 subframes and if the uplink grant is a configured grant, and if the HARQ buffer of the identified HARQ process is not empty, and if HARQ\_FEEDBACK of the identified HARQ process is NACK; or if the MAC entity is configured with *ul-SchedInterval* shorter than 10 subframes and if the uplink grant is a preallocated uplink grant, and if the HARQ buffer of the identified HARQ process is not empty, and if HARQ\_FEEDBACK of the identified HARQ process is NACK:

- instruct the identified HARQ process to generate a non-adaptive retransmission.

- else:

- if the UL HARQ operation is synchronous, and the uplink grant is a preallocated uplink grant, and a MAC PDU has previously been obtained from the "Multiplexing and assembly" entity during this handover attempt:

- ignore the uplink grant;

- else:

- obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity, if any;

- if a MAC PDU to transmit has been obtained:

- deliver the MAC PDU and the uplink grant and the HARQ information to the identified HARQ process;

- instruct the identified HARQ process to trigger a new transmission.

- else:

- flush the HARQ buffer of the identified HARQ process.

- else:

- if the MAC entity is configured with *skipUplinkTxSPS* and if the uplink grant received on PDCCH was addressed to the Semi-Persistent Scheduling C-RNTI or to the UL Semi-Persistent Scheduling V-RNTI and if the HARQ buffer of the identified process is empty; or

- if UL HARQ operation is autonomous for the identified HARQ process and if the uplink grant is a configured UL grant and if the HARQ buffer of the identified process is empty; or

- if the previous uplink grant delivered to the HARQ entity for the same HARQ process was a configured uplink grant for which the UL HARQ operation was autonomous, and if the corresponding UL grant size was different from the UL grant size indicated by the uplink grant for this TTI:

- ignore the uplink grant;

- else:

- deliver the uplink grant and the HARQ information (redundancy version) to the identified HARQ process;

- if UL HARQ operation is autonomous for the identified HARQ process and if the uplink grant is a configured UL grant:

- instruct the identified HARQ process to generate a non adaptive retransmission.

- else:

- instruct the identified HARQ process to generate an adaptive retransmission.

- else, if the HARQ buffer of this HARQ process is not empty:

- instruct the identified HARQ process to generate a non-adaptive retransmission;

- if the non-adaptive retransmission collides with a transmission of another HARQ process scheduled using Short Processing Time:

- instruct the identified HARQ process to generate a positive acknowledgement (ACK) of the data in the corresponding TB.

When determining if NDI has been toggled compared to the value in the previous transmission the MAC entity shall ignore NDI received in all uplink grants on PDCCH for its Temporary C-RNTI.

Next Change

#### 5.4.3.1 Logical channel prioritization

The Logical Channel Prioritization procedure is applied when a new transmission is performed.

RRC controls the scheduling of uplink data by signalling for each logical channel: *priority* where an increasing *priority* value indicates a lower priority level, *prioritisedBitRate* which sets the Prioritized Bit Rate (PBR), *bucketSizeDuration* which sets the Bucket Size Duration (BSD), and optionally *allowedTTI-Lengths* which sets the allowed TTI lengths. For NB-IoT, *prioritisedBitRate*, *bucketSizeDuration* and the corresponding steps of the Logical Channel Prioritisation procedure (i.e., Step 1 and Step 2 below) are not applicable.

The MAC entity shall maintain a variable Bj for each logical channel j. Bj shall be initialized to zero when the related logical channel is established, and incremented by the product PBR × TTI duration for each TTI, where PBR is Prioritized Bit Rate of logical channel j. However, the value of Bj can never exceed the bucket size and if the value of Bj is larger than the bucket size of logical channel j, it shall be set to the bucket size. The bucket size of a logical channel is equal to PBR × BSD, where PBR and BSD are configured by upper layers.

The MAC entity shall perform the following Logical Channel Prioritization procedure when a new transmission is performed on an UL grant with a certain TTI length:

- The MAC entity shall allocate resources to the logical channels that are allowed to transmit using the TTI length of the grant, in the following steps:

- Step 1: All the allowed logical channels with Bj > 0 are allocated resources in a decreasing priority order. If the PBR of a logical channel is set to "infinity", the MAC entity shall allocate resources for all the data that is available for transmission on the logical channel before meeting the PBR of the lower priority logical channel(s);

- Step 2: the MAC entity shall decrement Bj by the total size of MAC SDUs served to logical channel j in Step 1;

NOTE 1: The value of Bj can be negative.

- Step 3: if any resources remain, all the allowed logical channels are served in a strict decreasing priority order (regardless of the value of Bj) until either the data for that logical channel or the UL grant is exhausted, whichever comes first. Logical channels configured with equal priority should be served equally.

- The UE shall also follow the rules below during the scheduling procedures above:

- the UE should not segment an RLC SDU (or partially transmitted SDU or retransmitted RLC PDU) if the whole SDU (or partially transmitted SDU or retransmitted RLC PDU) fits into the remaining resources of the associated MAC entity;

- if the UE segments an RLC SDU from the logical channel, it shall maximize the size of the segment to fill the grant of the associated MAC entity as much as possible;

- the UE should maximise the transmission of data.

- if the MAC entity is given an UL grant size that is equal to or larger than 4 bytes while having data available for transmission, the MAC entity shall not transmit only padding BSR and/or padding (unless the UL grant size is less than 7 bytes and an AMD PDU segment needs to be transmitted);

- for transmissions on serving cells operating according to Frame Structure Type 3, the MAC entity shall only consider logical channels for which *laa-UL-Allowed* has been configured;

- if a logical channel has been configured with *lch-CellRestriction* and if PDCP duplication is activated, for this logical channel the MAC entity shall not consider the cells indicated by *lch-CellRestriction* to be restricted for transmission.

- for NB-IoT UEs, BL UEs or UEs in enhanced coverage, if *edt-SmallTBS-Enabled* is set to *TRUE* for the corresponding PRACH resource, the UE shall choose a TB size among the set of possible TB sizes as described in clauses 8.6.2 and 16.3.3 of TS 36.213 [2]

The MAC entity shall not transmit data for a logical channel corresponding to a radio bearer that is suspended (the conditions for when a radio bearer is considered suspended are defined in TS 36.331 [8]).

If the MAC PDU includes only the MAC CE for padding BSR or periodic BSR with zero MAC SDUs and there is no aperiodic CSI requested for this TTI, as specified in TS 36.213 [2], the MAC entity shall not generate a MAC PDU for the HARQ entity in the following cases:

- in case the MAC entity is configured with *skipUplinkTxDynamic* and the grant indicated to the HARQ entity was addressed to a C-RNTI; or

- in case the MAC entity is configured with *skipUplinkTxSPS* and the grant indicated to the HARQ entity is a configured uplink grant activated by the MAC entity's Semi-Persistent Scheduling C-RNTI or by the MAC entity's UL Semi-Persistent Scheduling V-RNTI; or

- in case the grant indicated to the HARQ entity is a configured uplink grant activated by the MAC entity's AUL C-RNTI.

- in case the grant indicated to the HARQ entity is a preconfigured uplink grant.

