**3GPP TSG-RAN WG2 Meeting #130** **R2-250xxxx**

**Malta, Malta, May 19th – 23th, 2025**

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| *CR-Form-v12.3* |
| **CHANGE REQUEST** |
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|  | **36.321** | **CR** | **Draft** | **rev** | **-** | **Current version:** | **18.4.0** |  |
|  |
| *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:***  | MAC Running CR for Rel-19 IoT NTN |
|  |  |
| ***Source to WG:*** | MediaTek Inc. |
| ***Source to TSG:*** | R2 |
|  |  |
| ***Work item code:*** | IoT\_NTN\_Ph3-Core |  | ***Date:*** | 2025-04-14 |
|  |  |  |  |  |
| ***Category:*** | **B** |  | ***Release:*** | Rel-19 |
|  | *Use one of the following categories:****F*** *(correction)****A*** *(mirror corresponding to a change in an earlier release)****B*** *(addition of feature),* ***C*** *(functional modification of feature)****D*** *(editorial modification)*Detailed explanations of the above categories canbe found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | *Use one of the following releases:Rel-8 (Release 8)Rel-9 (Release 9)Rel-10 (Release 10)Rel-11 (Release 11)…Rel-17 (Release 17)Rel-18 (Release 18)Rel-19 (Release 19)Rel-20 (Release 20)* |
|  |  |
| ***Reason for change:*** | Draft MAC CR for Rel-19 IoT NTN enhancements. This MAC Running CR captures the RAN2 agreements up to RAN2#129bis. |
|  |  |
| ***Summary of change:*** | A new section is added to capture the IoT NTN enhancments on CB-Msg3  |
|  |  |
| ***Consequences if not approved:*** | No support for Release-19 enhancements for IoT NTN |
|  |  |
| ***Clauses affected:*** | 3.1, 3.2, 5.1a.xx (new), 6.1.xx(new), 7.1 |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** |  | **x** |  Other core specifications  | TS/TR ... CR ...  |
| ***affected:*** |  | **x** |  Test specifications | TS/TR ... CR ...  |
| ***(show related CRs)*** |  | **x** |  O&M Specifications | TS/TR ... CR ...  |
|  |  |
| ***Other comments:*** |  |
|  |  |
| ***This CR's revision history:*** | R2-2502768 first version of Rel-19 IoT NTN MAC running CR. |

# 3 Definitions and abbreviations

## 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.

Editor’s note:FFS a defintion for CB-Msg3-EDT.

**CB-Msg3:** Contention-Basedmessage transmitted on UL-SCH containing a CCCH SDU optionally multiplexed with DTCH for the UP solution, submitted from upper layer and associated with the UE Contention Resolution Identity, as part of a CB-Msg3-EDT procedure. The same CB-Msg3 may be transmitted one or multiple times within the CB-Msg3 transmission window according to the configuration.

**CB-RNTI:** The Contention-Based RNTI is used to scramble CB-Msg3 and on the PDCCH when response messages for CB-Msg3 are transmitted during the CB-Msg3-EDT procedure.

***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, or after PDCCH indicates a new UL or DL transmission for one TB when the UE is configured with multiple HARQ processes. 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.

**NR sidelink communication**: AS functionality enabling at least V2X Communication as defined in TS 23.287 [23], between two or more nearby UEs, using NR technology but not traversing any network node.

**Non-terrestrial networks:** An E-UTRAN consisting of eNBs, which provide non-terrestrial LTE access to UEs by means of an NTN payload embarked on a space-borne NTN vehicle and an NTN Gateway.

***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 36.331 [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.

**UE-eNB RTT:** For non-terrestrial networks, the sum of the UE's Timing Advance value (see TS 36.211 [7], clause 8.1) and *k-Mac* in units of subframe, not rounded or truncated toward an integer number of subframes.

**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.

## 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].

AS Access Stratum

AUL Autonomous Uplink

BL Bandwidth reduced Low complexity

BR Bandwidth Reduced

BSR Buffer Status Report

C-RNTI Cell RNTI

CB-RNTI Contention-Based RNTI

CBR Channel Busy Ratio

CC-RNTI Common Control RNTI

CG Cell Group

CQI Channel Quality Indicator

CRI CSI-RS Resource Indicator

CSI Channel State Information

DAPS Dual Active Protocol Stack

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

# 5 MAC procedures

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### 5.1a.xx CB-Msg3-EDT Procedure

#### 5.1a.xx.1 CB-Msg3-EDT initialization

The CB-Msg3-EDT procedure described in this clause is initiated by the RRC sublayer. If the UE is an NB-IoT UE, the CB-Msg3-EDT procedure is performed on the anchor carrier or one of the non-anchor carriers for which CB-Msg3-EDT resource has been configured in system information.

The following information is assumed to be available before the procedure can be initiated for NB-IoT UEs, BL UEs or UEs in enhanced coverage operating in CE mode A in a non-terrestrial network, as specified in TS 36.331 [8]:

- if the UE is a BL UE or a UE in enhanced coverage operating in CE mode A:

- the available set of PUSCH resources in time domain associated with each enhanced coverage level for the transmission of the CB-Msg3, *cb-Msg3-EDT-StartTimeParameters*.

- the available set of PUSCH resources in frequnecy domain associated with each enhanced coverage level for the transmission of the CB-Msg3, *cb-Msg3-EDT-PUSCH-Config*.

- if the UE is an NB-IoT UE:

- the available sets of PUSCH resources in time domain on the anchor carrier, *cb-Msg3-EDT-StartTimeParameters* and on the non-anchor carriers, in *ul-ConfigList*.

- the available sets of PUSCH resources in frequnecy domain on the anchor carrier, *cb-Msg3-EDT-PUSCH-Config* and on the non-anchor carriers, in *ul-ConfigList*.

