3GPP RAN WG2 Meeting #123 R2-230XXXX

**Toulouse, France, 21 - 25 Aug, 2023**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *CR-Form-v12.2* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
|  | | | | | | | | |
|  | **36.321** | **CR** | **draft** | **rev** | **-** | **Current version:** | **17.5.0** |  |
|  | | | | | | | | |
| *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)*.* | | | | | | | | |
|  | | | | | | | | |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network | **x** | Core Network |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | | | | | |
| ***Title:*** | Stage-3 running CR for TS 36.321 for Rel-18 IoT-NTN | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Source to WG:*** | MediaTek | | | | | | | | | |
| ***Source to TSG:*** | R2 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | IoT\_NTN\_enh-Core | | | | |  | ***Date:*** | | | 2023-09-01 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | **B** |  | | | | | ***Release:*** | | | Rel-18 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) …  Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | Introduction of Release-18 enhancement for IoT-NTN | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | This running CR captures agreements made for LTE eMTC and NB-IoT to support IoT-NTN for Release-18 up to RAN2-123. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | No support for Release-18 enhancements for NTN in IoT | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 5.3.2.2, 5.4.3.1, 5.4.xx(new), 5.7, 5.xx (new), 6.1.3.xx (new), 6.1.3.yy (new), 6.2.1 | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | | **X** |  | Other core specifications | | | | TS 36.300, TS 36.331, TS 36.304, TS 36.306 | | |
| ***affected:*** | |  |  | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  |  | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | | [R2-2303950](file:///C:\Data\3GPP\Extracts\R2-2303950%20Running%20CR%20MAC_36.321_IoT-NTN.docx): Submitted at RAN2 #121bis-e  [R2-2304737](file:///C:\Data\3GPP\Extracts\R2-2304737%20Running%20CR%20MAC_36.321_IoT-NTN.docx): Submitted at RAN2 #122  R2-2306962: First endorsed version after RAN2#122  R2-2308944: Ported on June 2023 specification, before RAN2 #123 | | | | | | | | |

Start of changes

## 5.3 DL-SCH data transfer

### 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, PUR-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, PUR-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 PUR-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.

### 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.

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.

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; or

- 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.

Next change

### 5.3.3 Disassembly and demultiplexing

The MAC entity shall disassemble and demultiplex a MAC PDU as defined in clause 6.1.2.

## 5.4 UL-SCH data transfer

### 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 provided by RRC for transmission using PUR (see clause 5.4.7). 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 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 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.

### 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:

- 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.

### 5.4.3 Multiplexing and assembly

#### 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.

Before the successful completion of the contention based Random Access procedure initiated for DAPS handover, the target MAC entity shall not select the logical channel(s) corresponding to non-DAPS DRB(s) for the uplink grant received in a Random Access Response. The source MAC entity shall select only the logical channel(s) corresponding to DAPS DRB(s) during DAPS handover.

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 within the same MAC entity (i.e. CA duplication) is activated, for this logical channel the MAC entity shall consider the cells indicated by *lch-CellRestriction* to be restricted for transmission.

- the MAC entity shall map the logical channel configued with *allowedHARQ-mode* to the HARQ process with corresponding UL HARQ mode 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; or

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

NOTE 1a: If at least one MAC PDU is to be generated for the HARQ entity for this TTI, the MAC entity generates MAC PDUs corresponding to all UL grants indicated to the HARQ entity for this TTI.

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 Timing Advance Report;

- MAC control element for GNSS Validity Duration Report;- 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, with exception of when DCQR is to be included in Msg3;

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

- MAC control element for DCQR and AS RAI, when DCQR is to be included in Msg3;

- 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.

Editor’s Note: TBD for priority of remaining GNSS measurement validity duration report MAC CE.

Next change

#### 5.4.3.2 Multiplexing of MAC Control Elements and MAC SDUs

The MAC entity shall multiplex MAC control elements and MAC SDUs in a MAC PDU according to clauses 5.4.3.1 and 6.1.2.

### 5.4.4 Scheduling Request

The Scheduling Request (SR) is used for requesting UL-SCH resources for new transmission.

When an SR is triggered, it shall be considered as pending until it is cancelled. All pending SR(s) shall be cancelled and *sr-ProhibitTimer* and *ssr-ProhibitTimer* shall be stopped when a MAC PDU is assembled and this PDU includes a BSR which contains buffer status up to (and including) the last event that triggered a BSR (see clause 5.4.5), or, if all pending SR(s) are triggered by Sidelink BSR, when a MAC PDU is assembled and this PDU includes a Sidelink BSR which contains buffer status up to (and including) the last event that triggered a Sidelink BSR (see clause 5.14.1.4), or, if all pending SR(s) are triggered by Sidelink BSR, when upper layers configure autonomous resource selection, or when the UL grant(s) can accommodate all pending data available for transmission.

If the MAC entity has resources for SR configured on only one of SPUCCH and PUCCH, that SR resource is valid for all logical channels. If the MAC entity has resources for SR configured on both PUCCH and SPUCCH, MAC entity shall consider all logical channels that have triggered an SR (and at *retxBSR-Timer* expiry, MAC entity shall consider all logical channels, belonging to a LCG, with data available for transmission):

- PUCCH resources for SR are valid if *logicalChannelSr-Restriction* is not configured, or if *logicalChannelSr-Restriction* allows SR on PUCCH, for any of the logical channels;

- SPUCCH resources for SR are valid if *logicalChannelSr-Restriction* is not configured, or if *logicalChannelSr-Restriction* allows SR on SPUCCH, for any of the logical channels.

If an SR is triggered and there is no other SR pending, the MAC entity shall set the SR\_COUNTER and the SSR\_COUNTER to 0.

As long as one SR is pending, the MAC entity shall for each TTI:

- if no UL-SCH resources are available for a transmission in this TTI:

- Except for NB-IoT:

- if the MAC entity has no valid PUCCH nor valid SPUCCH resource for SR configured in any TTI:

- if the MAC entity is a MCG MAC entity and *rach-Skip* is not configured; or

- if the MAC entity is a SCG MAC entity and *rach-SkipSCG* is not configured:

- initiate a Random Access procedure (see clause 5.1) on the corresponding SpCell and cancel all pending SRs;

- else if this TTI is not part of a measurement gap or Sidelink Discovery Gap for Transmission, and if transmission of V2X sidelink communication is not prioritized in this TTI as described in clause 5.14.1.2.2:

- if the MAC entity has at least one valid SPUCCH resource for SR configured for this TTI and if *ssr-ProhibitTimer* is not running:

- if SSR\_COUNTER < *dssr-TransMax*:

- increment SSR\_COUNTER by 1;

- instruct the physical layer to signal the SR on one valid SPUCCH resource for SR;

- start the *ssr-ProhibitTimer*.

- else:

- notify RRC to release SPUCCH for all serving cells;

- if the MAC entity has no valid PUCCH resource for SR configured in any TTI:

- notify RRC to release PUCCH for all serving cells;

- notify RRC to release SRS for all serving cells;

- clear any configured downlink assignments and uplink grants;

- initiate a Random Access procedure (see clause 5.1) on the SpCell and cancel all pending SRs.

- if the MAC entity has at least one valid PUCCH resource for SR configured for this TTI and if *sr-ProhibitTimer* is not running:

- if SR\_COUNTER < *dsr-TransMax*:

- increment SR\_COUNTER by 1;

- instruct the physical layer to signal the SR on one valid PUCCH resource for SR;

- start the *sr-ProhibitTimer*.

- else:

- notify RRC to release PUCCH and SPUCCH for all serving cells;

- notify RRC to release SRS for all serving cells;

- clear any configured downlink assignments and uplink grants;

- initiate a Random Access procedure (see clause 5.1) on the SpCell and cancel all pending SRs.

- For NB-IoT:

- if the MAC entity has no valid resource for SR together with acknowledgement of the data in this TTI and no valid PRACH resource for SR configured in any TTI:

- initiate a Random Access Procedure (see clause 5.1), and cancel all pending SRs in the first subframe containing PRACH for preamble transmission.

- else:

- if the MAC entity has valid resource for SR together with acknowledgement of the data in this TTI:

- instruct the physical layer to signal the SR together with acknowledgement of the data.

- cancel, if any, initiated Random Access Procedure for SR.

- else:

- if the MAC entity has valid PRACH resource for SR configured in this TTI and *sr-ProhibitTimer* is not running:

- instruct the physical layer to signal the SR on one valid PRACH resource for SR.

- start the *sr-ProhibitTimer* in the subframe containing the last repetition of the corresponding SR transmission.

NOTE 1: The selection of which valid PUCCH/SPUCCH resource for SR to signal SR on when the MAC entity has more than one valid PUCCH/SPUCCH resource for SR in one TTI or overlapping TTIs is left to UE implementation.

NOTE 2: SR\_COUNTER is incremented for each SR bundle. *sr-ProhibitTimer* is started in the first TTI of an SR bundle.

### 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.

### 5.4.5a Data Volume and Power Headroom Reporting

The Data Volume and Power Headroom reporting procedure is only applicable for NB-IoT UEs and 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, and to provide the serving eNB with information about the difference between the nominal UE maximum transmission power and the estimated transmission power for UL-SCH transmission for the Serving Cell. The reporting is done using the DPR MAC control element, which is sent in Msg3 together with a CCCH SDU. For EDT, the Data Volume in DPR MAC control element is set to zero.

If *enhancedPHR* is configured and the UE supports extended power headroom reporting, the UE shall:

- if the UE supports power class 14dBm and the MAC entity considers itself to be in enhanced coverage level other than 0:

- report power headroom level using the DPR MAC control element;

- else:

- report extended power headroom level using the DPR MAC control element for Extended Power Headroom level reporting.

### 5.4.6 Power Headroom Reporting

The Power Headroom reporting procedure is used to provide the serving eNB with information about the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission or SRS transmission per activated Serving Cell and also with information about the difference between the nominal UE maximum power and the estimated power for UL-SCH and PUCCH/SPUCCH transmission on SpCell and PUCCH SCell.

The reporting period, delay and mapping of Power Headroom are defined in TS 36.133 [9] and TS 38.133 [19]. RRC controls Power Headroom reporting by configuring the two timers *periodicPHR-Timer* and *prohibitPHR-Timer*, and by signalling *dl-PathlossChange* which sets the change in measured downlink pathloss and the required power backoff due to power management (as allowed by P-MPRc, see TS 36.101 [10] and TS 38.101-3 [21]) to trigger a PHR, as specified in TS 36.331 [8].

A Power Headroom Report (PHR) shall be triggered if any of the following events occur:

- *prohibitPHR-Timer* expires or has expired and the path loss has changed more than *dl-PathlossChange* dB for at least one activated Serving Cell of any MAC entity which is used as a pathloss reference since the last transmission of a PHR in this MAC entity when the MAC entity has UL resources for new transmission;

- *periodicPHR-Timer* expires;

- upon configuration or reconfiguration of the power headroom reporting functionality by upper layers, as specified in TS 36.331 [8], which is not used to disable the function;

- activation of an SCell of any MAC entity with configured uplink;

- addition of the PSCell (i.e. PSCell is newly added or PSCell is changed);

*- prohibitPHR-Timer* expires or has expired, when the MAC entity has UL resources for new transmission, and the following is true in this TTI for any of the activated Serving Cells of any MAC entity with configured uplink:

- there are UL resources allocated for transmission or there is a PUCCH/SPUCCH transmission on this cell, and the required power backoff due to power management (as allowed by P-MPRc, see TS 36.101 [10] and TS 38.101-3 [21]) for this cell has changed more than *dl-PathlossChange* dB since the last transmission of a PHR when the MAC entity had UL resources allocated for transmission or PUCCH/SPUCCH transmission on this cell.

NOTE 1: The MAC entity should avoid triggering a PHR when the required power backoff due to power management decreases only temporarily (e.g. for up to a few tens of milliseconds) and it should avoid reflecting such temporary decrease in the values of PCMAX,c/PH when a PHR is triggered by other triggering conditions.

NOTE 2: If UL HARQ operation is autonomous for the HARQ entity and if the PHR 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 PHR content.

If the MAC entity has UL resources allocated for new transmission for this TTI the MAC entity shall:

- if it is the first UL resource allocated for a new transmission since the last MAC reset, start *periodicPHR-Timer*;

- if the Power Headroom reporting procedure determines that at least one PHR has been triggered and not cancelled, and;

- if the allocated UL resources can accommodate the MAC control element for PHR which the MAC entity is configured to transmit, plus its subheader, as a result of logical channel prioritization:

- if *extendedPHR* is configured:

- for each activated Serving Cell with configured uplink:

- obtain the value of the Type 1 or Type 3 power headroom;

- if the MAC entity has UL resources allocated for transmission on this Serving Cell for this TTI:

- obtain the value for the corresponding PCMAX,c field from the physical layer;

- if *simultaneousPUCCH-PUSCH* is configured or a serving cell operating according to Frame Structure Type 3 with uplink is configured and activated:

- obtain the value of the Type 2 power headroom for the PCell;

- obtain the value for the corresponding PCMAX,c field from the physical layer (see clause 5.1.1.2 of TS 36.213 [2]);

- instruct the Multiplexing and Assembly procedure to generate and transmit an Extended PHR MAC control element for *extendedPHR* as defined in clause 6.1.3.6a based on the values reported by the physical layer;

- else if *extendedPHR2* is configured:

- for each activated Serving Cell with configured uplink:

- obtain the value of the Type 1 or Type 3 power headroom;

- if the MAC entity has UL resources allocated for transmission on this Serving Cell for this TTI:

- obtain the value for the corresponding PCMAX,c field from the physical layer;

- if a PUCCH SCell is configured and activated:

- obtain the value of the Type 2 power headroom for the PCell and PUCCH SCell;

- obtain the values for the corresponding PCMAX,c fields from the physical layer (see clause 5.1.1.2 ofTS 36.213 [2]);

- else:

- if *simultaneousPUCCH-PUSCH* is configured for the PCell or a serving cell operating according to Frame Structure Type 3 with uplink is configured and activated:

- obtain the value of the Type 2 power headroom for the PCell;

- obtain the value for the corresponding PCMAX,c field from the physical layer (see clause 5.1.1.2 of TS 36.213 [2]);

- instruct the Multiplexing and Assembly procedure to generate and transmit an Extended PHR MAC control element for *extendedPHR2* according to configured *ServCellIndex* and the PUCCH(s) for the MAC entity as defined in clause 6.1.3.6a based on the values reported by the physical layer;

- else if *dualConnectivityPHR* is configured:

- for each activated Serving Cell with configured uplink associated with any MAC entity:

- obtain the value of the Type 1 or Type 3 power headroom;

- if this MAC entity has UL resources allocated for transmission on this Serving Cell for this TTI or if the other MAC entity has UL resources allocated for transmission on this Serving Cell for this TTI and *phr-ModeOtherCG* is set to *real* by upper layers:

- obtain the value for the corresponding PCMAX,c field from the physical layer;

- if *simultaneousPUCCH-PUSCH* is configured or a serving cell operating according to Frame Structure Type 3 with uplink is configured and activated:

- obtain the value of the Type 2 power headroom for the SpCell;

- obtain the value for the corresponding PCMAX,c field for the SpCell from the physical layer (see clause 5.1.1.2 of TS 36.213 [2]);

- if the other MAC entity is E-UTRA MAC entity:

- obtain the value of the Type 2 power headroom for the SpCell of the other MAC entity.