For the Logical Channel Prioritization procedure, the MAC entity shall take into account the following relative priority in decreasing order:

- MAC control element for C-RNTI or data from UL-CCCH;

- MAC control element for DPR;

- MAC control element for SPS confirmation;

- MAC control element for AUL confirmation;

- MAC control element for BSR, with exception of BSR included for padding;

- MAC control element for PHR, Extended PHR, or Dual Connectivity PHR;

- MAC control element for Sidelink BSR, with exception of Sidelink BSR included for padding;

- MAC control element for DCQR and AS RAI;

- data from any Logical Channel, except data from UL-CCCH;

- MAC control element for Recommended bit rate query;

- MAC control element for BSR included for padding;

- MAC control element for Sidelink BSR included for padding.

When AS RAI has been triggered, DCQR and AS RAI MAC control element shall have higher priority than data from any Logical Channel, except data from UL-CCCH, only if after logical channel prioritization including AS RAI in the resulting MAC PDU does not require segmenting RLC SDU. Otherwise data from any Logical Channel shall have higher priority than DCQR and AS RAI MAC control element.

NOTE 2: When the MAC entity is requested to transmit multiple MAC PDUs in one TTI, steps 1 to 3 and the associated rules may be applied either to each grant independently or to the sum of the capacities of the grants. Also the order in which the grants are processed is left up to UE implementation. It is up to the UE implementation to decide in which MAC PDU a MAC control element is included when MAC entity is requested to transmit multiple MAC PDUs in one TTI. When the UE is requested to generate MAC PDU(s) in two MAC entities in one TTI, it is up to UE implementation in which order the grants are processed.

Next Change

### 5.4.5 Buffer Status Reporting

The Buffer Status reporting procedure is used to provide the serving eNB with information about the amount of data available for transmission in the UL buffers associated with the MAC entity. RRC controls BSR reporting by configuring the three timers *periodicBSR-Timer*, *retxBSR-Timer* and *logicalChannelSR-ProhibitTimer* and by, for each logical channel, optionally signalling *logicalChannelGroup* which allocates the logical channel to an LCG, as specified in TS 36.331 [8].

For the Buffer Status reporting procedure, the MAC entity shall consider all radio bearers which are not suspended and may consider radio bearers which are suspended.

For NB-IoT the Long BSR is not supported and all logical channels belong to one LCG.

A Buffer Status Report (BSR) shall be triggered if any of the following events occur:

- UL data, for a logical channel which belongs to a LCG, becomes available for transmission in the RLC entity or in the PDCP entity (the definition of what data shall be considered as available for transmission is specified in TS 36.322 [3] and TS 36.323 [4] or TS 38.323 [17] respectively) and either the data belongs to a logical channel with higher priority than the priorities of the logical channels which belong to any LCG and for which data is already available for transmission, or there is no data available for transmission for any of the logical channels which belong to a LCG, in which case the BSR is referred below to as "Regular BSR";

- UL resources are allocated and number of padding bits is equal to or larger than the size of the Buffer Status Report MAC control element plus its subheader, in which case the BSR is referred below to as "Padding BSR";

- *retxBSR-Timer* expires and the MAC entity has data available for transmission for any of the logical channels which belong to a LCG, in which case the BSR is referred below to as "Regular BSR";

- *periodicBSR-Timer* expires, in which case the BSR is referred below to as "Periodic BSR".

For Regular BSR:

- if the BSR is triggered due to data becoming available for transmission for a logical channel for which *logicalChannelSR-Prohibit* is configured by upper layers:

- start or restart the *logicalChannelSR-ProhibitTimer*;

- else:

- if running, stop the *logicalChannelSR-ProhibitTimer*.

For Regular and Periodic BSR:

- if more than one LCG has data available for transmission in the TTI where the BSR is transmitted: report Long BSR;

- else report Short BSR.

For Padding BSR:

- if the number of padding bits is equal to or larger than the size of the Short BSR plus its subheader but smaller than the size of the Long BSR plus its subheader:

- if more than one LCG has data available for transmission in the TTI where the BSR is transmitted: report Truncated BSR of the LCG with the highest priority logical channel with data available for transmission;

- else report Short BSR.

- else if the number of padding bits is equal to or larger than the size of the Long BSR plus its subheader, report Long BSR.

For NB-IoT or BL UEs:

- if *rai-Activation* is configured, and a buffer size of zero bytes has been triggered for the BSR, and the UE may have more data to send or receive in the near future:

- cancel any pending BSR.

If the Buffer Status reporting procedure determines that at least one BSR has been triggered and not cancelled:

- if the MAC entity has UL resources allocated for new transmission for this TTI:

- instruct the Multiplexing and Assembly procedure to generate the BSR MAC control element(s);

- start or restart *periodicBSR-Timer* except when all the generated BSRs are Truncated BSRs;

- start or restart *retxBSR-Timer*.

- else if a Regular BSR has been triggered and *logicalChannelSR-ProhibitTimer* is not running:

- if an uplink grant is not configured or the Regular BSR was not triggered due to data becoming available for transmission for a logical channel for which logical channel SR masking (*logicalChannelSR-Mask*) is setup by upper layers; or

- if *sr-WithHARQ-ACK-Config* is configured and there is valid resource for SR together with acknowledgement of the data in this TTI:

- a Scheduling Request shall be triggered.

A MAC PDU shall contain at most one MAC BSR control element, even when multiple events trigger a BSR by the time a BSR can be transmitted in which case the Regular BSR and the Periodic BSR shall have precedence over the padding BSR.

For EDT, the MAC entity shall not generate a BSR MAC control element if new transmission is for Msg3.

For CP-PUR, the MAC entity shall not generate a BSR MAC control element if new transmission is intended for preconfigured uplink grant.

The MAC entity shall restart *retxBSR-Timer* upon indication of a grant for transmission of new data on any UL-SCH.

All triggered BSRs shall be cancelled in case the UL grant(s) in this TTI can accommodate all pending data available for transmission but is not sufficient to additionally accommodate the BSR MAC control element plus its subheader. All triggered BSRs shall be cancelled when a BSR is included in a MAC PDU for transmission.

The MAC entity shall transmit at most one Regular/Periodic BSR in a TTI. If the MAC entity is requested to transmit multiple MAC PDUs in a TTI, it may include a padding BSR in any of the MAC PDUs which do not contain a Regular/Periodic BSR.

All BSRs transmitted in a TTI always reflect the buffer status after all MAC PDUs have been built for this TTI. Each LCG shall report at the most one buffer status value per TTI and this value shall be reported in all BSRs reporting buffer status for this LCG.

NOTE 1: A Padding BSR is not allowed to cancel a triggered Regular/Periodic BSR, except for NB-IoT. A Padding BSR is triggered for a specific MAC PDU only and the trigger is cancelled when this MAC PDU has been built.

NOTE 2: If UL HARQ operation is autonomous for the HARQ entity and if the BSR is already included in a MAC PDU for transmission by this HARQ entity, but not yet transmitted by lower layers, it is up to UE implementation how to handle the BSR content.