Editor’s note: FFS which IE in SIB22-NB contains the CB-Msg3-EDT configuration.

- the mapping of the PUSCH resources into enhanced coverage levels is determined according to the following:

- the number of enhanced coverage levels is equal to one plus the number of RSRP thresholds present in *cb-Msg3-EDT-RSRP-ThresholdList*.

Editor’s note: FFS how the mapping of PUSCH resources and CE levels are done for NB-IoT.

Editor’s note: FFS how the NB-IoT UE selects a carrier for CB-Msg3-EDT when multiple carriers provide PUSCH resources for the same enhanced coverage level.

- the criteria to select PUSCH resources based on RSRP measurement per enhanced coverage level, *cb-Msg3-EDT-RSRP-ThresholdList*.

- the number of replicas for CB-Msg3-EDT transmission corresponding to the selected enhanced coverage level, *cb-Msg3-EDT-NumReplicas*.

- CB-Msg3 transmission window configuration corresponding to the selected enhanced coverage level, *cb-Msg3-EDT-TransmissionWindow*.

- CB-Msg3 response window length corresponding to the selected enhanced coverage level, *cb-Msg3-EDT-ResponseWindowLength*.

- the maximum number of transmission attempts per enhanced coverage level, *maxNumCBMsg3AttemptCE*.

- [FFS other parameters]

Editor’s note: FFS the transmission power parameters and power ramping parameters.

The CB-Msg3-EDT procedure shall be performed as follows:

- flush the Msg3 buffer;

- set the CB\_MSG3\_TRANSMISSION\_COUNTER\_CE to 1;

- if the UE is an NB-IoT UE and if the RSRP threshold of enhanced coverage level 2 configured by upper layers in *cb-Msg3-EDT-RSRP-ThresholdList* and the measured RSRP is less than the RSRP threshold of enhanced coverage level 2:

- the MAC entity considers to be in enhanced coverage level 2;

- else if the measured RSRP is less than the RSRP threshold of enhanced coverage level 1 as configured by upper layers in cb*-Msg3-EDT-RSRP-ThresholdList* then:

- the MAC entity considers to be in enhanced coverage level 1;

- else:

- the MAC entity considers to be in enhanced coverage level 0;

Editor’s note: To confirm the CE level 2 and 3 are not applicable to eMTC UE operating in CE mode A.

- set the backoff parameter value to 0 ms;

- proceed to the selection of the CB-Msg3 Resource (see clause 5.1a.xx.2).

#### 5.1a.xx.2 CB-Msg3 Resource selection

The CB-Msg3 Resource selection procedure shall be performed as follows:

Editor’s note: FFS whether the TBS is per CE level. If the TBS is per CE level, UE may need to cancel CB-Msg3-EDT if the size of pending UL data is more than the TBS when moving to the next CE level.

- the UE shall select *cb-Msg3-EDT-NumReplicas* UL grants for CB-Msg3 transmission as follows:

- select the next upcoming CB-Msg3 transmission window provided by the *cb-Msg3-EDT-TransmissionWindow* associated with the selected enhanced coverage level;

- randomly select *cb-Msg3-EDT-NumReplicas* PUSCH resources in the time domain within the selected CB-Msg3 transmission window from the CB-Msg3 resources provided by *cb-Msg3-EDT-StartTimeParameters* associated with the selected enhanced coverage level;

- randomly select a frequency domain PUSCH resource for each selected time domain resource provided by *cb-Msg3-EDT-PUSCH-Config* associated with the selected enhanced coverage level.

- select the *cb-Msg3-EDT-responseWindowLength* associated with the selected enhanced coverage level.

- proceed to the transmission of the CB-Msg3 (see clause 5.1a.xx.3).

#### 5.1a.xx.3 CB-Msg3 transmission

The CB-Msg3 transmission shall be performed as follows:

Editor’s note: FFS CB-RNTI calculation.

Editor’s note: FFS the power ramping parameters and how the power ramping is done.

- if this is the first transmission of CB-Msg3-EDT procedure:

- obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity and store it in the Msg3 buffer.

#### 5.1a.xx.4 CB-Msg3 response reception

After the CB-Msg3 transmission, the MAC entity shall monitor PDCCH identified by CB-RNTI in the CB-Msg3 response window.

- the CB-Msg3 response window starts at the subframe that contains the end of selected the CB-Msg3-EDT transmission window plus UE-eNB RTT and has length *cb-**Msg3-EDT-ResponseWindowLength* for the corresponding enhanced coverage level;

Editor’s note: FFS processing time is needed.

Editor’s Note: To update when to start PDCCH monitoring after more FFS is resolved from below agreements:

* FFS it will also be possible for the NW to configure that the Msg4 monitoring window starts in the subframe containing the last (N)PUSCH repetition of the first replica plus UE-eNB RTT (FFS NW/UE processing time). To possibly resolve the FFS it needs to be clarified what happens if the Msg4 monitoring window is overlapping with replica, i.e. whether the UE prioritize the replica transmission or monitoring.

If notification of a reception of a PDCCH transmission is received from lower layers within the CB-Msg3 response window:

- if the MAC PDU is successfully decoded:

- if the MAC PDU contains UE Contention Resolution Identitie; and

- if there is a UE Contention Resolution Identity in the CB-Msg3 response that matches the 48 first bits of the CCCH SDU transmitted in CB-Msg3(s):

- if there is no C-RNTI information in the CB-Msg3 response corresponding to the matched Contention Resolution Identity:

- the MAC entity shall stop monitoring for CB-Msg3 Response(s).

Editor’s note: FFS whether L2 ACK is supported.

Editor’s note: To update the Msg4 structure including Contention Resolution Identities, C-RNTIs, Backoff parameters, TA information.