- if *phr-ModeOtherCG* is set to *real* by upper layers:

- obtain the value for the corresponding PCMAX,c field for the SpCell of the other MAC entity from the physical layer (see clause 5.1.1.2 of TS 36.213 [2]);

- instruct the Multiplexing and Assembly procedure to generate and transmit a Dual Connectivity PHR MAC control element as defined in clause 6.1.3.6b based on the values reported by the physical layer;

- else:

- obtain the value of the Type 1 power headroom from the physical layer;

- instruct the Multiplexing and Assembly procedure to generate and transmit a PHR MAC control element as defined in clause 6.1.3.6 based on the value reported by the physical layer;

- start or restart *periodicPHR-Timer*;

- start or restart *prohibitPHR-Timer*;

- cancel all triggered PHR(s).

### 5.4.7 Preconfigured Uplink Resource

#### 5.4.7.1 Transmission using PUR

Transmission using PUR is initiated by the RRC layer. When transmission using PUR is initiated, RRC layer provides MAC with the following information:

- PUR-RNTI;

- Duration of PUR response window *pur-ResponseWindowTimer*;

- UL grant information.

If the MAC entity has a PUR-RNTI, the MAC entity shall for each TTI for which RRC layer has provided uplink grant for transmission using PUR:

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

After transmission using PUR, the MAC entity shall monitor PDCCH identified by PUR-RNTI in the PUR response window using timer *pur-ResponseWindowTimer*:

- if PUR was transmitted in a non-terrestrial network and UE supports delaying the start of the *pur-ResponseWindowTimer*:

- the MAC entity shall start *pur-ResponseWindowTimer* at the subframe that contains the end of the corresponding PUSCH transmission plus 4 subframes plus UE-eNB RTT.

- else:

- the MAC entity shall start *pur-ResponseWindowTimer* at the subframe that contains the end of the corresponding PUSCH transmission plus 4 subframes*.*

While *pur-ResponseWindowTimer* is running, the MAC entity shall:

- if the PDCCH transmission is addressed to the PUR-RNTI and contains an UL grant for a retransmission:

- if PUR was transmitted in a non-terrestrial network and UE supports delaying the start of the *pur-ResponseWindowTimer*:

- restart *pur-ResponseWindowTimer* at the last subframe of a PUSCH transmission corresponding to the retransmission indicated by the UL grant plus 4 subframes plus UE-eNB RTT.

- else:

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

- if L1 ACK for transmission using PUR is received from lower layers; or

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

- stop *pur-ResponseWindowTimer*;

- if L1 ACK for transmission using PUR is received from lower layers or the MAC PDU contains only Timing Advance Command MAC control element:

- indicate to upper layers the transmission using PUR was successful;

- if repetition adjustment for transmission using PUR is received from lower layers:

- indicate the value of the repetition adjustment to upper layers.

- discard the PUR-RNTI.

- else if fallback indication for PUR is received from lower layers:

- stop *pur-ResponseWindowTimer*;

- indicate to upper layers PUR fallback indication is received;

- if repetition adjustment for transmission using PUR is received from lower layers:

- indicate the value of the repetition adjustment to upper layers.

- discard the PUR-RNTI.

- if the *pur-ResponseWindowTimer* expires:

- if PUR was transmitted in a non-terrestrial network:

- if no notification of a reception of a PDCCH transmission addressed to the PUR-RNTI containing an UL grant for a retransmission was received after the start of *pur-ResponseWindowTimer*:

- indicate to upper layers the transmission using PUR has failed;

- discard the PUR-RNTI.

- else:

- indicate to upper layers the transmission using PUR has failed;

- discard the PUR-RNTI.

Editor’s note: HARQ mode B is not applicable for UL transmission using PUR. FFS whether HARQ mode can be configured for PUR.

#### 5.4.7.2 Maintenance of PUR Uplink Time Alignment

MAC entity may be configured with timer *pur-TimeAlignmentTimer* by upper layers as specified in TS 36.331 [8], clause 5.3.8.3.

The MAC entity shall:

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

- start or restart *pur-TimeAlignmentTimer*.

- when *pur-TimeAlignmentTimer* is released by upper layers:

- stop the *pur-TimeAlignmentTimer*, if running.

- when a Timing Advance Command MAC control element is received or PDCCH indicates timing advance adjustment as specified in TS 36.212 [5] and if a NTA has been stored or maintained:

- if the Timing Advance Command MAC control element or PDCCH indicating timing advance adjustment is addressed with a PUR-RNTI:

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

- start or restart the *pur-TimeAlignmentTimer*, if configured;

- indicate to upper layers that the Timing Advance value has been adjusted.

- upon considering a Random Access procedure successfully completed:

- start or restart the *pur-TimeAlignmentTimer*, if configured;

- indicate to upper layers that the Timing Advance value has been adjusted;

- if a temporary NTA has been stored, delete the stored temporary NTA.

- upon considering a Random Access procedure unsuccessfully completed, if a temporary NTA has been stored:

- set the NTA to the stored temporary NTA;

- delete the stored temporary NTA.

Upon request from upper layers, MAC entity shall indicate whether *pur-TimeAlignmentTimer* is running.

### 5.4.8 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 DCQR 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 a result of logical channel prioritization, AS RAI is cancelled, for other transmissions if AS RAI is not included in the resulting MAC PDU as a result of logical channel prioritization, AS RAI may be cancelled.

If *rai-Activation* is configured and a buffer size of zero bytes has been triggered for the BSR and no subsequent DL and UL data transmission is expected, and if *rai-ActivationEnh* is enabled and applicable as specified in TS 36.331 [8], it is up to UE to send BSR MAC control element or DCQR and AS RAI MAC control element.

### 5.4.9 Timing Advance Reporting

The UE may be configured to report information about UE specific timing advance during a Random Access procedure and in RRC\_CONNECTED Mode.

The Timing Advance reporting procedure is used in a non-terrestrial network to provide the eNB with an estimate of the UE's Timing Advance, see TTA in TS 36.211 [7] clause 8.1.

Timing Advance reporting shall be triggered if any of the following events occur:

- if triggered by upper layers;

- upon configuration of *offsetThresholdTA* by upper layers, if the UE has not previously reported Timing Advance value to current Serving Cell;

- if the variation between current information about Timing Advance and the last reported information about Timing Advance is equal to or larger than *offsetThresholdTA*, if configured.

If the Timing Advance reporting procedure determines that at least one Timing Advance Report has been triggered and not cancelled:

- if the MAC entity has UL resources allocated for new transmission for this TTI, and;

- if the allocated UL resources can accommodate the Timing Advance Report MAC control element plus its subheader, as a result of logical channel prioritization:

- instruct the Multiplexing and Assembly procedure to generate the Timing Advance report MAC control element as defined in clause 6.1.3.20.

A MAC PDU shall contain at most one Timing Advance Report MAC CE, even when multiple events have triggered a Timing Advance report. The Timing Advance Report MAC CE shall be generated based on the latest available estimate of the UE's Timing Advance value prior to the MAC PDU assembly.

All triggered Timing Advance reports shall be cancelled when a Timing Advance Report MAC CE is included in a MAC PDU for transmission.

### 5.4.xx GNSS validity duration reporting

For a NB-IoT UE, a BL UE or a UE in enhanced coverage in a non-terrestrial network, an indication may be sent by upper layer to report the remaining GNSS measurement validity duration.

If the GNSS validity duration reporting procedure has been triggered:

- if the MAC entity has UL resources allocated for new transmission for this TTI, and;

- if the allocated UL resources can accommodate the GNSS Validity Duration Report MAC control element plus its subheader, as a result of logical channel prioritization:

- instruct the Multiplexing and Assembly procedure to generate the GNSS Validity Duration Report MAC control element as defined in clause 6.1.3.yy.

## 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). For non-terrestrial network, to disable or enable HARQ feedback per DL HARQ process, downlinkHARQ-FeedbackDisabled may be configured by RRC or an indication may be sent by lower layer; *uplinkHARQ-Mode* may be configued by RRC to set the HARQ mode per UL HARQ process.

Editor’s Note: Discuss if the downlinkHARQ-FeedbackDisabled needs to be described in 5.3.2.1 instead of here in 5.7.

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). If this Serving Cell is part of a non-terrestrial network, the Active Time is started after the Scheduling Request transmission that is performed when the *SR\_COUNTER* is 0 for all the SR configurations with pending SR(s) plus the UE-eNB RTT; 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. If this Serving Cell is part of a non-terrestrial network, the Active Time starts after the first repetition within the bundle plus the UE-eNB RTT when repetitions within the bundle are being transmitted.

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 downlinkHARQ-FeedbackDisabled is not configued; or- if the HARQ feedback is enabled for the corresponding HARQ process:

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

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

- start or restart drx-InactivityTimer in the subframe containing the last repetition of the corresponding PDSCH reception + 12 subframes + deltaPDCCH, where deltaPDCCH is the interval starting from the subframe containing the last repetition of the corresponding PDSCH reception plus 12 subframes to the first subframe of the next PDCCH occasion.

Editor’s Note: Discuss if the condition “if the NB-IoT UE is configured with single UL and DL HARQ process” can be removed by following LS-response from RAN1.

- 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; and

- if the corresponding HARQ process is not configured with HARQ mode B:

- 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:

- if the corresponding HARQ process is not configured with HARQ mode B*:*

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

- if the corresponding HARQ process is configured with HARQ mode B:

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

- start or restart drx-InactivityTimer in the subframe containing the last repetition of the corresponding PUSCH transmission + 1 subframe + deltaPDCCH, where deltaPDCCH is the interval starting from the subframe containing the last repetition of the corresponding PUSCH transmission plus 1 subframes to the first subframe of the next PDCCH occasion.

Editor’s Note: Discuss if the condition “if the NB-IoT UE is configured with single UL and DL HARQ process” can be removed by following LS-response from RAN1.

- 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*:

- if the lower layer had indicated scheduling of transmission of multiple TBs:

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

- else 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

## 5.7a Discontinuous Reception (DRX) for SC-PTM

Each G-RNTI and, for NB-IoT UEs, BL UEs or UEs in enhanced coverage, each SC-RNTI of the MAC entity may be configured by RRC with a DRX functionality that controls the UE's PDCCH monitoring activity for this G-RNTI and SC-RNTI as specified in TS 36.331 [8]. When in RRC\_IDLE or RRC\_CONNECTED, if DRX is configured, the MAC entity is allowed to monitor the PDCCH for this G-RNTI or SC-RNTI discontinuously using the DRX operation specified in this clause; otherwise the MAC entity monitors the PDCCH for this G-RNTI or SC-RNTI continuously. For each G-RNTI or SC-RNTI of the MAC entity, RRC controls its DRX operation by configuring the timers *onDurationTimerSCPTM*, *drx-InactivityTimerSCPTM*, the *SCPTM-SchedulingCycle* and the value of the *SCPTM-SchedulingOffset* for G-RNTI and for SC-RNTI. The DRX operation specified in this clause is performed independently for each G-RNTI and SC-RNTI and independently from the DRX operation specified in subcaluse 5.7.

When DRX is configured for a G-RNTI or for SC-RNTI, the Active Time includes the time while:

*- onDurationTimerSCPTM* or *drx-InactivityTimerSCPTM* is running.

When DRX is configured for a G-RNTI or for SC-RNTI as specified in TS 36.331 [8], the MAC entity shall for each subframe for this G-RNTI or SC-RNTI:

- if [(H-SFN \* 10240 + SFN \* 10) + subframe number] modulo (*SCPTM-SchedulingCycle*) = *SCPTM-SchedulingOffset*:

- start *onDurationTimerSCPTM*.

- during the Active Time, for a PDCCH-subframe:

- monitor the PDCCH;

- if the PDCCH indicates a DL transmission:

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

- start or re-start the *drx-InactivityTimerSCPTM* in the subframe containing the last repetition of the corresponding PDSCH reception.

- if the UE is an NB-IoT UE:

- stop *onDurationTimerSCPTM*;

- stop *drx-InactivityTimerSCPTM*;

- start the *drx-InactivityTimerSCPTM* in the first subframe of the next PDCCH occasion following the subframe containing the last repetition of the corresponding PDSCH reception.

- else:

- start or restart *drx-InactivityTimerSCPTM*.

NOTE: If H-SFN is not configured its value is set to 0 in the calculation of the starting subframe.

## 5.8 MAC reconfiguration

When a reconfiguration of the MAC entity is requested by upper layers, the MAC entity shall:

- upon addition of an SCell, initialize the corresponding HARQ entity;

- upon removal of an SCell, remove the corresponding HARQ entity;

- for timers apply the new value when the timer is (re)started;

- when counters are initialized apply the new maximum parameter value;

- for other parameters, apply immediately the configurations received from upper layers.

## 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;

- except for *pur-TimeAlignmentTimer,* if configured*,* 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;

- cancel, if any, triggered Recommended bit rate query procedure;

- cancel, if any, triggered Timing Advance 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.

## 5.10 Semi-Persistent Scheduling

Except for NB-IoT, multiple UL Semi-Persistent Scheduling configurations are supported per Serving Cell. For NB-IoT, UL Semi-Persistent Scheduling configuration is only supported for BSR per Serving Cell. On one Serving Cell, multiple UL configurations can be active simultaneously only for the same TTI length. Multiple UL/DL configurations can also be active simultaneously on different Serving Cells.

When Semi-Persistent Scheduling is enabled by RRC, the following information is provided, as specified in TS 36.331 [8]:

- Semi-Persistent Scheduling C-RNTI or UL Semi-Persistent Scheduling V-RNTI;

- Uplink Semi-Persistent Scheduling interval *semiPersistSchedIntervalUL* if short TTI in UL for the SpCell is not configured or *semiPersistSchedIntervalUL*-*sTTI* in UL for the SpCellifshort TTIis configured and number of empty transmissions before implicit release *implicitReleaseAfter*, if Semi-Persistent Scheduling with Semi-Persistent Scheduling C-RNTI is enabled for the uplink;

- Uplink Semi-Persistent Scheduling interval *semiPersistSchedIntervalUL* and number of empty transmissions before implicit release *implicitReleaseAfter* for each SPS configuration, if Semi-Persistent Scheduling with UL Semi-Persistent Scheduling V-RNTI is enabled for the uplink;

- Whether *twoIntervalsConfig* is enabled or disabled for uplink, only for TDD;

- Downlink Semi-Persistent Scheduling interval *semiPersistSchedIntervalDL* if short TTI in DL for the SpCell is not configured or *semiPersistSchedIntervalDL*-*sTTI* ifshort TTI in DL for the SpCellis configured and number of configured HARQ processes for Semi-Persistent Scheduling *numberOfConfSPS-Processes*, if Semi-Persistent Scheduling is enabled for the downlink;

- *sTTIStartTimeDl* if short TTI in DL for the SpCell is configured and *sTTIStartTimeUl* if short TTI in UL for the SpCell is configured;

When Semi-Persistent Scheduling for uplink or downlink is disabled by RRC, the corresponding configured grant or configured assignment shall be discarded.

Semi-Persistent Scheduling is not supported for RN communication with the E-UTRAN in combination with an RN subframe configuration.