Next Change

### 5.4.x Preconfigured Uplink Resource

#### 5.4.x.1 Transmission using PUR

Preconfigured Uplink Resource may be configured by upper layers for a NB-IoT UE. When PUR has been configured by upper layers, the following information is provided in *PUR-config,* as specified in TS 36.331 [8]:

* PUR C-RNTI;
* Duration of PUR response window *pur-ResponseWindowSize*;
* Number *pur-ImplicitReleaseAfter* of skipped preconfigured uplink grants before implicit release;
* Time alignment timer for PUR, *pur-TimeAlignmentTimer*, if configured;
* Periodicity of resources, *pur-Periodicity*;
* Offset indicating PUR starting time, *pur-StartTime*;

Editor's note: FFS wheter *pur-NumOccasions* should be counted in MAC or in RRC. FFS if any other configuration information is needed.

The MAC entity shall consider sequentially that the Nth preconfigured uplink grant occurs in the TTI according to *pur-StartTime* and N \* *pur-Periodicity.*

Editor's note: Exact calculation above depends on further details of the configuration.

When PUR configuration is released by upper layers, MAC entity shall discard the corresponding preconfigured uplink grants.

If the MAC entity has a PUR C-RNTI, *pur-TimeAligmentTimer* is configured and TA is valid as specified in TS 36.331 [8] , the MAC entity shall in RRC\_IDLE for each TTI that has a running *pur-TimeAlignmentTimer* and a preconfigured uplink grant:

* deliver the preconfigured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

After transmission using preconfigured uplink grant, the MAC entity shall monitor PDCCH identified by PUR C-RNTI in the PUR response window using timer *pur-ResponseWindowTimer*, which starts at the subframe that contains the end of the corresponding PUSCH transmission, plus 4 subframes and has the length *pur-ResponseWindowSize.* While *pur-ResponseWindowTimer* is running, the MAC entity shall:

- if an uplink grant has been received on PDCCH for PUR C-RNTI for retransmission:

- restart *pur-ResponseWindowTimer* at the last subframe at the last subframe of a PUSCH transmission corresponding to the retransmission indicated by the UL grant, plus 4 subframes;

Editor's note: FFS whether restarting the window is indended in this case.

- if PDCCH indicates L1 ACK for PUR; or

- if PDCCH transmission is addressed to its PUR C-RNTI and the MAC PDU is successfully decoded:

- stop *pur-ResponseWindowTimer*;

- consider transmission using PUR successful;

- indicate to upper layers the PUR transmission was successful.

- if PDCCH indicates fallback for PUR:

- stop *pur-ResponseWindowTimer*;

- consider transmission using PUR transmission has failed;

- indicate to upper layers PUR fallback indication was received.

- if the *pur-ResponseWindowTimer* expires:

- consider the preconfigured uplink grant as skipped;

- indicate to upper layers the PUR transmission has failed.

Additionally, MAC entity shall consider a preconfigured uplink grant skipped if no MAC PDU is generated according to 5.4.3.1 for the preconfigured uplink grant.

The MAC entity shall discard the preconfigured uplink grants immediately after *pur-ImplicitReleaseAfter* number of consecutive skipped preconfigured uplink grants in RRC\_IDLE. MAC entity shall notify RRC to release PUR configuration when preconfigured uplink grants are discarded.

Editor's note: How MAC entity knows whether UE is in RRC\_IDLE or RRC\_CONNECTED above.

#### 5.4.x.2 Maintenance of PUR Uplink Time Alignment

MAC entity may have a configurable timer *pur-TimeAlignmentTimer* when upper layers have configured Preconfigured Uplink Resource.

The MAC entity shall:

- when *pur-TimeAlignmentTimer* configuration is received from upper layers:

- start *pur-TimeAlignmentTimer.*

- if upper layers indicate PUR TA is validated:

- start or restart the *pur-TimeAlignmentTimer.*

- when a Timing Advance Command MAC control element is received or PDCCH indicates timing advance adjustment as specified in TS 36.212 [5]:

- apply the Timing Advance Command or the timing advance adjustment;

- start or restart the *pur-TimeAlignmentTimer*.

- when a *pur-TimeAlignmentTimer* expires:

- indicate to upper layers the expiry of PUR TA timer.

Editor's note: How RRC indicates to MAC that TA is valid or instructs MAC to use PUR.

Upon request from upper layers, MAC entity shall indicate if *pur-TimeAlignmentTimer* is running or not.

Editor's note: FFS whether cell change can be captured in MAC or whether only in RRC and the exact interaction needed.

Next Change

### 5.4.y Access Stratum Release Assistance Indication

Access Stratum Release Assistance Indication is used to provide the serving eNB with information whether subsequent DL or UL transmission is expected. AS RAI uses the DPQR and AS RAI MAC Control Element. Upper layers trigger AS RAI.

For EDT and transmission using PUR, if AS RAI is triggered by upper layers but is not included in the resulting MAC PDU with the MAC SDU, AS RAI is cancelled.

Editor's note: FFS non-EDT, non-PUR.

Next Change

## 5.7 Discontinuous Reception (DRX)

The MAC entity may be configured by RRC with a DRX functionality that controls the UE's PDCCH monitoring activity for the MAC entity's C-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, Semi-Persistent Scheduling C-RNTI (if configured), UL Semi-Persistent Scheduling V-RNTI (if configured), eIMTA-RNTI (if configured), SL-RNTI (if configured), SL-V-RNTI (if configured), CC-RNTI (if configured), SRS-TPC-RNTI (if configured), and AUL C-RNTI (if configured). When in RRC\_CONNECTED, if DRX is configured, the MAC entity is allowed to monitor the PDCCH discontinuously using the DRX operation specified in this clause; otherwise the MAC entity monitors the PDCCH continuously. When using DRX operation, the MAC entity shall also monitor PDCCH according to requirements found in other clauses of this specification. RRC controls DRX operation by configuring the timers *onDurationTimer*, *drx-InactivityTimer*, *drx-RetransmissionTimer* (for HARQ processes scheduled using 1ms TTI, one per DL HARQ process except for the broadcast process), *drx-RetransmissionTimerShortTTI* (for HARQ processes scheduled using short TTI, one per DL HARQ process), *drx-ULRetransmissionTimer* (for HARQ processes scheduled using 1ms TTI, one per asynchronous UL HARQ process), *drx-ULRetransmissionTimerShortTTI* (for HARQ processes scheduled using short TTI, one per asynchronous UL HARQ process), the *longDRX-Cycle*, the value of the *drxStartOffset* and optionally the *drxShortCycleTimer* and *shortDRX-Cycle*. A HARQ RTT timer per DL HARQ process (except for the broadcast process) and UL HARQ RTT Timer per asynchronous UL HARQ process is also defined (see clause 7.7).