If none of all received CB-Msg3 responses within the CB-Msg3-EDT response window contains a Contention Resolution Identity that matchs the 48 first bits of the CCCH SDU transmitted in CB-Msg3(s).

- flush the HARQ buffer used for transmission of the MAC PDU in the Msg3 buffer;

- increment CB\_MSG3\_TRANSMISSION\_COUNTER\_CE by 1;

- if CB\_MSG3\_TRANSMISSION\_COUNTER\_CE = *maxNumCBMsg3**AttemptCE* for the corresponding enhanced coverage level + 1:

- reset CB\_MSG3\_TRANSMISSION\_COUNTER\_CE;

- if the UE has reached the maximum enhanced coverage level:

- consider the CB-Msg3-EDT procedure unsuccessfully completed.

Editor’s note: Whether the UE can initiate the legacy 4-step RA when the CB-Msg3 procedure fails.

- else

- consider to be in the next enhanced coverage level.

Editor’s note: FFS whether UE will be in the next CE level when max re-attempt number has been reached.

- based on the backoff parameter, select a random backoff time according to a uniform distribution between 0 and the Backoff Parameter Value;

- delay the subsequent CB-Msg3-EDT by the backoff time;

- proceed to the selection of a CB-Msg3 Resource (see clause 5.1a.xx.2).

Editor’s Note: To update how to do contention resolution based on below agreement:

* RAN2 confirms the working assumption that one CB-Msg4 can target multiple UEs simultaneously. FFS how the multiplexing is organized.

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## 5.3 DL-SCH data transfer

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### 5.3.2 HARQ operation

#### 5.3.2.1 HARQ Entity

There is one HARQ entity at the MAC entity for each Serving Cell which maintains a number of parallel HARQ processes. Each HARQ process is associated with a HARQ process identifier. The HARQ entity directs HARQ information and associated TBs received on the DL-SCH to the corresponding HARQ processes (see clause 5.3.2.2).

The number of DL HARQ processes per HARQ entity is specified in TS 36.213 [2], clause 7.

When the physical layer is configured for downlink spatial multiplexing, as specified in TS 36.213 [2], one or two TBs are expected per TTI and they are associated with the same HARQ process. Otherwise, one TB is expected per TTI.

For NB-IoT UEs or BL UEs or UEs in enhanced coverage, the parameter DL\_REPETITION\_NUMBER provides the number of transmissions repeated in a bundle. For each bundle, DL\_REPETITION\_NUMBER is set to a value provided by lower layers. Within a bundle, after the initial (re)transmission, DL\_REPETITION\_NUMBER-1 HARQ retransmissions follow. The HARQ feedback is transmitted for the bundle and a downlink assignment corresponding to a new transmission or a retransmission of the bundle is received after the last repetition of the bundle. A retransmission of a bundle is also a bundle. HARQ feedback may be disabled per HARQ process by configuring *downlinkHARQ-FeedbackDisabledBitmap(-NB)* and/or by indication from lower layers.

If the MAC entity is configured with *blindSlotSubslotPDSCH-Repetitions* or *blindSubframePDSCH-Repetitions* on a serving cell (TS 36.331 [8]), the parameter DL\_REPETITION\_NUMBER provides the number of transmissions repeated in a bundle for a downlink assignment received on that serving cell. For each bundle, DL\_REPETITION\_NUMBER and the redundancy version for each transmission within a bundle are set to values provided by lower layers. Within a bundle, after the initial (re-)transmission, DL\_REPETITION\_NUMBER-1 HARQ retransmissions follow. The HARQ feedback is sent only one time for the bundle and after the last transmission of the bundle.

In addition to the broadcast HARQ process, NB-IoT has one or two DL HARQ processes.

The MAC entity shall:

- If a downlink assignment has been indicated for this TTI; or

- If this TTI is for a retransmission within a bundle:

- allocate the TB(s) received from the physical layer and the associated HARQ information to the HARQ process indicated by the associated HARQ information.

- If a downlink assignment has been indicated for the broadcast HARQ process:

- allocate the received TB to the broadcast HARQ process.

NOTE: In case of BCCH and BR-BCCH a dedicated broadcast HARQ process is used.

#### 5.3.2.2 HARQ process

For each TTI where a transmission takes place for the HARQ process, one or two (in case of downlink spatial multiplexing) TBs and the associated HARQ information are received from the HARQ entity.

Editor’s Note: FFS how the HARQ feedback is used for each response in Msg4 when there is multiplexing in Msg4.

For each received TB and associated HARQ information, the HARQ process shall:

- if the NDI, when provided, has been toggled compared to the value of the previous received transmission corresponding to this TB; or

- if the HARQ process is equal to the broadcast process and if this is the first received transmission for the TB according to the system information schedule indicated by RRC; or

- if this is the very first received transmission for this TB (i.e. there is no previous NDI for this TB):

- consider this transmission to be a new transmission.

- else:

- consider this transmission to be a retransmission.

The MAC entity then shall:

- if this is a new transmission:

- attempt to decode the received data.

- else if this is a retransmission:

- if the data for this TB has not yet been successfully decoded:

- combine the received data with the data currently in the soft buffer for this TB and attempt to decode the combined data.

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

- if the data for this TB was successfully decoded before:

- if the HARQ process is equal to the broadcast process:

- deliver the decoded MAC PDU to upper layers.

- else if this is the first successful decoding of the data for this TB:

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

- generate a positive acknowledgement (ACK) of the data in this TB.

- else:

- replace the data in the soft buffer for this TB with the data which the MAC entity attempted to decode.

- generate a negative acknowledgement (NACK) of the data in this TB.