NOTE: When eIMTA is configured, if a configured uplink grant or a configured downlink assignment occurs on a subframe that can be reconfigured through eIMTA L1 signalling, then the UE behaviour is left unspecified.

### 5.10.1 Downlink

After a Semi-Persistent downlink assignment is configured, the MAC entity shall consider sequentially that the Nth assignment occurs in the TTI for which:

- subframe SPS is used:

- (10 \* SFN + subframe) = [(10 \* SFNstart time + subframestart time) + N \* *semiPersistSchedIntervalDL*] modulo 10240.

- slot or subslot SPS is used:

- (10 \* SFN \* sTTI\_Number\_Per\_Subframe + subframe \* sTTI\_Number\_Per\_Subframe + sTTI\_number) = [(10 \* SFNstart time \* sTTI\_Number\_Per\_Subframe + subframestart time \* sTTI\_Number\_Per\_Subframe + *sTTIStartTimeDl*) + N \**semiPersistSchedIntervalDL-sTTI*] modulo (10240 \* sTTI\_Number\_Per\_Subframe).

Where SFNstart time, subframestart time and *sTTIStartTimeDl* are the SFN, subframe and sTTI\_number, respectively, at the time the configured downlink assignment were (re-)initialised. The sTTI\_Number\_Per\_Subframe is 6 when subslot TTI is configued and 2 when slot TTI is configured for short TTI operation. sTTI\_number refers to the index of the short TTI, i.e., index of subslot or slot within the subframe.

For BL UEs or UEs in enhanced coverage SFNstart time and subframestart time refer to SFN and subframe of the first transmission of PDSCH where configured downlink assignment was (re-)initialized.

### 5.10.2 Uplink

After a Semi-Persistent Scheduling uplink grant is configured, the MAC entity shall:

- if *twoIntervalsConfig* is enabled by upper layer:

- set the Subframe\_Offset according to Table 7.4-1.

- else:

- set Subframe\_Offset to 0.

- consider sequentially that the Nth grant occurs in the TTI for which:

- subframe SPS is used:

- (10 \* SFN + subframe) = [(10 \* SFNstart time + subframestart time) + N \* *semiPersistSchedIntervalUL* + Subframe\_Offset \* (N modulo 2)] modulo 10240.

- slot or subslot SPS is used:

- (10 \* SFN \* sTTI\_Number\_Per\_Subframe + subframe \* sTTI\_Number\_Per\_Subframe + sTTI\_number) = [(10 \* SFNstart time \* sTTI\_Number\_Per\_Subframe + subframestart time \* sTTI\_Number\_Per\_Subframe + *sTTIStartTimeUl*) + N \**semiPersistSchedIntervalUL-sTTI*+ Subframe\_Offset \* (N modulo 2) \* sTTI\_Number\_Per\_Subframe] modulo (10240 \* sTTI\_Number\_Per\_Subframe).

Where SFNstart time, subframestart time and *sTTIStartTimeUl* are the SFN, subframe and sTTI\_number, respectively, at the time the configured uplink grant were (re-)initialised. The sTTI\_Number\_Per\_Subframe is 6 when subslot TTI is configued and 2 when slot TTI is configured for short TTI operation. sTTI\_number refers to the index of the short TTI, i.e., index of subslot or slot within the subframe.

Except for NB-IoT, for TDD, the MAC entity is configured with *semiPersistSchedIntervalUL* shorter than 10 subframes, the Nth grant shall be ignored if it occurs in a downlink subframe or a special subframe.

Except for NB-IoT, if the MAC entity is not configured with *skipUplinkTxSPS*, the MAC entity shall clear the configured uplink grant immediately after *implicitReleaseAfter*, as specified in TS 36.331 [8], number of consecutive new MAC PDUs each containing zero MAC SDUs have been provided by the Multiplexing and Assembly entity, on the Semi-Persistent Scheduling resource.

If SPS confirmation 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 an SPS confirmation MAC Control Element as defined in clause 6.1.3.11;

- cancel the triggered SPS confirmation.

The MAC entity shall clear the configured uplink grant immediately after first transmission of SPS confirmation MAC Control Element triggered by the SPS release.

NOTE: Retransmissions for Semi-Persistent Scheduling can continue after clearing the configured uplink grant.

For NB-IoT UEs, BL UEs or UEs in enhanced coverage SFNstart time and subframestart time refer to SFN and subframe of the first transmission of PUSCH where configured uplink grant was (re-)initialized.

In the event of a resource conflict between multiple UL SPS configurations configured with Uplink Semi-Persistent Scheduling V-RNTI, the UE behaviour is undefined.

In the event of a resource conflict in the same serving cell between the initial transmision within a configured grant bundle from multiple different UL SPS configurations configured with Uplink Semi-Persistent Scheduling C-RNTI, the UE behaviour is undefined.

For NB-IoT UEs, a configured uplink grant shall be used only for BSR or SPS confirmation transmission, and *skipUplinkTxSPS* is implicitly configured.

## 5.11 Handling of unknown, unforeseen and erroneous protocol data

When a MAC entity receives a MAC PDU for the MAC entity's C-RNTI or Semi-Persistent Scheduling C-RNTI, or by the configured downlink assignment, containing reserved or invalid values, the MAC entity shall:

- discard the received PDU.

When a MAC entity receives a MAC PDU on MCH containing reserved values, or on DL-SCH containing reserved values for G-RNTI or SC-RNTI, or on SL-SCH, the MAC entity shall:

- ignore the MAC PDU subheaders containing reserved values and the corresponding MAC SDUs;

- in the MAC control elements, ignore the fields containing reserved values and the fields associated with the fields containing reserved values.

## 5.12 MCH reception

MCH transmission may occur in subframes configured by upper layer for MCCH or MTCH transmission. For each such subframe, upper layer indicates if *signallingMCS* or *dataMCS* applies. The transmission of an MCH occurs in a set of subframes defined by *PMCH-Config*. An MCH Scheduling Information MAC control element is included in the first subframe allocated to the MCH within the MCH scheduling period to indicate the position of each MTCH and unused subframes on the MCH. If *pmch-InfoListExt* is configured for an MCH, an Extended MCH Scheduling Information MAC control element is included in the first subframe allocated to the corresponding MCH within the MCH scheduling period to indicate the position of each MTCH and unused subframes on the MCH, and to indicate whether MTCH transmission is to be suspended. The MAC entity shall assume that the first scheduled MTCH starts immediately after the MCCH or the MCH Scheduling Information MAC control element or the Extended MCH Scheduling Information MAC control element if the MCCH is not present, and the other scheduled MTCH(s) start immediately after the previous MTCH, at the earliest in the subframe where the previous MTCH stops. When the MAC entity needs to receive MCH, the MAC entity shall:

- attempt to decode the TB on the MCH;

- if a TB on the MCH has been successfully decoded:

- demultiplex the MAC PDU and deliver the MAC SDU(s) to upper layers.

When the MAC entity receives the Extended MCH Scheduling Information MAC control element, the MAC entity shall indicate the MTCH(s) to be suspended to the upper layers.

NOTE: The MAC entity should continue receiving MCH until the MTCH is removed from the MCCH.

## 5.13 Activation/Deactivation of SCells

If the MAC entity is configured with one or more SCells, the network may activate and deactivate the configured SCells. The SpCell is always activated. The network activates and deactivates the SCell(s) by sending Activation/Deactivation and/or Hibernation MAC control element(s) described in clause 6.1.3.8 and 6.1.3.15 respectively. Furthermore, the MAC entity maintains a *sCellDeactivationTimer* timer per configured SCell (except the SCell configured with PUCCH/SPUCCH, if any) and deactivates the associated SCell upon its expiry. In case the *sCellHibernationTimer* is configured, it takes priority over *sCellDeactivationTimer*. The same initial timer value applies to each instance of the *sCellDeactivationTimer* and it is configured by RRC. The configured SCells are initially deactivated upon addition and after a handover unless the parameter *sCellState* is set to *activated* or *dormant* for the SCell within RRC configuration. The configured SCG SCells are initially deactivated after a SCG change unless the parameter *sCellState* is set to *activated* or *dormant* for the SCell within RRC configuration.

The MAC entity shall for each TTI and for each configured SCell:

- if the MAC entity is configured with an activated SCell upon SCell configuration or receives MAC control element(s) in this TTI activating the SCell, the MAC entity shall in the TTI according to the timing defined in TS 36.213 [2]:

- activate the SCell; i.e. apply normal SCell operation including:

- SRS transmissions on the SCell;

- if *cqi-ShortConfigSCell* is configured:

- CQI/PMI/RI/PTI/CRI reporting for the SCell using the short period of the CSI (CQI/PMI/RI/PTI/CRI) reporting resource configured by *cqi-ShortConfigSCell* according to the timing defined in TS 36.213 [2].

- else:

- CQI/PMI/RI/PTI/CRI reporting for the SCell using the configuration in *cqi-ReportConfigSCell*.

- PDCCH monitoring on the SCell;

- PDCCH monitoring for the SCell;

- PUCCH/SPUCCH transmissions on the SCell, if configured.

- start or restart the *sCellDeactivationTimer* associated with the SCell;

- if *sCellHibernationTimer* associated with the SCell is configured;

- start or restart the *sCellHibernationTimer* associated with the SCell.

- trigger PHR according to clause 5.4.6.

- else, if the MAC entity receives MAC control element(s) in this TTI deactivating the SCell; or

- if the *sCellDeactivationTimer* associated with the activated SCell expires in this TTI and *sCellHibernationTimer* is not configured:

- in the TTI according to the timing defined in TS 36.213 [2]:

- deactivate the SCell;

- stop the *sCellDeactivationTimer* associated with the SCell;

- clear any configured downlink assignments and uplink grants associated with the SCell;

- flush all HARQ buffers associated with the SCell.

- if PDCCH on the activated SCell indicates an uplink grant or downlink assignment; or

- if PDCCH on the Serving Cell scheduling the activated SCell indicates an uplink grant or a downlink assignment for the activated SCell; or

- if a MAC PDU is transmitted in a configured uplink grant or received in a configured downlink assignment:

- restart the *sCellDeactivationTimer* associated with the SCell;

- if *sCellHibernationTimer* associated with the SCell is configured;

- restart the *sCellHibernationTimer* associated with the SCell;

- if the SCell is activated and the *cqi-ShortConfigSCell* expires in this TTI, according to the timing defined in TS 36.213 [2]:

- apply SCell CQI/PMI/RI/PTI/CRI reporting for the SCell using the configuration in *cqi-ReportConfigSCell*;

- if the SCell is deactivated:

- not transmit SRS on the SCell;

- not report CQI/PMI/RI/PTI/CRI for the SCell;

- not transmit on UL-SCH on the SCell;

- not transmit on RACH on the SCell;

- not monitor the PDCCH on the SCell;

- not monitor the PDCCH for the SCell;

- not transmit PUCCH/SPUCCH on the SCell.

HARQ feedback for the MAC PDU containing Activation/Deactivation MAC control element shall not be impacted by PCell, PSCell and PUCCH SCell interruptions due to SCell activation/deactivation, as specified in TS 36.133 [9].

NOTE: When SCell is deactivated, the ongoing Random Access procedure on the SCell, if any, is aborted.

## 5.14 SL-SCH Data transfer

### 5.14.1 SL-SCH Data transmission

#### 5.14.1.1 SL Grant reception and SCI transmission

In order to transmit on the SL-SCH the MAC entity must have at least one sidelink grant.

Sidelink grants are selected as follows for sidelink communication:

- if the MAC entity is configured to receive a single sidelink grant dynamically on the PDCCH and more data is available in STCH than can be transmitted in the current SC period, the MAC entity shall:

- using the received sidelink grant determine the set of subframes in which transmission of SCI and transmission of first transport block occur according to clause 14.2.1 of TS 36.213 [2];

- consider the received sidelink grant to be a configured sidelink grant occurring in those subframes starting at the beginning of the first available SC Period which starts at least 4 subframes after the subframe in which the sidelink grant was received, overwriting a previously configured sidelink grant occurring in the same SC period, if available;

- clear the configured sidelink grant at the end of the corresponding SC Period;

- else, if the MAC entity is configured by upper layers to receive multiple sidelink grants dynamically on the PDCCH and more data is available in STCH than can be transmitted in the current SC period, the MAC entity shall for each received sidelink grant:

- using the received sidelink grant determine the set of subframes in which transmission of SCI and transmission of first transport block occur according to clause 14.2.1 of TS 36.213 [2];

- consider the received sidelink grant to be a configured sidelink grant occurring in those subframes starting at the beginning of the first available SC Period which starts at least 4 subframes after the subframe in which the sidelink grant was received, overwriting a previously configured sidelink grant received in the same subframe number but in a different radio frame as this configured sidelink grant occurring in the same SC period, if available;

- clear the configured sidelink grant at the end of the corresponding SC Period;

- else, if the MAC entity is configured by upper layers to transmit using one or multiple pool(s) of resources as indicated in clause 5.10.4 of TS 36.331 [8] and more data is available in STCH than can be transmitted in the current SC period, the MAC entity shall for each sidelink grant to be selected:

- if configured by upper layers to use a single pool of resources:

- select that pool of resources for use;

- else, if configured by upper layers to use multiple pools of resources:

- select a pool of resources for use from the pools of resources configured by upper layers whose associated priority list includes the priority of the highest priority of the sidelink logical channel in the MAC PDU to be transmitted;

NOTE 1: If more than one pool of resources has an associated priority list which includes the priority of the sidelink logical channel with the highest priority in the MAC PDU to be transmitted, it is left for UE implementation which one of those pools of resources to select.

- randomly select the time and frequency resources for SL-SCH and SCI of a sidelink grant from the selected resource pool. The random function shall be such that each of the allowed selections (see TS 36.213 [2]) can be chosen with equal probability;

- use the selected sidelink grant to determine the set of subframes in which transmission of SCI and transmission of first transport block occur according to clause 14.2.1 of TS 36.213 [2];

- consider the selected sidelink grant to be a configured sidelink grant occurring in those subframes starting at the beginning of the first available SC Period which starts at least 4 subframes after the subframe in which the sidelink grant was selected;

- clear the configured sidelink grant at the end of the corresponding SC Period;

NOTE 2: Retransmissions on SL-SCH cannot occur after the configured sidelink grant has been cleared.

NOTE 3: If the MAC entity is configured by upper layers to transmit using one or multiple pool(s) of resources as indicated in clause 5.10.4 of TS 36.331 [8], it is left for UE implementation how many sidelink grants to select within one SC period taking the number of sidelink processes into account.

Sidelink grants are selected as follows for V2X sidelink communication:

- if the MAC entity is configured to receive a sidelink grant dynamically on the PDCCH and data is available in STCH, the MAC entity shall for each carrier configured in *sl-V2X-ConfigDedicated* for which a sidelink grant has been dynamically received on the PDCCH for this TTI:

- use the received sidelink grant to determine the number of HARQ retransmissions and the set of subframes in which transmission of SCI and SL-SCH occur according to clauses 14.2.1 and 14.1.1.4A of TS 36.213 [2];

- consider the received sidelink grant to be a configured sidelink grant for the carrier;

- if the MAC entity is configured by upper layers to receive a sidelink grant on the PDCCH addressed to SL Semi-Persistent Scheduling V-RNTI, the MAC entity shall for each SL SPS configuration and for each carrier configured in *sl-V2X-ConfigDedicated* for which a sidelink grant has been received on the PDCCH addressed to SL Semi-Persistent Scheduling V-RNTI either for this TTI or for this PDCCH occasion according to clause 3.1 of TS 38.321 [24]:

- if PDCCH contents indicate SPS activation:

- use the received sidelink grant to determine the number of HARQ retransmissions and the set of subframes in which transmission of SCI and SL-SCH occur according to clauses 14.2.1 and 14.1.1.4A of TS 36.213 [2];

- consider the received sidelink grant to be a configured sidelink grant for the carrier.