When a DRX cycle is configured, the Active Time includes the time while:

*- onDurationTimer* or *drx-InactivityTimer* or *drx-RetransmissionTimer* or *drx-RetransmissionTimerShortTTI* or *drx-ULRetransmissionTimer* or *drx-ULRetransmissionTimerShortTTI* or *mac-ContentionResolutionTimer* (as described in clause 5.1.5) is running; or

- a Scheduling Request is sent on PUCCH/SPUCCH and is pending (as described in clause 5.4.4); or

- an uplink grant for a pending HARQ retransmission can occur and there is data in the corresponding HARQ buffer for synchronous HARQ process; or

- a PDCCH indicating a new transmission addressed to the C-RNTI of the MAC entity has not been received after successful reception of a Random Access Response for the preamble not selected by the MAC entity (as described in clause 5.1.4) ; or

- *mpdcch-UL-HARQ-ACK-FeedbackConfig* is configured and repetitions within a bundle are being transmitted according to UL\_REPETITION\_NUMBER.

When DRX is configured, the MAC entity shall for each subframe:

- if a HARQ RTT Timer expires in this subframe:

- if the data of the corresponding HARQ process was not successfully decoded:

- start the *drx-RetransmissionTimer* or *drx-RetransmissionTimerShortTTI* for the corresponding HARQ process;

*-* if NB-IoT:

- if lower layers had indicated multiple TBs were scheduled for the associated expired HARQ RTT Timer:

- start or restart *drx-InactivityTimer* when all HARQ RTT Timers have expired;

- else:

- start or restart the *drx-InactivityTimer.*

- if an UL HARQ RTT Timer expires in this subframe:

- start the *drx-ULRetransmissionTimer* or *drx-ULRetransmissionTimerShortTTI* for the corresponding HARQ process.

- if NB-IoT:

- if lower layers had indicated multiple TBs were scheduled for the associated expired HARQ RTT Timer:

- start or restart *drx-InactivityTimer* when all HARQ RTT Timers have expired;

- else:

- start or restart the *drx-InactivityTimer*.

- if a DRX Command MAC control element or a Long DRX Command MAC control element is received:

- stop *onDurationTimer*;

- stop *drx-InactivityTimer*.

- if *drx-InactivityTimer* expires or a DRX Command MAC control element is received in this subframe:

- if the Short DRX cycle is configured:

- start or restart *drxShortCycleTimer*;

- use the Short DRX Cycle.

- else:

- use the Long DRX cycle.

- if *drxShortCycleTimer* expires in this subframe:

- use the Long DRX cycle.

- if a Long DRX Command MAC control element is received:

- stop *drxShortCycleTimer*;

- use the Long DRX cycle.

- If the Short DRX Cycle is used and [(SFN \* 10) + subframe number] modulo (*shortDRX-Cycle*) = (*drxStartOffset*) modulo (*shortDRX-Cycle*); or

- if the Long DRX Cycle is used and [(SFN \* 10) + subframe number] modulo (*longDRX-Cycle*) = *drxStartOffset*:

- if NB-IoT:

- if there is at least one HARQ process for which neither HARQ RTT Timer nor UL HARQ RTT Timer is running, start *onDurationTimer*.

- else:

- start onDurationTimer.

- during the Active Time, for a PDCCH-subframe, if the subframe is not required for uplink transmission for half-duplex FDD UE operation, and if the subframe is not a half-duplex guard subframe, as specified in TS 36.211 [7], and if the subframe is not part of a configured measurement gap and if the subframe is not part of a configured Sidelink Discovery Gap for Reception, and for NB-IoT if the subframe is not required for uplink transmission or downlink reception other than on PDCCH; or

- during the Active Time, for a subframe other than a PDCCH-subframe and for a UE capable of simultaneous reception and transmission in the aggregated cells, if the subframe is a downlink subframe indicated by a valid eIMTA L1 signalling for at least one serving cell not configured with *schedulingCellId*, as specified in TS 36.331 [8] and if the subframe is not part of a configured measurement gap and if the subframe is not part of a configured Sidelink Discovery Gap for Reception; or

- during the Active Time, for a subframe other than a PDCCH-subframe and for a UE not capable of simultaneous reception and transmission in the aggregated cells, if the subframe is a downlink subframe indicated by a valid eIMTA L1 signalling for the SpCell and if the subframe is not part of a configured measurement gap and if the subframe is not part of a configured Sidelink Discovery Gap for Reception:

- monitor the PDCCH;

- if the PDCCH indicates a DL transmission or if a DL assignment has been configured for this subframe:

- if the UE is an NB-IoT UE, a BL UE or a UE in enhanced coverage:

- if lower layers have indicated scheduling of transmission of multiple TBs:

- start the HARQ RTT Timers for all HARQ processes corresponding to the scheduled TBs in the subframe containing the last repetition of the PDSCH corresponding to the last scheduled TB;

- else:

- start the HARQ RTT Timer for the corresponding HARQ process in the subframe containing the last repetition of the corresponding PDSCH reception;

- else:

- start the HARQ RTT Timer for the corresponding HARQ process;

- stop the *drx-RetransmissionTimer* or *drx-RetransmissionTimerShortTTI* for the corresponding HARQ process.

- if NB-IoT, stop *drx-ULRetransmissionTimer* for all UL HARQ processes.

- if the PDCCH indicates an UL transmission for an asynchronous HARQ process or if an UL grant has been configured for an asynchronous HARQ process for this subframe, or if the PDCCH indicates an UL transmission for an autonomous HARQ process or;

- if the uplink grant is a configured grant for the MAC entity's AUL C-RNTI and if the corresponding PUSCH transmission has been performed in this subframe:

- if *mpdcch-UL-HARQ-ACK-FeedbackConfig* is not configured:

- if lower layers have indicated scheduling of transmission of multiple TBs:

- start the UL HARQ RTT Timers for all scheduled HARQ processes in the subframe containing the last repetition of the PUSCH corresponding to the last scheduled TB;

- else:

- start the UL HARQ RTT Timer for the corresponding HARQ process in the subframe containing the last repetition of the corresponding PUSCH transmission;

- stop the *drx-ULRetransmissionTimer* or *drx-ULRetransmissionTimerShortTTI* for the corresponding HARQ process;

- if *mpdcch-UL-HARQ-ACK-FeedbackConfig* is configured and an UL HARQ-ACK feedback has not been received on PDCCH until the last repetition of the corresponding PUSCH transmission:

- start or restart the *drx-ULRetransmissionTimer* for the corresponding HARQ process in the subframe containing the last repetition of the corresponding PUSCH transmission;

- if NB-IoT, stop *drx-RetransmissionTimer* for all DL HARQ processes.

- if the PDCCH indicates a new transmission (DL, UL or SL):

- except for an NB-IoT UE configured with a single DL and UL HARQ process and when PDCCH indicates the transmission is not for multiple TBs:

- start or restart *drx-InactivityTimer*.

- if the PDCCH indicates a transmission (DL, UL) for an NB-IoT UE:

- if the NB-IoT UE is configured with a single DL and UL HARQ process; or

- if the PDCCH indicates the transmission is for multiple TBs:

- stop *drx-Inactivity*Timer.

- stop *onDurationTimer.*

- if the PDCCH indicates an UL HARQ-ACK feedback for an asynchronous UL HARQ process for a UE configured with *mpdcch-UL-HARQ-ACK-FeedbackConfig*; and

- if the PUSCH transmission is completed:

- stop *drx-ULRetransmissionTimer* for all UL HARQ processes.