- if the HARQ process is associated with a transmission indicated with a Temporary C-RNTI and the Contention Resolution is not yet successful (see clause 5.1.5); or

- if the HARQ process is equal to the broadcast process; or

- if the HARQ process is not associated with a transmission indicated with a PUR-RNTI and the *timeAlignmentTimer*, associated with the TAG containing the serving cell on which the HARQ feedback is to be transmitted, is stopped or expired:

- do not indicate the generated positive or negative acknowledgement to the physical layer.

- else if the HARQ feedback is disabled for the corresponding HARQ process:

- if *harq-FeedbackEnablingforSPSactive* is configured and the transmission is the first SPS PDSCH transmission after SPS activation:

- indicate the generated positive or negative acknowledgement for this TB to the physical layer.

- else:

- do not indicate the generated positive or negative acknowledgement to the physical layer.

- else:

- indicate the generated positive or negative acknowledgement for this TB to the physical layer.

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

NOTE 1: When the MAC entity is configured with more than one serving cell, UE behaviors for storing data to the soft buffer is specified in TS 36.213 [2].

NOTE 2: If the MAC entity receives a retransmission with a TB size different from the last valid TB size signalled for this TB, the UE behavior is left up to UE implementation.

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## 5.4 UL-SCH data transfer

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### 5.4.2 HARQ operation

#### 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 and for transmission using PUR, 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 addressed neither to a Temporary C-RNTI nor to a PUR-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 provided by RRC for transmission using PUR; or

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

Editor’s note: FFS whether the HARQ operation is applicable to CB-Msg3-EDT.

- 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 and PUR-RNTI.

#### 5.4.2.2 HARQ process

Each HARQ process is associated with a HARQ buffer.

For synchronous HARQ, each HARQ process shall maintain a state variable CURRENT\_TX\_NB, which indicates the number of transmissions that have taken place for the MAC PDU currently in the buffer, and a state variable HARQ\_FEEDBACK, which indicates the HARQ feedback for the MAC PDU currently in the buffer. When the HARQ process is established, CURRENT\_TX\_NB shall be initialized to 0.

The sequence of redundancy versions is 0, 2, 3, 1. The variable CURRENT\_IRV is an index into the sequence of redundancy versions. This variable is up-dated modulo 4. For serving cells configured with *pusch-EnhancementsConfig*, BL UEs or UEs in enhanced coverage see clause 8.6.1 in TS 36.213 [2] for the sequence of redundancy versions and redundancy version determination. For NB-IoT UEs see clause 16.5.1.2 in TS 36.213 [2] for the sequence of redundancy versions and redundancy version determination. For an SPS configuration with *totalNumberPUSCH-SPS-STTI-UL-Repetitions* or *totalNumberPUSCH-SPS-UL-Repetitions* (TS 36.331 [8]), the redundancy version for each transmission within a bundle are determined by *rv-SPS-STTI-UL-Repetitions* or *rv-SPS-UL-Repetitions* in the SPS configuration (TS 36.331 [8]).

For NB-IoT UEs, BL UEs or UEs in enhanced coverage for UL\_REPETITION\_NUMBER for Mode B operation, the same redundancy version is used multiple times before cycling to the next redundancy version as specified in clauses 16.5.1.2, 8.6.1 and 7.1.7.1 in TS 36.213 [2].

New transmissions are performed on the resource and with the MCS indicated on PDCCH or Random Access Response. Adaptive retransmissions are performed on the resource and, if provided, with the MCS indicated on PDCCH. Non-adaptive retransmission is performed on the same resource and with the same MCS as was used for the last made transmission attempt.

For synchronous HARQ, the MAC entity is configured with a maximum number of HARQ transmissions and a maximum number of Msg3 HARQ transmissions by RRC: *maxHARQ-Tx* and *maxHARQ-Msg3Tx* respectively. For transmissions on all HARQ processes and all logical channels except for transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions shall be set to *maxHARQ-Tx*. For transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions shall be set to *maxHARQ-Msg3Tx*.

For autonomous HARQ, each HARQ process shall maintain a state variable HARQ\_FEEDBACK, which indicates the HARQ feedback for the MAC PDU currently in the buffer, and a timer *aul-RetransmissionTimer* which prohibits new transmission or retransmission for the same HARQ process on the configured autonomous uplink when the timer is running.

When the HARQ feedback is received for this TB, the HARQ process shall:

- set HARQ\_FEEDBACK to the received value;

- if running, stop the *aul-RetransmissionTimer*.

When an uplink grant addressed to C-RNTI is received for this HARQ process and if the UL HARQ operation is autonomous, the HARQ process shall:

- if running, stop the *aul-RetransmissionTimer*.

When PUSCH transmission is performed for this TB and if the uplink grant is a configured grant for the MAC entity's AUL C-RNTI, the HARQ process shall:

- start or restart the *aul-RetransmissionTimer*.

If the HARQ entity requests a new transmission, the HARQ process shall:

- if UL HARQ operation is synchronous:

- set CURRENT\_TX\_NB to 0;

- set HARQ\_FEEDBACK to NACK;

- set CURRENT\_IRV to 0;

- else:

- if UL HARQ operation is autonomous asychronous:

- set HARQ\_FEEDBACK to NACK.

- if the uplink grant was addressed to the AUL C-RNTI:

- set CURRENT\_IRV to 0.

- else:

- set CURRENT\_IRV to the index corresponding to the redundancy version value provided in the HARQ information;

- store the MAC PDU in the associated HARQ buffer;

- store the uplink grant received from the HARQ entity;

- generate a transmission as described below.

If the HARQ entity requests a retransmission, the HARQ process shall:

- if UL HARQ operation is synchronous:

- increment CURRENT\_TX\_NB by 1;

- if the HARQ entity requests an adaptive retransmission:

- store the uplink grant received from the HARQ entity;

- set CURRENT\_IRV to the index corresponding to the redundancy version value provided in the HARQ information;

- if UL HARQ operation is synchronous; or

- if UL HARQ operation is autonomous:

- set HARQ\_FEEDBACK to NACK;

- generate a transmission as described below.