- if PDCCH contents indicate SPS release:

- clear the corresponding configured sidelink grant for the carrier.

- if the MAC entity is configured by upper layers to transmit using pool(s) of resources in one or multiple carriers as indicated in either clause 5.10.13.1 of TS 36.331 [8] or TS 38.331 [25] based on sensing, or partial sensing, or random selection only if upper layers indicates that transmissions of multiple MAC PDUs are allowed according to either clause 5.10.13.1a of TS 36.331 [8] or TS 38.331 [25], and the MAC entity selects to create a configured sidelink grant corresponding to transmissions of multiple MAC PDUs, and data is available in STCH associated with one or multiple carriers, the MAC entity shall for each Sidelink process configured for multiple transmissions:

- if there is no configured sidelink grant associated with the Sidelink process on any carrier allowed for the STCH as indicated by upper layers, as specified in TS 24.386 [15]:

- trigger the TX carrier (re-)selection procedure as specified in clause 5.14.1.5;

- else if there is a configured sidelink grant associated with the Sidelink process:

- if SL\_RESOURCE\_RESELECTION\_COUNTER = 0 and when SL\_RESOURCE\_RESELECTION\_COUNTER was equal to 1 the MAC entity randomly selected, with equal probability, a value in the interval [0, 1] which is above the probability configured by upper layers in *probResourceKeep*; or

- if neither transmission nor retransmission has been performed by the MAC entity on any resource indicated in the configured sidelink grant during the last second; or

- if *sl-ReselectAfter* is configured and the number of consecutive unused transmission opportunities on resources indicated in the configured sidelink grant is equal to *sl-ReselectAfter*; or

- if none of the configured sidelink grant(s) on the carrier(s) allowed for the STCH have radio resources available in this TTI to accommodate a RLC SDU according to clause 5.14.1.3.1 by using the maximum allowed MCS configured by upper layers in *maxMCS-PSSCH* and the MAC entity selects not to segment the RLC SDU; or

NOTE 4: If none of the configured sidelink grant(s) on the carrier(s) allowed for the STCH have radio resources available in this TTI to accommodate the RLC SDU according to clause 5.14.1.3.1, it is left for UE implementation whether to perform segmentation or sidelink resource reselection.

- if none of the configured sidelink grant(s) on the carrier(s) allowed for the STCH have radio resources available in this TTI, according to clause 5.14.1.3.1 to fulfil the latency requirement of the data in a sidelink logical channel according to the associated PPPP, and the MAC entity selects not to perform transmission(s) corresponding to a single MAC PDU; or

NOTE 5: If the latency requirement is not met, it is left for UE implementation whether to perform transmission(s) corresponding to single MAC PDU or sidelink resource reselection.

- if the pool of resources where the sidelink grant is configured for the Sidelink process, is reconfigured by upper layers:

- trigger the TX carrier (re-)selection procedure as specified in clause 5.14.1.5;

- clear the configured sidelink grant associated to the Sidelink process;

- flush the HARQ buffer associated to the Sidelink process;

- else if SL\_RESOURCE\_RESELECTION\_COUNTER = 0 and when SL\_RESOURCE\_RESELECTION\_COUNTER was equal to 1 the MAC entity randomly selected, with equal probability, a value in the interval [0, 1] which is less than or equal to the probability configured by upper layers in *probResourceKeep*:

- clear the configured sidelink grant, if available;

- randomly select, with equal probability, an integer value in the interval [5, 15] for the resource reservation interval higher than or equal to 100ms, in the interval [10, 30] for the resource reservation interval equal to 50ms or in the interval [25, 75] for the resource reservation interval equal to 20ms, and set SL\_RESOURCE\_RESELECTION\_COUNTER to the selected value;

- use the previously selected sidelink grant for the number of transmissions of the MAC PDUs determined in clause 14.1.1.4B of TS 36.213 [2] with the resource reservation interval to determine the set of subframes in which transmissions of SCI and SL-SCH occur according to clauses 14.2.1 and 14.1.1.4B of TS 36.213 [2];

- consider the selected sidelink grant to be a configured sidelink grant;

- if the TX carrier (re-)selection procedure was triggered in above and one or more carriers have been (re-)selected in the Tx carrier (re-)selection according to clause 5.14.1.5:

- determine the order of the (re-)selected carriers, according to the decreasing order based on the highest priority of logical channels which are allowed on each (re-)selected carrier, and perform the following for each Sidelink process on each (re-)selected carrier according to the order:

- select one of the allowed values configured by upper layers in *restrictResourceReservationPeriod* and set the resource reservation interval by multiplying 100 with the selected value;

NOTE 6: How the UE selects this value is up to UE implementation.

- randomly select, with equal probability, an integer value in the interval [5, 15] for the resource reservation interval higher than or equal to 100ms, in the interval [10, 30] for the resource reservation interval equal to 50ms or in the interval [25, 75] for the resource reservation interval equal to 20ms, and set SL\_RESOURCE\_RESELECTION\_COUNTER to the selected value;

- select the number of HARQ retransmissions from the allowed numbers that are configured by upper layers in *allowedRetxNumberPSSCH* included in *pssch-TxConfigList* and, if configured by upper layers, overlapped in *allowedRetxNumberPSSCH* indicated in *cbr-pssch-TxConfigList* for the highest priority of the sidelink logical channel(s) allowed on the selected carrier and the CBR measured by lower layers according to TS 36.214 [6] if CBR measurement results are available or the corresponding *defaultTxConfigIndex* configured by upper layers if CBR measurement results are not available;

- select an amount of frequency resources within the range that is configured by upper layers between *minSubchannel-NumberPSSCH* and *maxSubchannel-NumberPSSCH* included in *pssch-TxConfigList* and, if configured by upper layers, overlapped between *minSubchannel-NumberPSSCH* and *maxSubchannel-NumberPSSCH* indicated in *cbr-pssch-TxConfigList* for the highest priority of the sidelink logical channel(s) allowed on the selected carrier and the CBR measured by lower layers according to TS 36.214 [6] if CBR measurement results are available or the corresponding *defaultTxConfigIndex* configured by upper layers if CBR measurement results are not available;

- randomly select the time and frequency resources for one transmission opportunity from the resources indicated by the physical layer according to clause 14.1.1.6 of TS 36.213 [2], according to the amount of selected frequency resources. The selected time and frequency resources shall fulfil the physical layer requirements as specified in TS 36.101 [10], and the random function shall be such that each of the allowed selections can be chosen with equal probability;

- use the randomly selected resource to select a set of periodic resources spaced by the resource reservation interval for transmission opportunities of SCI and SL-SCH corresponding to the number of transmission opportunities of MAC PDUs determined in clause 14.1.1.4B of TS 36.213 [2];

- if the number of HARQ retransmissions is equal to 1:

- if there are available resources left in the resources indicated by the physical layer according to clause 14.1.1.6 of TS 36.213 [2] that meet the conditions in clause 14.1.1.7 of TS 36.213 [2] for more transmission opportunities:

- randomly select the time and frequency resources for one transmission opportunity from the available resources, according to the amount of selected frequency resources. The selected time and frequency resources shall fulfil the physical layer requirements as specified in TS 36.101 [10], and the random function shall be such that each of the allowed selections can be chosen with equal probability;

- use the randomly selected resource to select a set of periodic resources spaced by the resource reservation interval for the other transmission opportunities of SCI and SL-SCH corresponding to the number of retransmission opportunities of the MAC PDUs determined in clause 14.1.1.4B of TS 36.213 [2];

- consider the first set of transmission opportunities as the new transmission opportunities and the other set of transmission opportunities as the retransmission opportunities;

- consider the set of new transmission opportunities and retransmission opportunities as the selected sidelink grant.

- else:

- consider the set as the selected sidelink grant;

- use the selected sidelink grant to determine the set of subframes in which transmissions of SCI and SL-SCH occur according to clause 14.2.1 and 14.1.1.4B of TS 36.213 [2];

- consider the selected sidelink grant to be a configured sidelink grant;

- else, if the MAC entity is configured by upper layers to transmit using pool(s) of resources in one or multiple carriers as indicated in either clause 5.10.13.1 of TS 36.331 [8] or TS 38.331 [25], the MAC entity selects to create a configured sidelink grant corresponding to transmission(s) of a single MAC PDU, and data is available in STCH associated with one or multiple carriers, the MAC entity shall for a Sidelink process:

- trigger the TX carrier (re-)selection procedure as specified in clause 5.14.1.5;

- if one or more carriers have been (re-)selected in the Tx carrier (re-)selection according to clause 5.14.1.5:

- determine the order of the (re-)selected carriers, according to the decreasing order based on the highest priority of logical channels which are allowed on each (re-)selected carrier, and perform the following for each Sidelink process on each (re-)selected carrier according to the order:

- select the number of HARQ retransmissions from the allowed numbers that are configured by upper layers in *allowedRetxNumberPSSCH* included in *pssch-TxConfigList* and, if configured by upper layers, overlapped in *allowedRetxNumberPSSCH* indicated in *cbr-pssch-TxConfigList* for the highest priority of the sidelink logical channel(s) allowed on the selected carrier and the CBR measured by lower layers according to TS 36.214 [6] if CBR measurement results are available or the corresponding *defaultTxConfigIndex* configured by upper layers if CBR measurement results are not available;

- select an amount of frequency resources within the range that is configured by upper layers between *minSubchannel-NumberPSSCH* and *maxSubchannel-NumberPSSCH* included in *pssch-TxConfigList* and, if configured by upper layers, overlapped between *minSubchannel-NumberPSSCH* and *maxSubchannel-NumberPSSCH* indicated in *cbr-pssch-TxConfigList* for the highest priority of the sidelink logical channel(s) allowed on the selected carrier and the CBR measured by lower layers according to TS 36.214 [6] if CBR measurement results are available or the corresponding *defaultTxConfigIndex* configured by upper layers if CBR measurement results are not available;

- randomly select the time and frequency resources for one transmission opportunity of SCI and SL-SCH from the resources indicated by the physical layer according to clause 14.1.1.6 of TS 36.213 [2] , according to the amount of selected frequency resources. The selected time and frequency resources shall fulfil the physical layer requirement as specified in TS 36.101 [10], and the random function shall be such that each of the allowed selections can be chosen with equal probability;

- if the number of HARQ retransmissions is equal to 1:

- if there are available resources left in the resources indicated by the physical layer according to clause 14.1.1.6 of TS 36.213 [2] that meet the conditions in subcause 14.1.1.7 of TS 36.213 [2] for one more transmission opportunity:

- randomly select the time and frequency resources for the other transmission opportunity of SCI and SL-SCH corresponding to additional transmission of the MAC PDU from the available resources, according to the amount of selected frequency resources. The selected time and frequency resources shall fulfil the physical layer requirements as specified in TS 36.101 [10], and the random function shall be such that each of the allowed selections can be chosen with equal probability;

- consider a transmission opportunity which comes first in time as the new transmission opportunity and a transmission opportunity which comes later in time as the retransmission opportunity;

- consider both of the transmission opportunities as the selected sidelink grant;

- else:

- consider the transmission opportunity as the selected sidelink grant;

- use the selected sidelink grant to determine the subframes in which transmission(s) of SCI and SL-SCH occur according to clause 14.2.1 and 14.1.1.4B of TS 36.213 [2];

- consider the selected sidelink grant to be a configured sidelink grant.

NOTE 7: For V2X sidelink communication, the UE should ensure the randomly selected time and frequency resources fulfill the latency requirement.

NOTE 8: For V2X sidelink communication, when there is no overlapping between the chosen configuration(s) in *pssch-TxConfigList* and chosen configuration(s) indicated in *cbr-pssch-TxConfigList*, it is up to UE implementation whether the UE transmits and which transmitting parameters the UE uses between allowed configuration(s) indicated in *pssch-TxConfigList* and allowed configuration(s) indicated in *cbr-pssch-TxConfigList*.

The MAC entity shall for each subframe:

- for each configured sidelink grant occurring in this subframe:

- if SL\_RESOURCE\_RESELECTION\_COUNTER = 1 for the Sidelink process associated with the configured sidelink grant and the MAC entity randomly selected, with equal probability, a value in the interval [0, 1] which is above the probability configured by upper layers in *probResourceKeep*:

- set the resource reservation interval for the configured sidelink grant equal to 0;

- if the configured sidelink grant corresponds to transmission of SCI:

- for V2X sidelink communication in UE autonomous resource selection:

- consider the selected transmission format to be *SL-V2X-TxProfile* for the highest priority of the sidelink logical channel(s) in the MAC PDU (TS 36.331 [8]);

- select a MCS which is, if configured, within the range that is configured by upper layers between *minMCS-PSSCH* and *maxMCS-PSSCH* included in *pssch-TxConfigList* associated with the selected transmission format and, if configured by upper layers, overlapped between *minMCS-PSSCH* and *maxMCS-PSSCH* indicated in *cbr-pssch-TxConfigList* associated with the selected transmission format for the highest priority of the sidelink logical channel(s) in the MAC PDU and the CBR measured by lower layers according to TS 36.214 [6] if CBR measurement results are available or the corresponding *defaultTxConfigIndex* configured by upper layers if CBR measurement results are not available;

NOTE 9: MCS selection is up to UE implementation if the MCS or the corresponding range is not configured by upper layers.

NOTE 10: For V2X sidelink communication, when there is no overlapping between the chosen configuration(s) included in *pssch-TxConfigList* and chosen configuration(s) indicated in *cbr-pssch-TxConfigList*, it is up to UE implementation whether the UE transmits and which transmitting parameters the UE uses between allowed configuration(s) indicated in *pssch-TxConfigList* and allowed configuration(s) indicated in *cbr-pssch-TxConfigList*.

- for V2X sidelink communication in scheduled resource allocation:

- consider the selected transmission format to be *SL-V2X-TxProfile* for the highest priority of the sidelink logical channel(s) in the MAC PDU (TS 36.331 [8]);

- select a MCS which is associated with the selected transmission format unless it is configured by upper layer;

- instruct the physical layer to transmit SCI corresponding to the configured sidelink grant;

- for V2X sidelink communication, deliver the configured sidelink grant, the associated HARQ information and the value of the highest priority of the sidelink logical channel(s) in the MAC PDU to the Sidelink HARQ Entity for this subframe;

- else if the configured sidelink grant corresponds to transmission of first transport block for sidelink communication:

- deliver the configured sidelink grant and the associated HARQ information to the Sidelink HARQ Entity for this subframe.

NOTE 11: If the MAC entity has multiple configured sidelink grants occurring in one subframe and if not all of them can be processed due to the single-cluster SC-FDM restriction, it is left for UE implementation which one of these to process according to the procedure above.