- if the PDCCH indicates HARQ feedback for one or more HARQ processes for which UL HARQ operation is autonomous:

- stop the *drx-ULRetransmissionTimer* for the corresponding HARQ process(es).

- in current subframe n, if the MAC entity would not be in Active Time considering grants/assignments/DRX Command MAC control elements/Long DRX Command MAC control elements received and Scheduling Request sent until and including subframe n-5 when evaluating all DRX Active Time conditions as specified in this clause, type-0-triggered SRS, as specified in TS 36.213 [2], shall not be reported.

- if CQI masking (*cqi-Mask*) is setup by upper layers:

- in current TTI n, if *onDurationTimer* would not be running considering grants/assignments/DRX Command MAC control elements/Long DRX Command MAC control elements received until and including TTI n-5 when evaluating all DRX Active Time conditions as specified in this clause, CQI/PMI/RI/PTI/CRI on PUCCH shall not be reported.

- else:

- in current TTI n, if the MAC entity would not be in Active Time considering grants/assignments/DRX Command MAC control elements/Long DRX Command MAC control elements received and Scheduling Request sent until and including TTI n-5 when evaluating all DRX Active Time conditions as specified in this clause, CQI/PMI/RI/PTI/CRI on PUCCH shall not be reported.

For NB-IoT, *onDurationTimer* may start within a PDCCH period and end within a PDCCH period. The UE shall monitor NPDCCH during these partial PDCCH periods while *onDurationTimer* is running.

Regardless of whether the MAC entity is monitoring PDCCH or not, the MAC entity receives and transmits HARQ feedback and transmits type-1-triggered SRS, as specified in TS 36.213 [2], when such is expected. The MAC entity monitors PDCCH addressed to CC-RNTI for a PUSCH trigger B, as specified in TS 36.213 [2], on the corresponding SCell even if the MAC entity is not in Active Time. when such is expected.

When the BL UE or the UE in enhanced coverage or NB-IoT UE receives PDCCH, the UE executes the corresponding action specified in this clause in the subframe following the subframe containing the last repetition of the PDCCH reception where such subframe is determined by the starting subframe and the DCI subframe repetition number field in the PDCCH specified in TS 36.213 [2], unless explicitly stated otherwise.

NOTE 1: The same Active Time applies to all activated serving cell(s).

NOTE 2: In case of downlink spatial multiplexing, if a TB is received while the HARQ RTT Timer is running and the previous transmission of the same TB was received at least N subframes before the current subframe (where N corresponds to the HARQ RTT Timer), the MAC entity should process it and restart the HARQ RTT Timer.

NOTE 3: The MAC entity does not consider PUSCH trigger B, as specified in TS 36.213 [2], to be an indication of a new transmission.

NOTE 4: For NB-IoT, for operation in FDD mode, and for operation in TDD mode with a single HARQ process, DL and UL transmissions will not be scheduled in parallel, i.e. if a DL transmission has been scheduled an UL transmission will not be scheduled until HARQ RTT Timer of the DL HARQ process has expired (and vice versa).

Next Change

## 5.9 MAC Reset

If a reset of the MAC entity is requested by upper layers, the MAC entity shall:

- initialize Bj for each logical channel to zero;

- except for *pur-timeAlignmentTimer,* if configured*,* stop (if running) all timers;

- consider all *timeAlignmentTimer*sas expired and perform the corresponding actions in clause 5.2;

- set the NDIs for all uplink HARQ processes to the value 0;

- stop, if any, ongoing RACH procedure;

- discard explicitly signalled *ra-PreambleIndex* and *ra-PRACH-MaskIndex*, if any;

- flush Msg3 buffer;

- cancel, if any, triggered Scheduling Request procedure;

- cancel, if any, triggered Buffer Status Reporting procedure;

- cancel, if any, triggered Power Headroom Reporting procedure;

- flush the soft buffers for all DL HARQ processes;

- for each DL HARQ process, consider the next received transmission for a TB as the very first transmission;

- release, if any, Temporary C-RNTI.

If a partial reset of the MAC entity is requested by upper layers, for a serving cell, the MAC entity shall for the serving cell:

- set the NDIs for all uplink HARQ processes to the value 0;

- flush all UL HARQ buffers;

- stop all running *drx-ULRetransmissionTimers*;

- stop all running UL HARQ RTT timers;

- stop, if any, ongoing RACH procedure;

- discard explicitly signalled *ra-PreambleIndex* and *ra-PRACH-MaskIndex*, if any;

- flush Msg3 buffer;

- release, if any, Temporary C-RNTI.

Editor's note: FFS what is the impact of PUR in this section.

Next Change

## 5.xx Transmission of Downlink Channel Quality Report

If the UE is a NB-IoT UE, a Downlink Channel Quality Report (DCQR) shall be triggered if any of the following events occur:

- DCQR Command MAC control element is received, in which case the DCQR is referred below to as "Regular DCQR";If any type of DCQR has been triggered:

- start performing DL channel quality measurements according to TS 36.133 [9].

If "Regular DCQR" has been triggered:

- if an uplink grant has been received on the PDCCH for MAC entity’s C-RNTI:

- instruct the Multiplexing and Assembly procedure to generate a DCQR and AS RAI MAC control element as defined in clause 6.1.3.xx;

- cancel the triggered "Downlink Channel Quality Report".

Next Change

#### 6.1.3.xx Downlink Channel Quality Report Command MAC Control Element

DCQR Command MAC control element is identified by a MAC PDU subheader with LCID as specified in Table 6.2.1-1.

It has a fixed size of zero bits.

#### 6.1.3.xy Downlink Channel Quality Report and AS RAI MAC Control Element

DCQR and AS RAI MAC control element is identified by a MAC PDU subheader with LCID as specified in Table 6.2.1-2. A MAC PDU shall contain at most one DCQR and AS RAI MAC control element.

It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.xx-1):

* R: Reserved bit, set to "0";
* AS RAI: The field corresponds to Access Stratum Release Assistance Indication as shown in Table 6.1.3.xy-1. The length of the field is 2 bits;

Quality Report: For an NB-IoT UE, the field corresponds to *CQI-NPDCCH-NB* as defined in TS 36.331 [8]. The length of the field is 4 bits. 