- else if the HARQ entity requests a non-adaptive retransmission:

- if UL HARQ operation is asynchronous or HARQ\_FEEDBACK = NACK:

- if both *skipUplinkTxSPS* and *fixedRV-NonAdaptive* are configured and the uplink grant of the initial transmission of this HARQ process was performed on a configured grant and UL HARQ operation is not autonomous; or

- if the uplink grant is a preallocated uplink grant:

- set CURRENT\_IRV to 0;

- else if UL HARQ operation is autonomous:

- set CURRENT\_IRV to the index corresponding to the redundancy version value selected by the UE implementation.

- generate a transmission as described below.

NOTE 1: When receiving a HARQ ACK alone, the MAC entity keeps the data in the HARQ buffer.

NOTE 2: When no UL-SCH transmission can be made due to the occurrence of a measurement gap or a Sidelink Discovery Gap for Transmission, or prioritization of V2X sidelink communication transmission described in clause 5.14.1.2.2, no HARQ feedback can be received and a non-adaptive retransmission follows.

NOTE 3: For asynchronous HARQ operation, UL retransmissions are triggered only by adaptive retransmission grants, except for retransmissions within a bundle.

To generate a transmission, the HARQ process shall:

- if the MAC PDU was obtained from the Msg3 buffer; or

- if Sidelink Discovery Gaps for Transmission are not configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer in this TTI; or

- if Sidelink Discovery Gaps for Transmission are configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is no Sidelink Discovery Gap for Transmission in this TTI; or

- if Sidelink Discovery Gaps for Transmission are configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is a Sidelink Discovery Gap for Transmission, and there is no configured grant for transmission on SL-DCH in this TTI:

- if there is neither transmission of V2X sidelink communication on SL-SCH nor transmission of NR sidelink communication in this TTI; or

- if the transmission of the MAC PDU is prioritized over sidelink transmission:

- instruct the physical layer to generate a transmission according to the stored uplink grant with the redundancy version corresponding to the CURRENT\_IRV value;

- increment CURRENT\_IRV by 1 if UL HARQ operation is not autonomous;

- if UL HARQ operation is synchronous and there is a measurement gap or Sidelink Discovery Gap for Reception at the time of the HARQ feedback reception for this transmission and if the MAC PDU was not obtained from the Msg3 buffer:

- set HARQ\_FEEDBACK to ACK at the time of the HARQ feedback reception for this transmission.

After performing above actions, if UL HARQ operation is synchronous the HARQ process then shall:

- if CURRENT\_TX\_NB = maximum number of transmissions – 1:

- flush the HARQ buffer;

The transmission of the MAC PDU is prioritized over sidelink transmission or can be performed simultaneously with sidelink transmission if one of the following conditions is met:

- if there are both a configured grant for transmission of V2X sidelink communication on SL-SCH in this TTI and a sidelink grant for transmission of NR sidelink communication as described in clause 5.22.1.1 of TS 38.321 [24] at the time of the transmission, and neither the transmissions of V2X sidelink communication is prioritized as described in clause 5.14.1.2.2 nor the transmission of NR sidelink communication is prioritized as described in clause 5.22.1.3.1a of TS 38.321 [24]; or

- if there are both a configured grant for transmission of V2X sidelink communication on SL-SCH in this TTI and a sidelink grant for transmission of NR sidelink communication as described in clause 5.22.1.1 of TS 38.321 [24] at the time of the transmission, and the MAC entity is able to perform this UL transmission simultaneously with the transmissions of V2X sidelink communication and/or the transmission of NR sidelink communication; or

- if there is only configured grant(s) for transmission of V2X sidelink communication on SL-SCH in this TTI, and either none of the transmissions of V2X sidelink communication is prioritized or the MAC entity is able to perform this UL transmission and the transmissions of V2X sidelink communication simultaneously; or

- if there is only a sidelink grant for transmission of NR sidelink communication in this TTI as described in clause 5.22.1.1 of TS 38.321 [24], and either no transmission of NR sidelink communication is prioritized as described in clause 5.22.1.3.1a of TS 38.321 [24] or the MAC entity is able to perform this UL transmission simultaneously with the transmission of NR sidelink communication; or

- if there are both a configured grant for transmission of V2X sidelink communication on SL-SCH in this TTI and a sidelink grant for transmission of NR sidelink communication as described in clause 5.22.1.1 of TS 38.321 [24] at the time of the transmission, and either only the transmissions of V2X sidelink communication is prioritized as described in clause 5.14.1.2.2 or only the transmission of NR sidelink communication is prioritized as described in clause 5.22.1.3.1a of TS 38.321 [24] and the MAC entity is able to perform this UL transmission simultaneously with the prioritized transmission of V2X sidelink communication or NR sidelink communication.

NOTE 4: Among the UL transmissions where the MAC entity is able to perform all transmissions of V2X sidelink communication prioritized simultaneously, if there are more than one UL transmission which the MAC entity is not able to perform simultaneously, it is up to UE implementation whether this UL transmission is performed.

NOTE 5: Among the UL transmissions that the MAC entity is able to perform simultaneously with the transmission of NR sidelink communication prioritized, if there are more than one UL transmission which the MAC entity is not able to perform simultaneously, it is up to UE implementation whether this UL transmission is performed.

NOTE 6: Among the UL transmissions where the MAC entity is able to perform all transmissions of V2X sidelink communication prioritized simultaneously with the transmission of NR sidelink communication prioritized, if there are more than one UL transmission which the MAC entity is not able to perform simultaneously, it is up to UE implementation whether this UL transmission is performed.