#### 5.14.1.2 Sidelink HARQ operation

##### 5.14.1.2.1 Sidelink HARQ Entity

The MAC entity is configured by upper layers to transmit using pool(s) of resources on one or multiple carriers as indicated in clause 5.10.13.1 of TS 36.331 [8]. For each carrier, there is one Sidelink HARQ Entity at the MAC entity for transmission on SL-SCH, which maintains a number of parallel Sidelink processes.

For sidelink communication, the number of transmitting Sidelink processes associated with the Sidelink HARQ Entity is defined in TS 36.331 [8].

For V2X sidelink communication, the maximum number of transmitting Sidelink processes associated with each Sidelink HARQ Entity is 8. A sidelink process may be configured for transmissions of multiple MAC PDUs. For transmissions of multiple MAC PDUs, the maximum number of transmitting Sidelink processes associated with each Sidelink HARQ Entity is 2.

A delivered and configured sidelink grant and its associated HARQ information are associated with a Sidelink process.

For each subframe of the SL-SCH and each Sidelink process, the Sidelink HARQ Entity shall:

- if a sidelink grant corresponding to a new transmission opportunity has been indicated for this Sidelink process and there is SL data, for sidelink logical channels of ProSe destination associated with this sidelink grant, available for transmission:

- obtain the MAC PDU from the "Multiplexing and assembly" entity;

- deliver the MAC PDU and the sidelink grant and the HARQ information to this Sidelink process;

- instruct this Sidelink process to trigger a new transmission.

- else, if this subframe corresponds to retransmission opportunity for this Sidelink process:

- instruct this Sidelink process to trigger a retransmission.

NOTE: The resources for retransmission opportunities are specified in clause 14.2.1 of TS 36.213 [2] unless specified in clause 5.14.1.1.

##### 5.14.1.2.2 Sidelink process

The Sidelink process is associated with a HARQ buffer.

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 updated modulo 4.

New transmissions and retransmissions either for a given SC period in sidelink communication or in V2X sidelink communication are performed on the resource indicated in the sidelink grant as specified in clause 5.14.1.1 and with the MCS selected as specified in clause 5.14.1.1.

If the sidelink process is configured to perform transmissions of multiple MAC PDUs for V2X sidelink communication the process maintains a counter SL\_RESOURCE\_RESELECTION\_COUNTER. For other configurations of the sidelink process, this counter is not available.

If the Sidelink HARQ Entity requests a new transmission, the Sidelink process shall:

- set CURRENT\_IRV to 0;

- store the MAC PDU in the associated HARQ buffer;

- store the sidelink grant received from the Sidelink HARQ Entity;

- generate a transmission as described below.

If the Sidelink HARQ Entity requests a retransmission, the Sidelink process shall:

- generate a transmission as described below.

To generate a transmission, the Sidelink process shall:

- if there is no uplink transmission; or if the MAC entity is able to perform uplink transmissions and transmissions on SL-SCH simultaneously at the time of the transmission; or if there is a MAC PDU to be transmitted in this TTI in uplink, except a MAC PDU obtained from the Msg3 buffer, and transmission of V2X sidelink communication is prioritized over uplink transmission; and

- if there is no Sidelink Discovery Gap for Transmission or no transmission on PSDCH at the time of the transmission; or, in case of transmissions of V2X sidelink communication, if the MAC entity is able to perform transmissions on SL-SCH and transmissions on PSDCH simultaneously at the time of the transmission:

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

- increment CURRENT\_IRV by 1;

- if this transmission corresponds to the last transmission of the MAC PDU:

- decrement SL\_RESOURCE\_RESELECTION\_COUNTER by 1, if available.

The transmission of the MAC PDU for V2X sidelink communication is prioritized over uplink transmissions if the following conditions are met:

- if the MAC entity is not able to perform all uplink transmissions and all transmissions of V2X sidelink communication simultaneously at the time of the transmission; and

- if uplink transmission is not prioritized by upper layer according to TS 24.386 [15]; and

- if *thresSL-TxPrioritization* is configured and the value of the highest priority of the sidelink logical channel(s) in the MAC PDU is lower than *thresSL-TxPrioritization*.

#### 5.14.1.3 Multiplexing and assembly

For PDU(s) associated with one SCI, MAC shall consider only logical channels with the same Source Layer-2 ID-Destination Layer-2 ID pair.

Multiple transmissions within overlapping SC periods to different ProSe Destinations are allowed subject to single-cluster SC-FDM constraint.

In V2X sidelink communication, multiple transmissions for different Sidelink processes are allowed to be independently performed in different subframes.

##### 5.14.1.3.1 Logical channel prioritization

The Logical Channel Prioritization procedure is applied when a new transmission is performed. Each sidelink logical channel has an associated priority which is the PPPP and optionally an associated PPPR. Multiple sidelink logical channels may have the same associated priority. The mapping between priority and LCID is left for UE implementation. If duplication is activated as specified in TS 36.323 [4], the MAC entity shall map different sidelink logical channels which correspond to the same PDCP entity onto different carriers in accordance with clause 5.14.1.5, or onto different carriers of different carrier sets (if configured in *allowedCarrierFreqList* for the corresponding destination). For a given sidelink logical channel, it is up to UE implementation which carrier set to select among the carrier sets configured in *allowedCarrierFreqList* (if configured) for the corresponding destination.

The MAC entity shall perform the following Logical Channel Prioritization procedure either for each SCI transmitted in an SC period in sidelink communication, or for each SCI corresponding to a new transmission in V2X sidelink communication:

- The MAC entity shall allocate resources to the sidelink logical channels in the following steps:

- Only consider sidelink logical channels not previously selected for this SC period and the SC periods (if any) which are overlapping with this SC period, to have data available for transmission in sidelink communication;

- Only consider sidelink logical channels which meet the following conditions:

- allowed on the carrier where the SCI is transmitted for V2X sidelink communication, if the carrier is configured by upper layers according to TS 36.331 [8] and TS 24.386 [15];

- having a priority whose associated *threshCBR-FreqReselection* is no lower than the CBR of the carrier when the carrier is (re-)selected in accordance with 5.14.1.5;

- Only consider one sidelink logical channel among sidelink logical channels corresponding to same PDCP entity, if duplication is activated as specified in TS 36.323 [4].

- Step 0: Select a ProSe Destination, having the sidelink logical channel with the highest priority, among the sidelink logical channels having data available for transmission and having the same transmission format as the one selected corresponding to the ProSe Destination;

NOTE: The sidelink logical channels belonging to the same ProSe Destination have the same transmission format.

- For each MAC PDU associated to the SCI:

- Step 1: Among the sidelink logical channels belonging to the selected ProSe Destination and having data available for transmission, allocate resources to the sidelink logical channel with the highest priority;

- Step 2: if any resources remain, sidelink logical channels belonging to the selected ProSe Destination are served in decreasing order of priority until either the data for the sidelink logical channel(s) or the SL grant is exhausted, whichever comes first. Sidelink 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) if the whole SDU (or partially transmitted SDU) fits into the remaining resources;

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

- the UE should maximise the transmission of data;

- if the MAC entity is given a sidelink grant size that is equal to or larger than 10 bytes (for sidelink communication) or 11 bytes (for V2X sidelink communication) while having data available for transmission, the MAC entity shall not transmit only padding.

##### 5.14.1.3.2 Multiplexing of MAC SDUs

The MAC entity shall multiplex MAC SDUs in a MAC PDU according to clauses 5.14.1.3.1 and 6.1.6.

#### 5.14.1.4 Buffer Status Reporting

The sidelink Buffer Status reporting procedure is used to provide the serving eNB with information about the amount of sidelink data available for transmission in the SL buffers associated with the MAC entity. RRC controls BSR reporting for the sidelink by configuring the two timers *periodic-BSR-TimerSL* and *retx-BSR-TimerSL*. Each sidelink logical channel belongs to a ProSe Destination. Each sidelink logical channel is allocated to an LCG depending on the priority and optionally the PPPR of the sidelink logical channel, and the mapping between LCG ID and priority and optionally the mapping between LCG ID and PPPR which are provided by upper layers in *logicalChGroupInfoList*, as specified in TS 36.331 [8]. LCG is defined per ProSe Destination.

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

- if the MAC entity has a configured SL-RNTI or a configured SL-V-RNTI:

- SL data, for a sidelink logical channel of a ProSe Destination, 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] respectively) and either the data belongs to a sidelink logical channel with higher priority than the priorities of the sidelink logical channels which belong to any LCG belonging to the same ProSe Destination and for which data is already available for transmission, or there is currently no data available for transmission for any of the sidelink logical channels belonging to the same ProSe Destination, in which case the Sidelink BSR is referred below to as "Regular Sidelink BSR";

- UL resources are allocated and number of padding bits remaining after a Padding BSR has been triggered is equal to or larger than the size of the Sidelink BSR MAC control element containing the buffer status for at least one LCG of a ProSe Destination plus its subheader, in which case the Sidelink BSR is referred below to as "Padding Sidelink BSR";

- *retx-BSR-TimerSL* expires and the MAC entity has data available for transmission for any of the sidelink logical channels, in which case the Sidelink BSR is referred below to as "Regular Sidelink BSR";

- *periodic-BSR-TimerSL* expires, in which case the Sidelink BSR is referred below to as "Periodic Sidelink BSR";

- else:

- An SL-RNTI or an SL-V-RNTI is configured by upper layers and SL data is 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] respectively), in which case the Sidelink BSR is referred below to as "Regular Sidelink BSR".

For Regular and Periodic Sidelink BSR:

- if the number of bits in the UL grant is equal to or larger than the size of a Sidelink BSR containing buffer status for all LCGs having data available for transmission plus its subheader:

- report Sidelink BSR containing buffer status for all LCGs having data available for transmission;

- else report Truncated Sidelink BSR containing buffer status for as many LCGs having data available for transmission as possible, taking the number of bits in the UL grant into consideration.

For Padding Sidelink BSR:

- if the number of padding bits remaining after a Padding BSR has been triggered is equal to or larger than the size of a Sidelink BSR containing buffer status for all LCGs having data available for transmission plus its subheader:

- report Sidelink BSR containing buffer status for all LCGs having data available for transmission;

- else report Truncated Sidelink BSR containing buffer status for as many LCGs having data available for transmission as possible, taking the number of bits in the UL grant into consideration.

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

- if the MAC entity has UL resources allocated for new transmission for this TTI and the allocated UL resources can accommodate a Sidelink BSR MAC control element plus its subheader as a result of logical channel prioritization:

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

- start or restart *periodic-BSR-TimerSL* except when all the generated Sidelink BSRs are Truncated Sidelink BSRs;

- start or restart *retx-BSR-TimerSL*;

- else if a Regular Sidelink BSR has been triggered:

- if an uplink grant is not configured:

- a Scheduling Request shall be triggered.

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

The MAC entity shall restart *retx-BSR-TimerSL* upon reception of an SL grant.

All triggered regular Sidelink BSRs shall be cancelled in case the remaining configured SL grant(s) valid for this SC Period can accommodate all pending data available for transmission in sidelink communication or in case the remaining configured SL grant(s) valid can accommodate all pending data available for transmission in V2X sidelink communication. All triggered Sidelink BSRs shall be cancelled in case the MAC entity has no data available for transmission for any of the sidelink logical channels. All triggered Sidelink BSRs shall be cancelled when a Sidelink BSR (except for Truncated Sidelink BSR) is included in a MAC PDU for transmission. All triggered Sidelink BSRs shall be cancelled, and *retx-BSR-TimerSL* and *periodic-BSR-TimerSL* shall be stopped, when upper layers configure autonomous resource selection.

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

All Sidelink 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 Sidelink BSRs reporting buffer status for this LCG.

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

#### 5.14.1.5 TX carrier (re-)selection for V2X sidelink communication

The MAC entity shall consider a CBR of a carrier to be one measured by lower layers according to TS 36.214 [6] if CBR measurement results are available, or the corresponding *defaultTxConfigIndex* configured by upper layers for the carrier if CBR measurement results are not available.

If the TX carrier (re-)selection is triggered for a Sidelink process according to clause 5.14.1.1, the MAC entity shall:

- if there is no configured sidelink grant on any carrier allowed for the sidelink logical channel where data is available as indicated by upper layers (TS 36.331 [8] and TS 24.386 [15]):

- for each carrier configured by upper layers associated with the concerned sidelink logical channel:

- if the CBR of the carrier is below *threshCBR-FreqReselection* associated with the priority of the sidelink logical channel:

- consider the carrier as a candidate carrier for TX carrier (re-)selection for the concerned sidelink logical channel.

- else:

- for each sidelink logical channel, if any, where data is available and that are allowed on the carrier for which Tx carrier (re-)selection is triggered according to clause 5.14.1.1:

- if the CBR of the carrier is below *threshCBR-FreqKeeping* associated with priority of the sidelink logical channel:

- select the carrier and the associated pool of resources.

- else:

- for each carrier configured by upper layers on which the sidelink logical channel is allowed, if the CBR of the carrier is below *threshCBR-FreqReselection* associated with the priority of the sidelink logical channel;

- consider the carrier as a candidate carrier for TX carrier (re-)selection.

The MAC entity shall:

- if one or more carriers are considered as the candidate carriers for TX carrier (re-)selection:

- for each sidelink logical channel allowed on the carrier where data is available and Tx carrier (re-)selection is triggered:

- select one or more carrier(s) and associated pool(s) of resources among the candidate carriers with increasing order of CBR from the lowest CBR.

NOTE 1: It is left to UE implementation how many carriers to select based on UE capability.

NOTE 2: It is left to UE implementation to determine the sidelink logical channels among the sidelink logical channels where data is available and that are allowed on the carrier for which Tx carrier (re-) selection is triggered.

NOTE 3: If the MAC entity is configured by the upper layer to receive a sidelink grant dynamically on the PDCCH, it is left to UE implementation to determine which carriers configured by upper layer in *sl-V2X-ConfigDedicated*, as specified in TS 36.331 [8] are considered as selected carriers for the sidelink synchronization procedures in clauses 5.10.7, 5.10.8 and 5.10.8a of TS 36.331 [8].

### 5.14.2 SL-SCH Data reception

#### 5.14.2.1 SCI reception

SCI transmitted on the PSCCH indicate if there is a transmission on SL-SCH and provide the relevant HARQ information.

The MAC entity shall:

- for each subframe during which the MAC entity monitors PSCCH:

- if SCI for this subframe has been received on the PSCCH for sidelink communication with a Group Destination ID of interest to this MAC entity:

- determine the set of subframes in which reception of the first transport blocks occur according to clause 14.2.2 of TS 36.213 [2] using the received SCI;

- store the SCI and associated HARQ information as SCI valid for the subframes corresponding to first transmission of each transport block;

- else if SCI for this subframe has been received on the PSCCH for V2X sidelink communication:

- determine the set of subframes in which reception of the transport block occur according to clause 14.1.2 of TS 36.213 [2] using the received SCI;

- store the SCI and associated HARQ information as SCI valid for the subframes corresponding to transmission(s) of the transport block;

- for each subframe for which the MAC entity has a valid SCI:

- deliver the SCI and the associated HARQ information to the Sidelink HARQ Entity.

#### 5.14.2.2 Sidelink HARQ operation

##### 5.14.2.2.1 Sidelink HARQ Entity

For each carrier, there is one Sidelink HARQ Entity at the MAC entity for reception of the SL-SCH, which maintains a number of parallel Sidelink processes.