Figure 6.1.3.xy-1: DCQR and AS RAI MAC control element

Table 6.1.3.xy-1: Values for AS RAI

|  |  |
| --- | --- |
| Codepoint/Index | Value |
| 00 | No RAI information |
| 01 | No subsequent DL and UL data transmission is expected |
| 10 | A single subsequent DL transmission is expected |
| 11 | Reserved |

Next Change

### 6.2.1 MAC header for DL-SCH, UL-SCH and MCH

The MAC header is of variable size and consists of the following fields:

- LCID: The Logical Channel ID field identifies the logical channel instance of the corresponding MAC SDU or the type of the corresponding MAC control element or padding as described in tables 6.2.1-1, 6.2.1-2 and 6.2.1-4 for the DL-SCH, UL-SCH and MCH respectively. There is one LCID field for each MAC SDU, MAC control element or padding included in the MAC PDU. In addition to that, one or two additional LCID fields are included in the MAC PDU, when single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU. If the LCID field is set to "10000", an additional octet is present in the MAC PDU subheader containing the eLCID field and this additional octet follows the octet containing LCID field. A UE of Category 0, as specified in TS 36.306 [12], except when in enhanced coverage, and *unicastFreqHoppingInd-r13* is indicated in the BR version of SI message carrying *SystemInformationBlockType2*, and UE supports frequency hopping for unicast, as specified in TS 36.306 [12], shall indicate CCCH using LCID "01011", a BL UE with support for frequency hopping for unicast, as specified in TS 36.306 [12], and a UE in enhanced coverage with support for frequency hopping for unicast, as specified in TS 36.306 [12], shall if *unicastFreqHoppingInd-r13* is indicated in the BR version of SI message carrying *SystemInformationBlockType2* indicate CCCH using LCID "01100", otherwise the UE shall indicate CCCH using LCID "00000". The LCID field size is 5 bits;

- eLCID: The extended Logical Channel ID field identifies the logical channel instance of the corresponding MAC SDU or the type of the corresponding MAC control element as described in tables 6.2.1-1a and 6.2.1-2a for the DL-SCH and UL-SCH respectively. The size of the eLCID field is 6 bits.

- L: The Length field indicates the length of the corresponding MAC SDU or variable-sized MAC control element in bytes. There is one L field per MAC PDU subheader except for the last subheader and subheaders corresponding to fixed-sized MAC control elements. The size of the L field is indicated by the F field and F2 field;

- F: The Format field indicates the size of the Length field as indicated in table 6.2.1-3. There is one F field per MAC PDU subheader except for the last subheader and subheaders corresponding to fixed-sized MAC control elements and except for when F2 is set to 1. The size of the F field is 1 bit. If the F field is included; if the size of the MAC SDU or variable-sized MAC control element is less than 128 bytes, the value of the F field is set to 0, otherwise it is set to 1;

- F2: The Format2 field indicates the size of the Length field as indicated in table 6.2.1-3. There is one F2 field per MAC PDU subheader. The size of the F2 field is 1 bit. If the size of the MAC SDU or variable-sized MAC control element is larger than 32767 bytes, and if the corresponding subheader is not the last subheader, the value of the F2 field is set to 1, otherwise it is set to 0.

- E: The Extension field is a flag indicating if more fields are present in the MAC header or not. The E field is set to "1" to indicate another set of at least R/F2/E/LCID fields. The E field is set to "0" to indicate that either a MAC SDU, a MAC control element or padding starts at the next byte;

- R: Reserved bit, set to "0".

The MAC header and subheaders are octet aligned.

Table 6.2.1-1 Values of LCID for DL-SCH

|  |  |
| --- | --- |
| Codepoint/Index | LCID values |
| 00000 | CCCH |
| 00001-01010 | Identity of the logical channel |
| 01011-01111 | Reserved |
| 10000 | Extended logical channel ID field |
| 10001 | DCQR Command  |
| 10010 | Activation/Deactivation of PDCP Duplication |
| 10011 | Hibernation (1 octet) |
| 10100 | Hibernation (4 octets) |
| 10101 | Activation/Deactivation of CSI-RS |
| 10110 | Recommended bit rate |
| 10111 | SC-PTM Stop Indication |
| 11000 | Activation/Deactivation (4 octets) |
| 11001 | SC-MCCH, SC-MTCH (see note) |
| 11010 | Long DRX Command |
| 11011 | Activation/Deactivation (1 octet) |
| 11100 | UE Contention Resolution Identity |
| 11101 | Timing Advance Command |
| 11110 | DRX Command |
| 11111 | Padding |
| NOTE: Both SC-MCCH and SC-MTCH cannot be multiplexed with other logical channels in the same MAC PDU except for Padding and SC-PTM Stop Indication |

Table 6.2.1-1a Values of eLCID for DL-SCH

|  |  |  |
| --- | --- | --- |
| Codepoint | Index | LCID values |
| 000000-000110 | 32-38 | Identity of the logical channel |
| 000111-111111 | 39-95 | Reserved |

For NB-IoT only the following LCID values for DL-SCH are applicable: CCCH, Identity of the logical channel, DCQR Command, SC-PTM Stop Indication, SC-MCCH/SC-MTCH, UE Contention Resolution Identity, Timing Advance Command, DRX Command and Padding.

Table 6.2.1-2 Values of LCID for UL-SCH

|  |  |
| --- | --- |
| Codepoint/Index | LCID values |
| 00000 | CCCH |
| 00001-01010 | Identity of the logical channel |
| 01011 | CCCH |
| 01100 | CCCH |
| 01101 | CCCH and Extended Power Headroom Report |
| 01110-01111 | Reserved |
| 10000 | Extended logical channel ID field |
| 10001 | DCQR and AS RAI |
| 10010 | AUL confirmation (4 octets) |
| 10011 | AUL confirmation (1 octet) |
| 10100 | Recommended bit rate query |
| 10101 | SPS confirmation |
| 10110 | Truncated Sidelink BSR |
| 10111 | Sidelink BSR |
| 11000 | Dual Connectivity Power Headroom Report |
| 11001 | Extended Power Headroom Report |
| 11010 | Power Headroom Report |
| 11011 | C-RNTI |
| 11100 | Truncated BSR |
| 11101 | Short BSR |
| 11110 | Long BSR |
| 11111 | Padding |

Table 6.2.1-2a Values of eLCID for UL-SCH

|  |  |  |
| --- | --- | --- |
| Codepoint | Index | LCID values |
| 000000-000110 | 32-38 | Identity of the logical channel |
| 000111-111111 | 39-95 | Reserved |

For NB-IoT only the following LCID values for UL-SCH are applicable: CCCH (LCID "00000"), Identity of the logical channel, CCCH and Extended Power Headroom Report, DCQR and AS RAI, SPS confirmation, C-RNTI, Short BSR and Padding.

Table 6.2.1-3 Values of F and F2 fields:

|  |  |  |
| --- | --- | --- |
| Index of F2 | Index of F | Size of Length field (in bits) |
| 0 | 0 | 7 |
| 1 | 15 |
| 1 | - | 16 |

Table 6.2.1-4 Values of LCID for MCH

|  |  |
| --- | --- |
| Index | LCID values |
| 00000 | MCCH (see note) |
| 00001-11100 | MTCH |
| 11101 | Reserved |
| 11110 | MCH Scheduling Information or Extended MCH Scheduling Information |
| 11111 | Padding |
| NOTE: If there is no MCCH on MCH, an MTCH could use this value. |

Next Change

## 7.1 RNTI values

RNTI values are presented in Table 7.1-1 and their usage and associated Transport Channels and Logical Channels are presented in Table 7.1-2.