NOTE 7: If there is a sidelink grant for transmission of NR sidelink communication in this TTI as described in clause 5.22.1.1 of TS 38.321 [24] and the MAC entity is not able to perform this UL transmission simultaneously with the transmission of NR sidelink communication, and prioritization-related information is not available prior to the time of the transmission due to processing time restriction, it is up to UE implementation whether this UL transmission is performed.

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# 6 Protocol Data Units, formats and parameters

## 6.1 Protocol Data Units

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### 6.1.xx MAC PDU (CB-Msg3 response)

Editor’s note: to be update CB-Msg3 response structure including Contention Resolution Identities, C-RNTIs, Backoff parameters, TA information.

# 7 Variables and constants

## 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, CB-RNTI, and PUR-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-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-RNTI | Transmission using Preconfigured Uplink Resource | DL-SCH, UL-SCH | CCCH, DCCH, DTCH |
| PUR-RNTI | Transmission using Preconfigured Uplink Resource (L1 ACK or fallback indication) | N/A | N/A |
| CB-RNTI | Contention-Based Msg3 transmission | UL-SCH | CCCH, DTCH |
| CB-RNTI | Contention-Based Msg3 response | DL-SCH | CCCH, DCCH,DTCH |

# Appendix – RAN2 Agreements on EDT enhancement

## Notes

* Assuming that only EDT enhancement agreements will impact MAC SPEC
* Agreements are highlighted as
	+ Already implemented.
	+ to be implemented or to be discussed whether and how to capture in the MAC SPEC
	+ No impact to MAC SPEC

## RAN2#129bis, Apr’25

Agreements:

1. Both SA and DSA are mandatorily supported by UEs supporting CB-msg3-EDT

2. We will specify one single procedure to support both DSA and SA, i.e. SA is a special setting (k=1) of the overall procedure

3. For CB-msg3-EDT, the transmission window can be configured by the network with a starting point (e.g. H-SFN offset), a window length, and a window periodicity (window length and periodicity could be the same).

4. We don’t introduce support for eMTC CE mode B case (it will not be possible to signal resources to be used for this case)

5. We specify support for NB-IoT with 15kHz with no specific enhancements, leaving to NW implementation whether to implement this or not, accepting potential performance degradation.

6. If we will decide to support OCC for CB-msg3-EDT, separate resources will be used for non-OCC and OCC based transmission.

7. The start of CB-msg3 EDT transmission window is aligned with the start of time domain (N)PUSCH resource.

8. The CB-msg3 EDT transmission window length and periodicity may be different. FFS on possible signalling optimization in case the length and periodicity are the same.

9. RAN2 assumes power ramping should be supported for CB-msg3-EDT (for both eMTC and NB-IoT) should be supported and will ask RAN1 for confirmation and in case which parameters should apply

(CB-Msg3-EDT configuration for eMTC)

10. For eMTC, introduce a new IE (e.g. CB-Msg3-ConfigSIB-r19) for shared resources configuration of CB-Msg3 in SIB2.

11. For eMTC, introduce MPDCCH configuration in shared resources configuration. The fields in IE PUR-MPDCCH-Config-r16 could be reused as baseline. Confirm with RAN1 on the detail parameters (e.g. whether additional narrow band is needed).

12. We will not support TDD related parameters.

13. For eMTC, introduce PUSCH configuration in shared resources configuration. The fields in IE PUR-PUSCH-Config-r16 could be reused as baseline. Confirm with RAN1 on the detail parameters. (e.g. whether pusch-CyclicShift-r16, pusch-NB-MaxTBS-r16 are needed, whether prb-AllocationInfo should be defined as a “set” format with intention to provide a set of shared frequency-domain resources).

14. For eMTC, check with RAN1 if anything is needed for PDSCH configuration in shared resources configuration

15. For eMTC, introduce PUCCH configuration in shared resources configuration. The fields in IE PUR-PUCCH-Config-r16 could be reused as baseline. Confirm with RAN1 on the detail parameters.

(CB-Msg3 configuration for NB-IoT)

16. For NB-IoT, introduce a new IE (e.g. CB-Msg3-ConfigSIB-NB-r19) for shared resources configuration of CB-Msg3 in SIB2-NB and SIB22-NB for non-anchor carrier.

17. For NB-IoT, introduce below physical layer parameters in shared resources configuration as below:

 - Number of resource units for NPUSCH (as in npusch-NumRUsIndex-r16)

 - Number of repetitions for NPUSCH (as in npusch-NumRepetitionsIndex-r16)

 - Set of subcarriers (similar to npusch-SubCarrierSetIndex but change it to a “set”), FFS whether subcarriers are provided as a contiguous set.

 - MCS configuration for NPUSCH (as in npusch-MCS-r16).

 - PDCCH parameters (as in NPDCCH-ConfigDedicated-NB-r13)

 - The non-anchor carrier index for monitoring Msg4. If this field is absent, anchor carrier is assumed to be used.

 NOTE: confirm with RAN1 is needed

18. For NB-IoT, FFS whether periodicity of CB-Msg3 resource may be larger than H-SFN duration

## RAN2#129, Feb’25

Agreements:

1. It is FFS if separate CB-msg3 resources would be needed for CB-msg-3 using OCC or if the same CB-msg3 resources could be used

2. RAN2 assumes that one possibility to take power imbalance under control is to define RSRP ranges that need to be respected to transmit CB-msg3 using OCC

3. RAN2 assumes that at least the following will be part of the shared resources configuration for CB-msg3 (FFS on other aspects)

 - Time domain resources for (N)PUSCH occasions: periodicity and start time (e.g., start subframe, start SFN)

 - Frequency domain resources for (N)PUSCH occasions

 - repetition number

 - (N)PDCCH resource

 - MCS

4. For CB-msg3 transmission, for eMTC NTN, up to three separate RSRP thresholds (on top of the minimum RSRP threshold and possibly different from the thresholds for PRACH) can be supported for achieving at most 4 CE levels; for NB-IoT NTN, up to two separate RSRP thresholds (on top of the minimum RSRP threshold possibly different from the thresholds for PRACH) can be supported for achieving at most 3 repetition levels.