Each Sidelink process is associated with SCI in which the MAC entity is interested. If SCI includes the Group Destination ID, this interest is as determined by the Group Destination ID of the SCI. The Sidelink HARQ Entity directs HARQ information and associated TBs received on the SL-SCH to the corresponding Sidelink processes.

The number of Receiving Sidelink processes associated with the Sidelink HARQ Entity is defined in TS 36.331 [8].

For each subframe of the SL-SCH, the Sidelink HARQ Entity shall:

- for each SCI valid in this subframe:

- allocate the TB received from the physical layer and the associated HARQ information to a Sidelink process, associate this Sidelink process with this SCI and consider this transmission to be a new transmission.

- for each Sidelink process:

- if this subframe corresponds to retransmission opportunity for the Sidelink process according to its associated SCI:

- allocate the TB received from the physical layer and the associated HARQ information to the Sidelink process and consider this transmission to be a retransmission.

##### 5.14.2.2.2 Sidelink process

For each subframe where a transmission takes place for the Sidelink process, one TB and the associated HARQ information is received from the Sidelink HARQ Entity.

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 updated modulo 4.

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

- if this is a new transmission:

- set CURRENT\_IRV to 0;

- store the received data in the soft buffer and optionally attempt to decode the received data according to CURRENT\_IRV.

- else if this is a retransmission:

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

- increment CURRENT\_IRV by 1;

- combine the received data with the data currently in the soft buffer for this TB and optionally attempt to decode the combined data according to the CURRENT\_IRV.

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

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

- if the DST field of the decoded MAC PDU subheader is equal to the 16 MSB of any of the Destination Layer-2 ID(s) of the UE for which the 8 LSB are equal to the Group Destination ID in the corresponding SCI:

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

- else if the DST field of the decoded MAC PDU subheader is equal to any of the Destination Layer-2 ID(s) of the UE:

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

#### 5.14.2.3 Disassembly and demultiplexing

The MAC entity shall disassemble and demultiplex a MAC PDU as defined in clause 6.1.6.

## 5.15 SL-DCH data transfer

### 5.15.1 SL-DCH data transmission

#### 5.15.1.1 Resource allocation

In order to transmit MAC PDU(s) on SL-DCH, the MAC entity shall for every discovery period and each MAC PDU:

- if the MAC entity is configured by upper layers with a specific grant as specified in TS 36.331 [8]:

- using the specific grant determine the set of subframes in which a transmission of new MAC PDU(s) occur according to clause 14.3.1 of TS 36.213 [2];

- consider the determined set of subframes to be a configured grant for the corresponding discovery period;

- for every subframe, if the MAC entity has a configured grant occurring in that subframe, deliver the configured grant and the MAC PDU to the Sidelink HARQ Entity;

- clear the configured grant at the end of the corresponding discovery period.

NOTE: Mapping between grant and physical resources is specified in clause 9.5.6 of TS 36.211 [7].

- else if the MAC entity is configured with a single pool of resources by upper layers:

- select a random value p1 in the range from 0 to 1, where the random function shall be such that each of the allowed selections can be chosen with equal probability;

- if p1 is less than *txProbability*:

- select a random resource from the pool of resources (excluding any resources which are overlapping with PRACH or resources belonging to the subframes of resources already selected for transmissions on SL-DCH in this discovery period), where the random function shall be such that each of the allowed selections (see clause 14.3.1 of TS 36.213 [2]) can be chosen with equal probability;

- using the selected resource determine the set of subframes in which the transmission of a MAC PDU can occur according to clause 14.3.1 of TS 36.213 [2]

- consider the determined set of subframes to be a configured grant for the corresponding discovery period;

- for every subframe, if the MAC entity has a configured grant occurring in that subframe, deliver the configured grant and the MAC PDU to the Sidelink HARQ Entity;

- clear the configured grant at the end of the corresponding discovery period.

#### 5.15.1.2 Sidelink HARQ operation

##### 5.15.1.2.1 Sidelink HARQ Entity

There is one Sidelink HARQ Entity at the MAC entity for transmission on SL-DCH, which maintains one Sidelink process for each MAC PDU.

For each subframe of the SL-DCH the Sidelink HARQ Entity shall:

- if a grant and a MAC PDU has been delivered for this subframe to the Sidelink HARQ Entity:

- deliver the MAC PDU and the grant to the Sidelink process;

- instruct the Sidelink process to trigger a new transmission.

- else, if this subframe corresponds to retransmission opportunity for the Sidelink process:

- instruct the Sidelink process to trigger a retransmission.

##### 5.15.1.2.2 Sidelink process

The Sidelink process is associated with a HARQ buffer.

The Sidelink 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. When the Sidelink 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.

The Sidelink process is configured with a maximum number of HARQ retransmissions by RRC: *numRetx*.

If the Sidelink HARQ Entity requests a new transmission, the Sidelink process shall:

- set CURRENT\_TX\_NB to 0;

- set CURRENT\_IRV to 0;

- store the MAC PDU in the associated HARQ buffer;

- store the grant received from the Sidelink HARQ Entity;

- generate a transmission as described below.

If the Sidelink HARQ Entity requests a retransmission, the Sidelink process shall:

- increment CURRENT\_TX\_NB by 1;

- generate a transmission as described below.

To generate a transmission, the Sidelink process shall:

- if there is no uplink transmission, no transmission or reception on PSCCH, and no transmission or reception on PSSCH at the time of the transmission; or

- if there is a Sidelink Discovery Gap for Transmission at the time of transmission and if there is a MAC PDU to be transmitted in this TTI in uplink, which is not obtained from the Msg3 buffer:

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

- increment CURRENT\_IRV by 1.

After performing above actions, the Sidelink process then shall:

- if CURRENT\_TX\_NB = *numRetx*:

- flush the HARQ buffer.

### 5.15.2 SL-DCH data reception

#### 5.15.2.1 Sidelink HARQ operation

##### 5.15.2.1.1 Sidelink HARQ Entity

There is one Sidelink HARQ Entity at the MAC entity for reception on the SL-DCH which maintains a number of parallel Sidelink processes. The Sidelink HARQ Entity directs HARQ information and associated TBs received on the SL-DCH to the corresponding Sidelink processes.

The number of receiving Sidelink processes per Sidelink HARQ Entity is specified in TS 36.331 [8].

For each subframe of the SL-DCH, the Sidelink HARQ Entity shall:

- receive the TB and the associated HARQ information from the physical layer;

- if this subframe corresponds to a new transmission opportunity:

- allocate the received TB (if any) and the associated HARQ information to a non-running Sidelink process and consider this transmission to be a new transmission.

- else, if this subframe corresponds to a retransmission opportunity:

- allocate the received TB (if any) and the associated HARQ information to its Sidelink process and consider this transmission to be a retransmission.

##### 5.15.2.1.2 Sidelink process

For each subframe where a transmission takes place for the Sidelink process, one TB and the associated HARQ information is received from the Sidelink HARQ Entity.

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 updated modulo 4.

The Sidelink process shall:

- if this subframe corresponds to a new transmission opportunity:

- set CURRENT\_IRV to 0;

- else, if this subframe corresponds to a retransmission opportunity:

- increment CURRENT\_IRV by 1.

- if a TB was allocated to the Sidelink process:

- if this is a new transmission:

- optionally store the received data in the soft buffer and attempt to decode the received data according to the CURRENT\_IRV.

- else if this is a retransmission:

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

- optionally combine the received data with the data currently in the soft buffer for this TB and attempt to decode the combined data according to the CURRENT\_IRV.

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

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

- deliver the decoded MAC PDU to upper layers.

## 5.16 SL-BCH data transfer

### 5.16.1 SL-BCH data transmission

When instructed to send SL-BCH, the MAC entity shall:

- obtain the MAC PDU to transmit from SBCCH;

- deliver the MAC PDU to the physical layer and instruct it to generate a transmission.

### 5.16.2 SL-BCH data reception

When the MAC entity needs to receive SL-BCH, the MAC entity shall:

- receive and attempt to decode the SL-BCH;

- if a TB on the SL-BCH has been successfully decoded:

- deliver the decoded MAC PDU to upper layers.

## 5.17 Data inactivity monitoring

The MAC entity may be configured by RRC with a Data inactivity monitoring functionality, when in RRC\_CONNECTED. RRC controls Data inactivity operation by configuring the timer *DataInactivityTimer*.

When *DataInactivityTimer* is configured, the MAC entity shall:

- if the MAC entity receives the MAC SDU for DTCH logical channel , DCCH logical channel, or CCCH logical channel; or

- if the MAC entity transmits the MAC SDU for DTCH logical channel, DCCH logical channel;

- start or restart *DataInactivityTimer*.

- if *DataInactivityTimer* expires, indicate the expiry of *DataInactivityTimer* to upper layers.

## 5.18 Recommended Bit Rate

The recommended bit rate procedure is used to provide the MAC entity with information about the bit rate which the eNB recommends. The bit rate is the recommended bit rate of the physical layer. Averaging window of default value 2000 ms will apply, as specified in TS 26.114 [16].

The eNB may transmit the Recommended bit rate MAC control element to the MAC entity to indicate the recommended bit rate for the UE for a specific logical channel and a specific direction (either uplink or downlink). Upon reception of a Recommended bit rate MAC control element the MAC entity shall:

- indicate to upper layers the recommended bit rate for the indicated logical channel and direction

The MAC entity may request the eNB to indicate the recommended bit rate for a specific logical channel and a specific direction. If the MAC entity is requested by upper layers to query the eNB for the recommended bit rate for a logical channel and for a direction (i.e. for uplink or downlink), the MAC entity shall:

- if a Recommended bit rate query for this logical channel and this direction has not been triggered:

- trigger a Recommended bit rate query for this logical channel, direction, and desired bit rate.

If the MAC entity has UL resources allocated for new transmission for this TTI the MAC entity shall:

- for each Recommended bit rate query that the Recommended Bit Rate procedure determines has been triggered and not cancelled:

- if *bitRateQueryProhibitTimer* for the logical channel and the direction of this Recommended bit rate query is configured, and it is not running; and

- if the MAC entity has UL resources allocated for new transmission for this TTI and the allocated UL resources can accommodate a Recommended bit rate MAC control element plus its subheader as a result of logical channel prioritization:

- instruct the Multiplexing and Assembly procedure to generate the Recommended bit rate MAC control element for the logical channel and the direction of this Recommended bit rate query;

- start the *bitRateQueryProhibitTimer* for the logical channel and the direction of this Recommended bit rate query

- cancel this Recommended bit rate query.

## 5.19 Activation/Deactivation of CSI-RS resources

The network may activate and deactivate the configured CSI-RS resources of a serving cell by sending the Activation/Deactivation of CSI-RS resources MAC control element described in clause 6.1.3.14. The configured CSI-RS resources are initially deactivated upon configuration and after a handover.

The MAC entity shall for each TTI:

- if the MAC entity receives an Activation/Deactivation of CSI-RS resources MAC control element in this TTI on a serving cell, the MAC entity shall indicate to lower layers the information regarding the Activation/Deactivation of CSI-RS resources MAC control element:

## 5.20 Preallocated uplink grant

When the preallocated uplink grant is configured by RRC, the following information is provided in *ul-ConfigInfo*:

- Uplink Scheduling interval *ul-SchedInterval*, starting subframe *ul-StartSubframe* of the preallocated uplink grant, the uplink grant *ul-Grant* and the number of HARQ process for the preallocated uplink grant *numberOfConfUL-Processes*.

When the preallocated uplink grant configuration is released by RRC, the corresponding preallocated uplink grant shall be discarded.

NOTE 1: When eIMTA is configured for the SpCell, if a preallocated grant occurs in a subframe that can be reconfigured through eIMTA L1 signalling, then the UE behaviour is left unspecified.

If *ul-ConfigInfo* is configured, the MAC entity shall:

- consider sequentially that the Nth grant occurs in the subframe for which:

- subframe = [N \* *ul-SchedInterval* + *ul-StartSubframe*] modulo 10.

For TDD, the MAC entity is configured with *ul-SchedInterval* shorter than 10 subframes, the Nth grant shall be ignored if it occurs in a downlink subframe or a special subframe.

NOTE 2: Retransmissions for uplink transmissions using the preallocated uplink grant can continue after clearing the preallocated uplink grant.

## 5.21 SC-PTM Stop Indication

For NB-IoT UEs, BL UEs or UEs in enhanced coverage, the eNB may transmit the SC-PTM Stop Indication MAC control element to the MAC entity to indicate that the transmission of SC-MTCH associated with a G-RNTI is stopped as described in clause 6.1.3.12.

Upon reception of the SC-PTM Stop Indication MAC control element associated with a G-RNTI, the MAC entity shall:

- stop monitoring the PDCCH for this G-RNTI;

- indicate to upper layers that the associated MBMS session is stopped.

## 5.22 Entering Dormant SCell state

If the MAC entity is configured with one or more SCells, the network may transition configured SCells into Dormant State. Dormant State is not applicable for SpCell or PUCCH SCell. The network transitions SCell(s) in and out of Dormant State by sending Activation/Deactivation and/or Hibernation MAC control element as described in clause 6.1.3.8 and 6.1.3.15 respectively.

Furthermore, the MAC entity maintains two timers related to the dormant state:

- If configured, an *sCellHibernationTimer* timer per configured SCell (except the SCell configured with PUCCH, if any). Upon the timer expiry, the MAC entity hibernates the associated SCell if it is in activated state. The same initial timer value applies to each instance of the *sCellHibernationTimer* and it is configured by RRC.

- If configured, a *dormantSCellDeactivationTimer* per configured SCell (except the SCell configured with PUCCH, if any). Upon the timer expiry, the MAC entity deactivates the associated SCell if it is in dormant state. The same initial timer value applies to each instance of the *dormantSCellDeactivationTimer* and it is configured by RRC.

An SCell will be in Dormant SCell state upon SCell configuration in case the parameter *sCellState* is set to *dormant* for the SCell within RRC configuration. The configured SCG SCells are dormant after a SCG change in case the parameter *sCellState* is set to *dormant* for the SCell within RRC configuration.

The MAC entity shall for each TTI and for each configured SCell:

- if the MAC entity is configured with dormant SCell upon SCell configuration or receives MAC control element(s) in this TTI for transitioning the SCell into Dormant State:

- in the TTI according to the timing defined in TS 36.213 [2]:

- transition the SCell into Dormant State;

- stop the *sCellDeactivationTimer* associated with the SCell;

- if *sCellHibernationTimer* associated with the SCell is configured;

- stop the *sCellHibernationTimer* associated with the SCell;

- start or restart the *dormantSCellDeactivationTimer* associated with the SCell;

- clear any configured downlink assignments and uplink grants associated with the SCell;

- flush all HARQ buffers associated with the SCell.

- if the *sCellHibernationTimer* associated with the activated SCell expires in this TTI:

- in the TTI according to the timing defined in TS 36.213 [2]:

- hibernate the SCell;

- stop the *sCellDeactivationTimer* associated with the SCell;

- stop the *sCellHibernationTimer* associated with the SCell;

- start the *dormantSCellDeactivationTimer* associated with the SCell;

- clear any configured downlink assignments and uplink grants associated with the SCell;

- flush all HARQ buffers associated with the SCell.