Table 7.1-1: RNTI values.

|  |  |
| --- | --- |
| Value (hexa-decimal) | RNTI |
| 0000 | N/A |
| 0001-09600001-1000 (Note 3) | RA-RNTI, C-RNTI, Semi-Persistent Scheduling C-RNTI, Temporary C-RNTI, eIMTA-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, SL-RNTI (see note), G-RNTI, SL-V-RNTI, UL Semi-Persistent Scheduling V-RNTI, SL Semi-Persistent Scheduling V-RNTI, SRS-TPC-RNTI, AUL C-RNTI, and PUR C-RNTI |
| 0961-FFF31001-FFF3 (Note 3) | C-RNTI, Semi-Persistent Scheduling C-RNTI, eIMTA-RNTI, Temporary C-RNTI, TPC-PUCCH-RNTI, TPC-PUSCH-RNTI, SL-RNTI, G-RNTI, SL-V-RNTI, UL Semi-Persistent Scheduling V-RNTI, SL Semi-Persistent Scheduling V-RNTI, SRS-TPC-RNTI, AUL C-RNTI, and PUR C-RNTI |
| FFF4-FFF8 | Reserved for future use |
| FFF9 | SI-RNTI |
| FFFA | SC-N-RNTI |
| FFFB | SC-RNTI |
| FFFC | CC-RNTI |
| FFFD | M-RNTI |
| FFFE | P-RNTI |
| FFFF | SI-RNTI |

NOTE 1: A MAC entity uses the same C-RNTI on all Serving Cells.

NOTE 2: SI-RNTI value FFFF may be used for MBMS-dedicated carrier. SI-RNTI value FFF9 is only used for MBMS-dedicated carrier.

NOTE 3: Range applicable for NB-IoT.

Table 7.1-2: RNTI usage.

|  |  |  |  |
| --- | --- | --- | --- |
| RNTI | Usage | Transport Channel | Logical Channel |
| P-RNTI | Paging and System Information change notification | PCH | PCCH |
| SI-RNTI | Broadcast of System Information | DL-SCH | BCCH, BR-BCCH |
| M-RNTI | MCCH Information change notification | N/A | N/A |
| RA-RNTI | Random Access Response | DL-SCH | N/A |
| eIMTA-RNTI | eIMTA TDD UL/DL configuration notification | N/A | N/A |
| Temporary C-RNTI | Contention Resolution(when no valid C-RNTI is available) | DL-SCH | CCCH, DCCH |
| Temporary C-RNTI | Msg3 transmission | UL-SCH | CCCH, DCCH, DTCH |
| C-RNTI | Dynamically scheduled unicast transmission | UL-SCH | DCCH, DTCH |
| C-RNTI | Dynamically scheduled unicast transmission | DL-SCH | CCCH, DCCH, DTCH |
| C-RNTI | Triggering of PDCCH ordered random access | N/A | N/A |
| Semi-Persistent Scheduling C-RNTI | Semi-Persistently scheduled unicast transmission(activation, reactivation and retransmission) | DL-SCH, UL-SCH | DCCH, DTCH |
| Semi-Persistent Scheduling C-RNTI | Semi-Persistently scheduled unicast transmission(deactivation) | N/A | N/A |
| TPC-PUCCH-RNTI | Physical layer Uplink power control | N/A | N/A |
| TPC-PUSCH-RNTI | Physical layer Uplink power control | N/A | N/A |
| SL-RNTI | Dynamically scheduled sidelink transmission for sidelink communication | SL-SCH | STCH |
| SC-RNTI | Dynamically scheduled SC-PTM control information | DL-SCH | SC-MCCH |
| G-RNTI | Dynamically scheduled SC-PTM transmission | DL-SCH | SC-MTCH |
| SC-N-RNTI | SC-MCCH Information change notification | N/A | N/A |
| CC-RNTI | Providing common control PDCCH information | N/A | N/A |
| SL-V-RNTI | Dynamically scheduled sidelink transmission for V2X sidelink communication | SL-SCH | STCH |
| UL Semi-Persistent Scheduling V-RNTI | Semi-Persistently scheduled uplink transmission for V2X communication(activation, reactivation and retransmission) | UL-SCH | DCCH, DTCH |
| UL Semi-Persistent Scheduling V-RNTI | Semi-Persistently scheduled uplink transmission for V2X communication(deactivation) | N/A | N/A |
| SL Semi-Persistent Scheduling V-RNTI | Semi-Persistently scheduled sidelink transmission for V2X sidelink communication(activation, reactivation and retransmission) | SL-SCH | STCH |
| SL Semi-Persistent Scheduling V-RNTI | Semi-Persistently scheduled sidelink transmission for V2X sidelink communication(deactivation) | N/A | N/A |
| SRS-TPC-RNTI | SRS and TPC for the PUSCH-less SCells | N/A | N/A |
| AUL C-RNTI | Autonomous Uplink C-RNTI unicast transmission (activation and reactivation) | UL-SCH | DCCH, DTCH |
| AUL C-RNTI | Autonomous Uplink C-RNTI unicast transmission (deactivation) | N/A | N/A |
| PUR C-RNTI | Transmission using Preconfigured Uplink Resource | DL-SCH, UL-SCH | CCCH, DCCH, DTCH |

Next Change

## 7.7 HARQ RTT Timers

For each serving cell, in case of FDD configuration not configured with *subframeAssignment-r15* and in case of Frame Structure Type 3 configuration on the serving cell which carries the HARQ feedback for this serving cell the HARQ RTT Timer is set to 8 subframes. For each serving cell, in case of TDD configuration or FDD with *subframeAssignment-r15* configured on the serving cell which carries the HARQ feedback for this serving cell the HARQ RTT Timer is set to k + 4 subframes, where k is the interval between the downlink transmission and the transmission of associated HARQ feedback, as indicated in clauses 10.1 and 10.2 of TS 36.213 [2], and for an RN configured with *rn-SubframeConfig*, as specified in TS 36.331 [8] and not suspended, as indicated in Table 7.5.1-1 of TS 36.216 [11].

For each serving cell, for HARQ processes scheduled using Short Processing Time (TS 36.331 [8]) the HARQ RTT is set to 6 subframes for FDD and Frame Structure Type 3 and set to k + 3 subframes for TDD, where k is the interval between the downlink transmission and the transmission of associated HARQ feedback, as indicated in clauses 10.1 and 10.2 of TS 36.213 [2].

For each serving cell, for HARQ processes scheduled using short TTI (TS 36.331 [8]) the HARQ RTT is set to 8 TTIs if the TTI length is one slot or if *proc-Timeline* is set to n+4 set1, to 12 TTIs if *proc-Timeline* is set to n+6 set1 or n+6 set2 and to 16 TTIs if *proc-Timeline* is set to n+8 set2 for FDD and Frame Structure Type 3.

For TDD short TTI the HARQ RTT is set to k + 4 TTIs, where k is the interval between the downlink transmission and the transmission of associated HARQ feedback, as indicated in clauses 10.1 and 10.2 of TS 36.213 [2].

For BL UEs and UEs in enhanced coverage, HARQ RTT Timer corresponds to 7 + N where N is the used PUCCH repetition factor, where only valid (configured) UL subframes as configured by upper layers in *fdd-UplinkSubframeBitmapBR* are counted. In case of TDD, HARQ RTT Timer corresponds to 3 + k + N, where k is the interval between the last repetition of downlink transmission and the first repetition of the transmission of associated HARQ feedback, and N is the used PUCCH repetition factor, where only valid UL subframes are counted as indicated in clauses 10.1 and 10.2 of TS 36.213 [2].