5. The UE shall at most have one ongoing CB EDT procedure at any time.

6. The CB EDT Config has one minimum RSRP threshold (as agreed in RAN2#128) to use CB EDT.

7. The CB EDT Config has two RSRP thresholds for NB-IoT for the three CE levels.

8. CB EDT Config has three RSRP thresholds for eMTC for the four CE levels.

7. As Signalling design Baseline RAN2 assumes the PUR config and the NPRACH config for shared (N)PUSCH config can be used and some of the parameters can be included in a new CB EDT config.

8. RAN2 consider a new CBEDT-ConfigSIB-NB IE for configuring the CB EDT feature

Working assumption:

1. One CB-MSG4 can target multiple UEs simultaneously (FFS on the details)
2. For CB-MSG3, the Transmission window is configured by the network with a starting point (e.g. H-SFN offset), a window length, and a window periodicity (window length and periodicity could be the same). For k=1 the window length can be equal to 1: same behaviour as today

 The UE first selects the next DSA transmission window and then randomly select K replicasinside the window.

 RAN2 assumes that a pointer solution is not needed in Rel-19

Agreements (part 2):

1. For CB-msg3-EDT we adopt a Single Msg4 monitoring window and Single RNTI (the RNTI is derived on the transmit resource for the transmission window).

2. The lengths of the Msg3 transmission and Msg4 monitoring windows are configured by the network (in case of k=1 it will be possible to configure the parameters in a way to have the same behaviour as for normal Random Access procedure)

3. The Msg4 monitoring starts at the end of CB-Msg3-EDT transmission window plus UE-eNB RTT (FFS NW/UE processing time is needed or not).

4. FFS it will also be possible for the NW to configure that the Msg4 monitoring window starts in the subframe containing the last (N)PUSCH repetition of the first replica plus UE-eNB RTT (FFS NW/UE processing time). To possibly resolve the FFS it needs to be clarified what happens if the Msg4 monitoring window is overlapping with replica, i.e. whether the UE prioritize the replica transmission or monitoring

Agreements (part3):

1. The CB-msg3-EDT configuration (e.g., number of replicas, number of time resources and number of frequency resources) is CE level specific.

2. The Msg4 monitoring window configuration (e.g. length) is CE level specific

3. RAN2 confirms the working assumption that one CB-Msg4 can target multiple UEs simultaneously. FFS how the multiplexing is organized.

4. RAN2 confirms that existing UP-EDT and CP-EDT RRC message procedures shall be applicable for CB-Msg3-EDT

 - For UP solution, after RRCConnectionResumeRequest, network may reply with RRCConnectionResume, RRCConnectionSetup, RRCConnectionRelease and RRCConnectionReject

 - For CP solution, after RRCEarlyDataRequest, the network can respond with RRCEarlyDataComplete, RRCConnectionSetup or RRCConnectionReject.

5. RAN2 also intends to support CB-msg3-EDT for MT cases

6. The C-RNTI is included in CB-Msg4 if the UE is expected to receive additional RRC messages or data from the network after CB-Msg4 (FFS how to include the C-RNTI)

7. Introduce a new RNTI (i.e. CB-RNTI) for CB-Msg4 monitoring and CB-Msg3 scrambling. We include this agreement in the LS to RAN1

8. The timing alignment information (FFS reusing TAC MAC-CE) can be included in the CB-Msg4.

9. Parameter for maximum re-attempt number per CE level is introduced and UE can re-attempt in the same CE level due to contention resolution failure until the max re-attempt number has been reached.

10. Backoff information could be included in CB-Msg4.

11. L1 ACK as the Msg4 for the CB-Msg3-EDT is not supported.

12. HARQ feedback is adopted to acknowledge Msg4. FFS for the detail (e.g., how the HARQ feedback is used for each response in Msg4 when there is multiplexing in Msg4.).

## RAN2#128, Nov’24

Agreements:

1. Only system Information is used to provide cell-specific CB-Msg3 PUSCH resources (FFS if anything is needed in dedicated signalling for the TA validation parameters, if needed, for the case of 15kHz SCS NB-IoT and eMTC CE mode B)

2. Reuse the existing CE level selection procedure for CB-Msg3, at least for the initial selection. FFS whether we can reuse the same thresholds. FFS on the number of levels

3. The UE triggers CB-Msg3 only if the size of pending UL data is less than the configured maximum TBS (FFS if the maximum TBS is same or different for different CE levels)

4. There will be a RSRP threshold that determines whether CB-Msg3 can be used (if the RSRP is below such threshold, PRACH will have to be used) (FFS if we need a separate set of thresholds, including a different minimum threshold, in case CB-msg3 EDT is combined with OCC)

5. The number of replicas for DSA will be configured by the NW: 1 (SA), 2, 3, 4. The configuration of the number of replicas is CE-level specific

6. There will be a configurable time window for DSA CB-Msg3 occasion selection. FFS on the details (e.g. when the time window starts)

7. For SA case (single replica), after the end of all repetition of CB-Msg3 PUSCH transmission, UE starts a window for response reception taking UE-eNB RTT into account. FFS if we need to consider additional delay e.g. for the processing time

8. For DSA case, FFS if we only have one or multiple PDCCH monitoring window(s) (i.e. one window per each replica) for response reception. FFS when the window(s) is/are started (or restarted) and stopped. FFS on the window length. FFS if the UE needs to monitor only one RNTI or multiple RNTIs)

9. The UE stops the PDCCH monitoring window(s) once it receives a CB-msg4 containing a matching Contention Resolution Identity (FFS if there is no RRC message together with the CB-msg4)

10. Assuming that there will be scenarios where it’s possible to receive a CB-msg4 before the UE transmits some replicas, a UE stops transmitting the remaining replicas if it has received a CB-msg4 containing a matching Contention Resolution Identity (FFS if there is no RRC message together with the CB-msg4)

11. Within the configured time window, the UE shall select randomly different time domain occasions for transmitting different replicas. And for each time domain occasion, the UE shall select randomly a frequency domain resource.