- if the *dormantSCellDeactivationTimer* associated with the dormant SCell expires in this TTI:

- in the TTI according to the timing defined in TS 36.213 [2]:

- deactivate the SCell;

- stop the *dormantSCellDeactivationTimer* associated with the SCell;

- if the SCell is in Dormant State:

- not transmit SRS on the SCell;

- report CQI/PMI/RI/PTI/CRI for the SCell according to the periodicity indicated by *cqi-ReportPeriodic-SCell-r15*;

- not transmit on UL-SCH on the SCell;

- not transmit on RACH on the SCell;

- not monitor the PDCCH on the SCell;

- not monitor the PDCCH for the SCell;

- not transmit PUCCH on the SCell.

HARQ feedback for the MAC PDU containing Hibernation MAC control element shall not be impacted by PCell, PSCell and PUCCH SCell interruptions due to SCell activation/deactivation or hibernation (TS 36.133 [9]).

NOTE: When SCell is in Dormant State, any ongoing Random Access procedure on the SCell is aborted.

## 5.23 Autonomous Uplink

Autonomous uplink is supported on the SCells only. At most one autonomous uplink configuration is supported per SCell. Multiple autonomous uplink configurations can be activated and be active simultaneously when there is more than one SCell. Autonomous uplink and Uplink Semi-Persistent Scheduling cannot be active simultaneously on the same SCell.

When autonomous uplink is configured by RRC, the following information is provided in *AUL-Config* (TS 36.331 [8]):

- AUL C-RNTI;

- HARQ process IDs *aul-HARQ-Processes* that are configured for autonomous UL HARQ operation, the time period *aul-RetransmissionTimer* before triggering a new transmission or a retransmission of the same HARQ process using autonomous uplink;

- The bitmap *aul-Subframes* that indicates the subframes that are configured for autonomous UL HARQ operation.

When the autonomous uplink configuration is released by RRC, the corresponding configured grant shall be cleared.

If *AUL-Config* is configured, the MAC entity shall:

- consider that a configured uplink grant occurs in those subframes for which *aul-Subframes* is set to 1 (TS 36.331 [8]).

If AUL confirmation 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 an AUL confirmation MAC Control Element as defined in clause 6.1.3.16;

- cancel the triggered AUL confirmation.

The MAC entity shall clear the configured uplink grant for the SCell immediately after first transmission of AUL confirmation MAC Control Element triggered by the AUL release for this SCell.

NOTE: Retransmissions for uplink transmissions using autonomous uplink can continue after clearing the corresponding configured uplink grant.

## 5.24 Activation/Deactivation of PDCP duplication

If one or more DRBs are configured with PDCP duplication, the network may activate and deactivate the PDCP duplication for the configured DRB(s) by sending the PDCP Duplication Activation/Deactivation MAC CE described in clause 6.1.3.17. In addition, PDCP duplication for DRB(s) may be activated upon configuration by upper layers (TS 36.331 [8]).

Upon reception of a PDCP Duplication Activation/Deactivation MAC CE, the MAC entity shall for each DRB configured with duplication:

- if the MAC CE indicates that PDCP duplication for the DRB shall be activated:

- indicate the activation of PDCP duplication for the DRB to upper layers.

- if the MAC CE indicates that PDCP duplication for the DRB shall be deactivated:

- indicate the deactivation of PDCP duplication for the DRB to upper layers.

## 5.25 Transmission of Downlink Channel Quality Report

The MAC entity of a BL UE or UE in enhanced coverage may be configured by upper layers to report DL channel quality in Msg3. DL channel quality in Msg3 in RRC\_CONNECTED is not reported.

If the UE is a BL UE or UE in enhanced coverage or an 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";

- for BL UE or UE in enhanced coverage, transmission of DCQR in Msg3 is configured by upper layers in *mpdcch-CQI-Reporting*, in which case DCQR is referred below to as "Msg3 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 6.1.3.19;

- cancel the triggered "Regular DCQR".

If "Msg3 DCQR" has been triggered:

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

- if the allocated resources can accommodate a DCQR and AS RAI MAC control element plus its subheader as a result of logical channel prioritization:

- instruct the Multiplexing and Assembly procedure to generate a DCQR and AS RAI MAC control element as defined in clause 6.1.3.19;

- else if the uplink grant is not for EDT:

- if configured by upper layers in *mpdcch-CQI-Reporting*, use R and F2 fields in the MAC PDU subheader, to transmit the measurement outcome, as defined in clause 6.2.1;

- cancel the triggered "Msg3 DCQR".

## 5.26 Update of Differential Koffset

The network may provide and update the Differential Koffset of a Serving Cell in a non-terrestrial network by sending the Differential Koffset MAC CE described in clause 6.1.3.21.

The MAC entity shall:

- if the MAC entity receives a Differential Koffset MAC CE on a Serving Cell:

- indicate to lower layers the information regarding the Differential Koffset MAC CE.

## 5.xx GNSS measurement

The network may request a NB-IoT UE, a BL UE or a UE in enhanced coverage in a non-terrestrial network to perform GNSS measurement by sending the GNSS Measurement Command MAC CE described in clause 6.1.3.xx.

The MAC entity shall:

- if the MAC entity receives a GNSS Measurement Command MAC CE on a Serving Cell:

- indicate to upper layers to require the UE to perform GNSS measurement.

Editor’s note: UE can autonomously start GNSS measurement during the inactive state of C-DRX.

Editor’s note: The exact time of starting GNSS measurement during the inactive state of C-DRX can be left for UE implementation.

Next change

# 6 Protocol Data Units, formats and parameters

## 6.1 Protocol Data Units

### 6.1.1 General

A MAC PDU is a bit string that is byte aligned (i.e. multiple of 8 bits) in length. In the figures in clause 6.1, bit strings are represented by tables in which the most significant bit is the leftmost bit of the first line of the table, the least significant bit is the rightmost bit on the last line of the table, and more generally the bit string is to be read from left to right and then in the reading order of the lines. The bit order of each parameter field within a MAC PDU is represented with the first and most significant bit in the leftmost bit and the last and least significant bit in the rightmost bit.

MAC SDUs are bit strings that are byte aligned (i.e. multiple of 8 bits) in length. An SDU is included into a MAC PDU from the first bit onward.

The MAC entity shall ignore the value of Reserved bits in downlink MAC PDUs and in MAC PDUs received in sidelink.

### 6.1.2 MAC PDU (DL-SCH and UL-SCH except transparent MAC and Random Access Response, MCH)

A MAC PDU consists of a MAC header, zero or more MAC Service Data Units (MAC SDU), zero, or more MAC control elements, and optionally padding; as described in Figure 6.1.2-3.

Both the MAC header and the MAC SDUs are of variable sizes.

A MAC PDU header consists of one or more MAC PDU subheaders; each subheader corresponds to either a MAC SDU, a MAC control element or padding.

A MAC PDU subheader consists of the header fields R/F2/E/LCID/(R/R/eLCID)/(F)/(L). The L field is present in the MAC PDU subheader except for the last subheader in the MAC PDU and fixed sized MAC control elements. The last subheader in the MAC PDU and subheaders for fixed sized MAC control elements consist of the header fields R/F2/E/LCID/(R/R/eLCID). A MAC PDU subheader corresponding to padding consists of the four header fields R/F2/E/LCID.





Figure 6.1.2-1: R/F2/E/LCID/(R/R/eLCID)/F/L MAC subheader with 7-bits and 15-bits L field



Figure 6.1.2-1a: R/F2/E/LCID/(R/R/eLCID)/L MAC subheader with 16-bits L field



Figure 6.1.2-2: R/F2/E/LCID/(R/R/eLCID) MAC subheader

MAC PDU subheaders have the same order as the corresponding MAC SDUs, MAC control elements and padding.

MAC control elements are always placed before any MAC SDU.

Padding occurs at the end of the MAC PDU, except when single-byte or two-byte padding is required. Padding may have any value and the MAC entity shall ignore it. When padding is performed at the end of the MAC PDU, zero or more padding bytes are allowed.

When single-byte or two-byte padding is required, one or two MAC PDU subheaders corresponding to padding are placed at the beginning of the MAC PDU before any other MAC PDU subheader.

A maximum of one MAC PDU can be transmitted per TB per MAC entity. A maximum of one MCH MAC PDU can be transmitted per TTI.



Figure 6.1.2-3: Example of MAC PDU consisting of MAC header, MAC control elements, MAC SDUs and padding

### 6.1.3 MAC Control Elements

#### 6.1.3.1 Buffer Status Report MAC Control Elements

Buffer Status Report (BSR) MAC control elements consist of either:

- Short BSR and Truncated BSR format: one LCG ID field and one corresponding Buffer Size field (figure 6.1.3.1-1); or

- Long BSR format: four Buffer Size fields, corresponding to LCG IDs #0 through #3 (figure 6.1.3.1-2).

The BSR formats are identified by MAC PDU subheaders with LCIDs as specified in table 6.2.1-2.

The fields LCG ID and Buffer Size are defined as follow:

- LCG ID: The Logical Channel Group ID field identifies the group of logical channel(s) which buffer status is being reported. The length of the field is 2 bits. For NB-IoT, the LCG ID is set to #0.

- Buffer Size: The Buffer Size field identifies the total amount of data available across all logical channels of a logical channel group after all MAC PDUs for the TTI have been built. The amount of data is indicated in number of bytes. It shall include all data that is available for transmission in the RLC layer and in the PDCP layer; 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. The size of the RLC and MAC headers are not considered in the buffer size computation. The length of this field is 6 bits. If *extendedBSR-Sizes* is not configured, the values taken by the Buffer Size field are shown in Table 6.1.3.1-1. If *extendedBSR-Sizes* is configured, the values taken by the Buffer Size field are shown in Table 6.1.3.1-2.



Figure 6.1.3.1-1: Short BSR and Truncated BSR MAC control element



Figure 6.1.3.1-2: Long BSR MAC control element

Table 6.1.3.1-1: Buffer size levels for BSR

|  |  |  |  |
| --- | --- | --- | --- |
| **Index** | **Buffer Size (BS) value [bytes]** | **Index** | **Buffer Size (BS) value [bytes]** |
| 0 | BS = 0 | 32 | 1132 < BS <= 1326 |
| 1 | 0 < BS <= 10 | 33 | 1326 < BS <= 1552 |
| 2 | 10 < BS <= 12 | 34 | 1552 < BS <= 1817 |
| 3 | 12 < BS <= 14 | 35 | 1817 < BS <= 2127 |
| 4 | 14 < BS <= 17 | 36 | 2127 < BS <= 2490 |
| 5 | 17 < BS <= 19 | 37 | 2490 < BS <= 2915 |
| 6 | 19 < BS <= 22 | 38 | 2915 < BS <= 3413 |
| 7 | 22 < BS <= 26 | 39 | 3413 < BS <= 3995 |
| 8 | 26 < BS <= 31 | 40 | 3995 < BS <= 4677 |
| 9 | 31 < BS <= 36 | 41 | 4677 < BS <= 5476 |
| 10 | 36 < BS <= 42 | 42 | 5476 < BS <= 6411 |
| 11 | 42 < BS <= 49 | 43 | 6411 < BS <= 7505 |
| 12 | 49 < BS <= 57 | 44 | 7505 < BS <= 8787 |
| 13 | 57 < BS <= 67 | 45 | 8787 < BS <= 10287 |
| 14 | 67 < BS <= 78 | 46 | 10287 < BS <= 12043 |
| 15 | 78 < BS <= 91 | 47 | 12043 < BS <= 14099 |
| 16 | 91 < BS <= 107 | 48 | 14099 < BS <= 16507 |
| 17 | 107 < BS <= 125 | 49 | 16507 < BS <= 19325 |
| 18 | 125 < BS <= 146 | 50 | 19325 < BS <= 22624 |
| 19 | 146 < BS <= 171 | 51 | 22624 < BS <= 26487 |
| 20 | 171 < BS <= 200 | 52 | 26487 < BS <= 31009 |
| 21 | 200 < BS <= 234 | 53 | 31009 < BS <= 36304 |
| 22 | 234 < BS <= 274 | 54 | 36304 < BS <= 42502 |
| 23 | 274 < BS <= 321 | 55 | 42502 < BS <= 49759 |
| 24 | 321 < BS <= 376 | 56 | 49759 < BS <= 58255 |
| 25 | 376 < BS <= 440 | 57 | 58255 < BS <= 68201 |
| 26 | 440 < BS <= 515 | 58 | 68201 < BS <= 79846 |
| 27 | 515 < BS <= 603 | 59 | 79846 < BS <= 93479 |
| 28 | 603 < BS <= 706 | 60 | 93479 < BS <= 109439 |
| 29 | 706 < BS <= 826 | 61 | 109439 < BS <= 128125 |
| 30 | 826 < BS <= 967 | 62 | 128125 < BS <= 150000 |
| 31 | 967 < BS <=1132 | 63 | BS > 150000 |

Table 6.1.3.1-2: Extended Buffer size levels for BSR

|  |  |  |  |
| --- | --- | --- | --- |
| **Index** | **Buffer Size (BS) value [bytes]** | **Index** | **Buffer Size (BS) value [bytes]** |
| 0 | BS = 0 | 32 | 4940 < BS <= 6074 |
| 1 | 0 < BS <= 10 | 33 | 6074 < BS <= 7469 |
| 2 | 10 < BS <= 13 | 34 | 7469 < BS <= 9185 |
| 3 | 13 < BS <= 16 | 35 | 9185 < BS <= 11294 |
| 4 | 16 < BS <= 19 | 36 | 11294 < BS <= 13888 |
| 5 | 19 < BS <= 23 | 37 | 13888 < BS <= 17077 |
| 6 | 23 < BS <= 29 | 38 | 17077 < BS <= 20999 |
| 7 | 29 < BS <= 35 | 39 | 20999 < BS <= 25822 |
| 8 | 35 < BS <= 43 | 40 | 25822 < BS <= 31752 |
| 9 | 43 < BS <= 53 | 41 | 31752 < BS <= 39045 |
| 10 | 53 < BS <= 65 | 42 | 39045 < BS <= 48012 |
| 11 | 65 < BS <= 80 | 43 | 48012 < BS <= 59039 |
| 12 | 80 < BS <= 98 | 44 | 59039 < BS <= 72598 |
| 13 | 98 < BS <= 120 | 45 | 72598 < BS <= 89272 |
| 14 | 120 < BS <= 147 | 46 | 89272 < BS <= 109774 |
| 15 | 147 < BS <= 181 | 47 | 109774 < BS <= 134986 |
| 16 | 181 < BS <= 223 | 48 | 134986 < BS <= 165989 |
| 17 | 223 < BS <= 274 | 49 | 165989 < BS <= 204111 |
| 18 | 274 < BS <= 337 | 50 | 204111 < BS <= 250990 |
| 19 | 337 < BS <= 414 | 51 | 250990 < BS <= 308634 |
| 20 | 414 < BS <= 509 | 52 | 308634 < BS <= 379519 |
| 21 | 509 < BS <= 625 | 53 | 379519 < BS <= 466683 |
| 22 | 625 < BS <= 769 | 54 | 466683 < BS <= 573866 |
| 23 | 769 < BS <= 945 | 55 | 573866 < BS <= 705666 |
| 24 | 945 < BS <= 1162 | 56 | 705666 < BS <= 867737 |
| 25 | 1162 < BS <= 1429 | 57 | 867737 < BS <= 1067031 |
| 26 | 1429 < BS <= 1757 | 58 | 1067031 < BS <= 1312097 |
| 27 | 1757 < BS <= 2161 | 59 | 1312097 < BS <= 1613447 |
| 28 | 2161 < BS <= 2657 | 60 | 1613447 < BS <= 1984009 |
| 29 | 2657 < BS <= 3267 | 61 | 1984009 < BS <= 2439678 |
| 30 | 3267 < BS <= 4017 | 62 | 2439678 < BS <= 3000000 |
| 31 | 4017 < BS <=4940 | 63 | BS > 3000000 |

#### 6.1.3.1a Sidelink BSR MAC Control Elements

Sidelink BSR and Truncated Sidelink BSR MAC control elements consist of one Destination Index field, one LCG ID field and one corresponding Buffer Size field per reported target group.