For NB-IoT, when single TB is scheduled by PDCCH or when multiple TBs are scheduled for the interleaved case when HARQ ACK bundling is configured the HARQ RTT Timer is set to k+3+N+deltaPDCCH subframes, where k is the interval between the last subframe of the downlink transmission and the first subframe of the associated HARQ feedback transmission and N is the transmission duration in subframes of the associated HARQ feedback, and deltaPDCCH is the interval starting from the subframe following the last subframe of the associated HARQ feedback transmission plus 3 subframes to the first subframe of the next PDCCH occasion.

For NB-IoT, when multiple TBs are scheduled by PDCCH for the non-interleaved case or for the interleaved case when HARQ ACK bundling is not configured, the HARQ RTT Timer is set to k+2\*N+1+deltaPDCCH subframes where k is the interval between the last subframe of the downlink transmission and the first subframe of the first HARQ feedback transmission and N is the transmission duration in subframes of the associated HARQ feedback, and deltaPDCCH is the interval starting from the subframe following the last subframe of the last HARQ feedback transmission plus 1 subframe to the first subframe of the next PDCCH occasion.

Except for NB-IoT and for HARQ processes scheduled using Short Processing Time and for short TTI, UL HARQ RTT Timer length is set to 4 subframes for FDD and Frame Structure Type 3, and set to kULHARQRTT subframes for TDD, where kULHARQRTT equals to the kPHICH value indicated in Table 9.1.2-1 of TS 36.213 [2] if the UE is not configured with upper layer parameter *symPUSCH-UpPts* for the serving cell, otherwise the kPHICH value is indicated in Table 9.1.2-3.

For NB-IoT, when single TB is scheduled by PDCCH the UL HARQ RTT timer length is set to 4+deltaPDCCH subframes, where deltaPDCCH is the interval starting from the subframe following the last subframe of the PUSCH transmission plus 3 subframes to the first subframe of the next PDCCH occasion.

For NB-IoT, when multiple TBs are scheduled by PDCCH the UL HARQ RTT timer length is set to 1+deltaPDCCH subframes, where deltaPDCCH is the interval starting from the subframe following the last subframe of the PUSCH transmission plus 1 subframe to the first subframe of the next PDCCH occasion.

For HARQ processes scheduled using Short Processing Time (TS 36.331 [8]), the UL HARQ RTT Timer length is set to 3 subframes for FDD and for Frame Structure Type 3, and set to kULHARQRTT subframes for TDD, where kULHARQRTT equals the value indicated in Table 7.7-1 and Table 7.7-2.

For HARQ processes scheduled using short TTI (TS 36.331 [8]), the UL HARQ RTT Timer length is set to 8 TTIs if the TTI length is one slot or if *proc-Timeline* is set to n+4 set1, to 12 TTIs if *proc-Timeline* is set to n+6 set1 or n+6 set2 and to 16 TTIs if *proc-Timeline* is set to n+8 set2 for FDD and Frame Structure Type 3. For TDD short TTI the UL HARQ RTT is set to kULHARQRTT TTIs, where kULHARQRTT equals the value indicated in Table 7.7-3, Table 7.7-4 and Table 7.7-5.

 Table 7.7-1: kULHARQRTT for TDD Short Processing Time when special subframe configurations 0~9 is configured

|  |  |
| --- | --- |
| **TDD UL/DLConfiguration** | **subframe index *n*** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| 0 |  |  | 3 | 3 | 6 |  |  | 3 | 3 | 6 |
| 1 |  |  | 3 | 3 |  |  |  | 3 | 3 |  |
| 2 |  |  | 3 |  |  |  |  | 3 |  |  |
| 3 |  |  | 3 | 3 | 3 |  |  |  |  |  |
| 4 |  |  | 3 | 3 |  |  |  |  |  |  |
| 5 |  |  | 3 |  |  |  |  |  |  |  |
| 6 |  |  | 3 | 3 | 5 |  |  | 3 | 3 |  |

Table 7.7-2: kULHARQRTT for TDD Short Processing Time applied when special subframe configuration 10 is configured

|  |  |
| --- | --- |
| **TDD UL/DLConfiguration** | **subframe index n** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| 0 |  | 4 | 3 | 3 | 6 |   | 4 | 3 | 3 | 6 |
| 1 |  | 3 | 3 | 3 |   |   | 3 | 3 | 3 |   |
| 2 |  | 3 | 3 |  |  |  | 3 | 3 |  |   |
| 3 |  | 4 | 3 | 3 | 3 |  |  |  |  |   |
| 4 |  | 3 | 3 | 3 |  |  |  |  |  |   |
| 5 |  | 3 | 3 |  |  |  |  |  |  |   |
| 6 |  | 4 | 3 | 3 | 5 |  | 3 | 3 | 3 |   |

Table 7.7-3: kULHARQRTT for TDD short TTI applied when special subframe configurations 1, 2, 3, 4, 6, 7 and 8 are configured

|  |  |
| --- | --- |
| **TDD UL/DLConfiguration** | **sTTI index *n*** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| 0 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 4 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 4 |
| 1 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |  |  |  |  | 4 | 4 | 4 | 4 |  |  |
| 2 |  |  |  |  | 4 | 4 |  |  |  |  |  |  |  |  | 4 | 4 |  |  |  |  |
| 3 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 4 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |

Table 7.7-4: kULHARQRTT for TDD short TTI applied when special subframe configurations 0, 5 and 9 are configured

|  |  |
| --- | --- |
| **TDD UL/DLConfiguration** | **sTTI index *n*** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| 0 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 11 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 11 |
| 1 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |  |  |  |  | 4 | 4 | 4 | 4 |  |  |
| 2 |  |  |  |  | 4 | 4 |  |  |  |  |  |  |  |  | 4 | 4 |  |  |  |  |
| 3 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  | 6 | 5 | 4 | 4 | 4 | 9 |  |  |  |  | 4 | 4 | 4 | 4 |  |  |

Table 7.7-5: kULHARQRTT for TDD short TTI applied when special subframe configuration 10 is configured

|  |  |
| --- | --- |
| **TDD UL/DLConfiguration** | **sTTI index *n*** |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** |
| 0 |  |  |  | 7 | 6 | 5 | 4 | 4 | 4 | 11 |  |  |  | 7 | 6 | 5 | 4 | 4 | 4 | 11 |
| 1 |  |  |  | 5 | 4 | 4 | 4 | 4 |  |  |  |  |  | 5 | 4 | 4 | 4 | 4 |  |  |
| 2 |  |  |  | 4 | 4 | 4 |  |  |  |  |  |  |  | 4 | 4 | 4 |  |  |  |  |
| 3 |  |  |  | 7 | 6 | 5 | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  | 5 | 4 | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  | 4 | 4 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  | 7 | 6 | 5 | 4 | 4 | 4 | 9 |  |  |  | 5 | 4 | 4 | 4 | 4 |  |  |

NOTE 4: In Case 7, if n is 1, there is no L field after the subheader of MAC SDU for DTCH.

End of changes