12. RAN2 understands that, for DSA, once the eNB successfully decodes one of the multiple replicas, it may respond without waiting for the remaining replica(s) (FFS when the response window(s) is/are started)

## RAN2#127bis, Oct’24

Agreements:

1. RAN2 will introduce support for DSA (i.e. the possibility to transmit more than one replica of CB-msg3, if configured by the NW). RAN2 does not intend to work on CRDSA in Rel-19.

2. RAN2 will continue their work on CB-msg3 assuming that OCC2 might also apply to CB-msg3 transmission (“CB-NPUSCH”) (final decision whether this is feasible is up to RAN1). FFS whether an LS to indicate this to RAN1 is needed.

3. At least system Information is used to provide CB-msg3 EDT cell-specific PUSCH resources for Msg3 transmission. FFS on signalling details.

4. CB-msg3 EDT cell specific PUSCH resources for Msg3 transmission are provided per CE level (FFS whether we have a CE level specific configuration for DSA)

5. RAN2 assumes that CB-msg3 EDT cell specific PUSCH resources are associated with number of repetitions, RSRP selection threshold to determine the CE level and largest TBS for Msg3 transmission, but this has to be confirmed by RAN1. FFS if there is an RSRP threshold that determines whether CB-msg3 EDT cannot be used (the UE will have to use 4-step RA)

6. At least in the cases confirmed by RAN1/RAN4, a running TAT is not needed to initiate a CB-msg3 EDT transmission

7. The RNTI used at least to schedule Msg4 transmission is derived based on the resource associated to the PUSCH occasion used for contention based Msg3 EDT transmission (FFS on the details. FFS how this is impacted by DSA)

8. CB-msg3 EDT procedures and any Msg4 enhancement are only introduced for IoT NTN.

## RAN2#127, Aug’24

Agreements:

1. RAN2 will continue working on a CB-msg3 EDT-like mechanism

2. RAN2 assumes that a DSA based scheme would not have RAN1 impacts, while RAN2 thinks that a CRDSA based scheme would necessarily have RAN1 impacts

3. In the next meeting continue the comparison (e.g. in terms of packet loss ratio, usage of UL/DL radio resources) between existing CB mechanism (Slotted Aloha) and other mechanisms (DSA, CRDSA, others) and try to decide on which way to go and in case whether/what to ask to RAN1.

4. For DSA and CRDSA, RAN2 can consider in the evaluation how to integrate them with repetition.

## RAN2#126, May’24

Agreements:

1. RAN2 focusses the study on contention-based Msg3 transmission to complete an EDT-like transaction (FFS on the details of Msg3. FFS on the procedural steps, e.g. how much we reuse of EDT and PUR procedures. FFS on allocation of resources).
2. RAN2 can continue the discussion on Diversity Slotted ALOHA (DSA) and Contention Resolution Diversity Slotted Aloha (CRDSA) for Msg3-EDT transmissions without msg1/ RAR, evaluating possible impacts on the specification, in the next RAN2 meeting (RAN2 might send an LS to RAN1 later on this)
3. If an IoT NTN UE in IDLE state is to use the new R19 contention-based procedure, the UE needs to verify/update the uplink synchronization (e.g. get GNSS fix, acquire TA) just before sending msg3.

## RAN2#125bis, April’24

Agreements:

1. Both NB-IoT and eMTC are within scope of uplink capacity enhancements
2. Both C-plane and U-plane solutions are within scope of uplink capacity enhancements.
3. Only CIoT EPS is within scope of uplink capacity enhancements

# Appendix - Open issue list

**Msg3 transmission**

1. FFS if the maximum TBS is same or different for different CE levels.
2. FFS the RNTI calculation.
3. FFS how the mapping of PUSCH resources and CE levels are done for NB-IoT.
4. FFS when multiple carriers provide PUSCH resources for the same enhanced coverage level, how the UE select the carriers for NB-IoT.
5. The power ramping parameters and how the power ramping is done.
6. FFS whether the HARQ operation is applicable to transmit CB-Msg3.
7. FFS which IE in SIB22-NB contains the CB-Msg3-EDT configuration.
8. FFS whether to revise the agreement that, due to only CE mode A is supported for eMTC NTN , only 1 separate RSRP thresholds and 2 CE levels can be supported.

**Response window**

1. FFS NW/UE processing time is needed or not.
2. FFS it will also be possible for the NW to configure that the Msg4 monitoring window starts in the subframe containing the last (N)PUSCH repetition of the first replica plus UE-eNB RTT
3. FFS it needs to be clarified what happens if the Msg4 monitoring window is overlapping with replica, i.e. whether the UE prioritize the replica transmission or monitoring.

**Msg4**

1. Whether the L2 ACK is supported.
2. FFS how the multiplexing in Msg4 is organized.
3. FFS the Msg4 structure including Contention Resolution Identities, C-RNTIs, Backoff parameters, TA information in the CB-Msg4.
4. FFS for the detail of HARQ operation on Msg4 (e.g., how the HARQ feedback is used for each response in Msg4 when there is multiplexing in Msg4.).

**Failure handling**

1. Whether the UE can initiate the legacy 4-step RA when the CB-Msg3 procedure fails. FFS on the condition for the UE to initiate the fallback to legacy 4-step RA.