The Sidelink BSR MAC control elements are identified by MAC PDU subheaders with LCIDs as specified in table 6.2.1-2. They have variable sizes.

For each included group, the fields are defined as follows (figures 6.1.3.1a-1 and 6.1.3.1a-2):

- Destination Index: The Destination Index field identifies the ProSe Destination or the destination for V2X sidelink communication. The length of this field is 4 bits. The value is set to the index of the destination reported in *destinationInfoList* for sidelink communication or is set to one index among index(es) associated to same destination reported in *v2x-DestinationInfoList* for V2X sidelink communication. If multiple such lists are reported, the value is indexed sequentially across all the lists in the same order as specified in TS 36.331 [8];

- LCG ID: The Logical Channel Group ID field identifies the group of logical channel(s) which buffer status is being reported. The length of the field is 2 bits;

- Buffer Size: The Buffer Size field identifies the total amount of data available across all logical channels of a LCG of a ProSe Destination after all MAC PDUs for the TTI have been built. The amount of data is indicated in number of bytes. It shall include all data that is available for transmission in the RLC layer and in the PDCP layer; the definition of what data shall be considered as available for transmission is specified in TS 36.322 [3] and TS 36.323 [4] respectively. The size of the RLC and MAC headers are not considered in the buffer size computation. The length of this field is 6 bits. The values taken by the Buffer Size field are shown in Table 6.1.3.1-1;

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

Buffer Sizes of LCGs are included in decreasing order of the highest priority of the sidelink logical channel belonging to the LCG irrespective of the value of the Destination Index field.



Figure 6.1.3.1a-1: Sidelink BSR and Truncated Sidelink BSR MAC control element for even N



Figure 6.1.3.1a-2: Sidelink BSR and Truncated Sidelink BSR MAC control element for odd N

#### 6.1.3.2 C-RNTI MAC Control Element

The C-RNTI MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-2.

It has a fixed size and consists of a single field defined as follows (figure 6.1.3.2-1):

- C-RNTI: This field contains the C-RNTI of the MAC entity. The length of the field is 16 bits.



Figure 6.1.3.2-1: C-RNTI MAC control element

#### 6.1.3.3 DRX Command MAC Control Element

The DRX 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.

#### 6.1.3.4 UE Contention Resolution Identity MAC Control Element

The UE Contention Resolution Identity MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1. This control element has a fixed 48-bit size and consists of a single field defined as follows (figure 6.1.3.4-1)

- UE Contention Resolution Identity: If this MAC control element is included in response to an uplink CCCH transmission, then this field contains the uplink CCCH SDU if the uplink CCCH SDU is 48 bits long. If the CCCH SDU is longer than 48 bits, this field contains the first 48 bits of the uplink CCCH SDU. If this MAC control element is included in response to an uplink DCCH transmission (i.e. the MAC entity is configured with *rach-Skip* or *rach-SkipSCG*), then the MAC entity shall ignore the contents of this field.



Figure 6.1.3.4-1: UE Contention Resolution Identity MAC control element

#### 6.1.3.5 Timing Advance Command MAC Control Element

The Timing Advance Command MAC control element is identified by MAC PDU subheader with LCID as specified in table 6.2.1-1.

It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.5-1):

- TAG Identity (TAG Id): This field indicates the TAG Identity of the addressed TAG. The TAG containing the SpCell has the TAG Identity 0. The length of the field is 2 bits;

- Timing Advance Command: This field indicates the index value *TA* (0, 1, 2… 63) used to control the amount of timing adjustment that MAC entity has to apply (see clause 4.2.3 of TS 36.213 [2]). The length of the field is 6 bits.



Figure 6.1.3.5-1: Timing Advance Command MAC control element

#### 6.1.3.6 Power Headroom Report MAC Control Element

The Power Headroom Report (PHR) MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a fixed size and consists of a single octet defined as follows (figure 6.1.3.6-1):

- R: reserved bit, set to "0";

- Power Headroom (PH): this field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.6-1 below (the corresponding measured values in dB can be found in clause 9.1.8.4 of TS 36.133 [9]).



Figure 6.1.3.6-1: PHR MAC control element

Table 6.1.3.6-1: Power Headroom levels for PHR

|  |  |
| --- | --- |
| PH | Power Headroom Level |
| 0 | POWER\_HEADROOM\_0 |
| 1 | POWER\_HEADROOM\_1 |
| 2 | POWER\_HEADROOM\_2 |
| 3 | POWER\_HEADROOM\_3 |
| … | … |
| 60 | POWER\_HEADROOM\_60 |
| 61 | POWER\_HEADROOM\_61 |
| 62 | POWER\_HEADROOM\_62 |
| 63 | POWER\_HEADROOM\_63 |

#### 6.1.3.6a Extended Power Headroom Report MAC Control Elements

For *extendedPHR*, the Extended Power Headroom Report (PHR) MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a variable size and is defined in Figure 6.1.3.6a-2. When Type 2 PH is reported, the octet containing the Type 2 PH field is included first after the octet indicating the presence of PH per SCell and followed by an octet containing the associated PCMAX,c field (if reported). Then follows an octet with the Type 1 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. If *SRS-ConfigAdd-r16* is configured for the PCell then follows an octet with the Type 3 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. And then follows in ascending order based on the *ServCellIndex*, as specified in TS 36.331 [8] an octet with the Type x PH field, wherein x is equal to 3 when the *ul-Configuration-r14* or *SRS-ConfigAdd-r16* is configured for this SCell, x is equal to 1 otherwise, and an octet with the associated PCMAX,c field (if reported), for each SCell indicated in the bitmap.

For *extendedPHR2*, the Extended Power Headroom Report (PHR) MAC control elements are identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. They have variable sizes and are defined in Figure 6.1.3.6a1-3, Figure 6.1.3.6a2-4 and Figure 6.1.3.6a3-5. One octet with C fields is used for indicating the presence of PH per SCell when the highest *SCellIndex* of SCell with configured uplink is less than 8, otherwise four octets are used. When Type 2 PH is reported for the PCell, the octet containing the Type 2 PH field is included first after the octet(s) indicating the presence of PH per SCell and followed by an octet containing the associated PCMAX,c field (if reported). Then follows the Type 2 PH field for the PUCCH SCell (if PUCCH on SCell is configured and Type 2 PH is reported for the PUCCH SCell), followed by an octet containing the associated PCMAX,c field (if reported). Then follows an octet with the Type 1 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. If *SRS-ConfigAdd-r16* is configured for the PCell then follows an octet with the Type 3 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. Then follows in ascending order based on the *ServCellIndex*, as specified in TS 36.331 [8] an octet with the Type x PH field, wherein, x is equal to 3 when the *ul-Configuration-r14* or *SRS-ConfigAdd-r16* is configured for this SCell, x is equal to 1 otherwise, and an octet with the associated PCMAX,c field (if reported), for each SCell indicated in the bitmap.

The Extended PHR MAC Control Elements are defined as follows:

- Ci: this field indicates the presence of a PH field for the SCell with *SCellIndex* i as specified in TS 36.331 [8]. The Ci field set to "1" indicates that a PH field for the SCell with *SCellIndex* i is reported. The Ci field set to "0" indicates that a PH field for the SCell with *SCellIndex* i is not reported;

- R: reserved bit, set to "0";

- V: this field indicates if the PH value is based on a real transmission or a reference format. For Type 1 PH, V=0 indicates real transmission on PUSCH and V=1 indicates that a PUSCH reference format is used. For Type 2 PH, V=0 indicates real transmission on PUCCH/SPUCCH and V=1 indicates that a PUCCH/SPUCCH reference format is used. For Type 3 PH, V=0 indicates real transmission on SRS and V=1 indicates that an SRS reference format is used. Furthermore, for Type 1, Type 2 and Type 3 PH, V=0 indicates the presence of the octet containing the associated PCMAX,c field, and V=1 indicates that the octet containing the associated PCMAX,c field is omitted;

- Power Headroom (PH): this field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.6-1 (the corresponding measured values in dB can be found in clause 9.1.8.4 of TS 36.133 [9]);

- P: this field indicates whether the MAC entity applies power backoff due to power management (as allowed by P-MPRc, see TS 36.101 [10]). The MAC entity shall set P=1 if the corresponding PCMAX,c field would have had a different value if no power backoff due to power management had been applied;

- PCMAX,c: if present, this field indicates the PCMAX,c or , as specified in TS 36.213 [2] used for calculation of the preceding PH field. The reported PCMAX,c and the corresponding nominal UE transmit power levels are shown in Table 6.1.3.6a-1 (the corresponding measured values in dBm can be found in clause 9.6.1 of TS 36.133 [9]).

Figure 6.1.3.6a-1: Void



Figure 6.1.3.6a-2: Extended PHR MAC Control Element



Figure 6.1.3.6a1-3: Extended PHR MAC Control Element supporting PUCCH on SCell



Figure 6.1.3.6a2-4: Extended PHR MAC Control Element supporting 32 serving cells with configured uplink



Figure 6.1.3.6a3-5: Extended PHR MAC Control Element supporting 32 serving cells with configured uplink and PUCCH on SCell

Table 6.1.3.6a-1: Nominal UE transmit power level for Extended PHR and for Dual Connectivity PHR

|  |  |
| --- | --- |
| PCMAX,c | Nominal UE transmit power level |
| 0 | PCMAX\_C\_00 |
| 1 | PCMAX\_C\_01 |
| 2 | PCMAX\_C\_02 |
| … | … |
| 61 | PCMAX\_C\_61 |
| 62 | PCMAX\_C\_62 |
| 63 | PCMAX\_C\_63 |

#### 6.1.3.6b Dual Connectivity Power Headroom Report MAC Control Element

The Dual Connectivity Power Headroom Report (PHR) MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a variable size and is defined in Figure 6.1.3.6b-1 and Figure 6.1.3.6b-2. One octet with Ci fields is used for indicating the presence of PH per serving cell other than PCell, when the highest *SCellIndex* of SCell with configured uplink is less than 8, otherwise four octets are used. In case EN-DC, NE-DC or NGEN-DC is configured, four octets with Ci fields is always used. When Type 2 PH is reported for the PCell, the octet containing the Type 2 PH field is included first after the octet(s) indicating the presence of PH per cell (PSCell and all SCells of all MAC entities) and followed by an octet containing the associated PCMAX,c field (if reported). Then after that, when Type 2 PH is reported for the PSCell, the octet containing the Type 2 PH field is included followed by an octet containing the associated PCMAX,c field (if reported). Then follows an octet with the Type 1 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. If *SRS-ConfigAdd-r16* is configured for the PCell then follows an octet with the Type 3 PH field and an octet with the associated PCMAX,c field (if reported), for the PCell. And then follows in ascending order based on the *ServCellIndex*, as specified in TS 36.331 [8], an octet with the Type x PH field, wherein x is either 1 or 3 according to TS 36.213 [2] and TS 38.213 [18] and an octet with the associated PCMAX,c field (if reported), for all serving cells of all MAC entities indicated in the bitmap. In case of EN-DC and NGEN-DC, for serving cells in the other MAC entity in which the UE does not support dynamic power sharing or dynamic power sharing is not applicable (clause 4.2.7.9, TS 38.306 [22]), the UE may omit the octets containing Power Headroom field and PCMAX,c field for those serving cells. In case of NE-DC, for serving cells in the other MAC entity in which the UE does not support dynamic power sharing or dynamic power sharing is not applicable, the UE may omit the octets containing Power Headroom field and PCMAX,f,c field for those serving cells except for the PCell in the other MAC entity and the reported values of Power Headroom and PCMAX,f,c for the PCell are up to UE implementation.

The Dual Connectivity PHR MAC Control Element is defined as follows:

- Ci: this field indicates the presence of a PH field for the serving cell of any MAC entity, except the PCell, with *ServCellIndex* (for EN-DC, NE-DC or NGEN-DC case) or *SCellIndex* i as specified in TS 36.331 [8]. The Ci field set to "1" indicates that a PH field for the serving cell with *ServCellIndex* (for EN-DC, NE-DC or NGEN-DC case) or *SCellIndex* i is reported. The Ci field set to "0" indicates that a PH field for the serving cell with *ServCellIndex* (for EN-DC, NE-DC or NGEN-DC case) or *SCellIndex* i is not reported;

- R: reserved bit, set to "0";

- V: this field indicates if the PH value is based on a real transmission or a reference format. For Type 1 PH, V=0 indicates real transmission on PUSCH and V=1 indicates that a PUSCH reference format is used. For Type 2 PH, V=0 indicates real transmission on PUCCH and V=1 indicates that a PUCCH reference format is used. For Type 3 PH, V=0 indicates real transmission on SRS and V=1 indicates that an SRS reference format is used. Furthermore, for Type 1 ,Type 2 and Type 3 PH, V=0 indicates the presence of the octet containing the associated PCMAX,c field, and V=1 indicates that the octet containing the associated PCMAX,c field is omitted. Whether the reported PH value for an activated NR Serving Cell is based on real transmission or a reference format is determined based on UL transmissions that have been scheduled or configured until 4 ms prior to the TTI in which this PHR MAC CE is transmitted;

- Power Headroom (PH): this field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.6-1 (the corresponding measured values in dB for the E-UTRA Serving Cell are specified in clause 9.1.8.4 of TS 36.133 [9] while the corresponding measured values in dB for the NR Serving Cell are specified in TS 38.133 [19]);

- P: this field indicates whether power backoff due to power management is applied (as allowed by P-MPRc, see TS 36.101 [10] and TS 38.101-3 [21]). The MAC entity shall set P=1 if the corresponding PCMAX,c field would have had a different value if no power backoff due to power management had been applied;

- PCMAX,c: if present, this field indicates the PCMAX,c or , as specified in TS 36.213 [2] for the E-UTRA Serving Cell and the PCMAX,f,c or P̃CMAX,f,c, as specified in TS 38.213 [18]) for the NR Serving Cell used for calculation of the preceding PH field. The reported PCMAX,c and the corresponding nominal UE transmit power levels are shown in Table 6.1.3.6a-1 (the corresponding measured values in dBm for the E-UTRA Serving Cell can be found in TS 36.133 [9] while the corresponding measured values in dBm for the NR Serving Cell can be found in TS 38.133 [19]).



Figure 6.1.3.6b-1: Dual Connectivity PHR MAC Control Element



Figure 6.1.3.6b-2: Dual Connectivity PHR MAC Control Element supporting 32 serving cells with configured uplink

#### 6.1.3.7 MCH Scheduling Information MAC Control Element

The MCH Scheduling Information MAC Control Element illustrated in Figure 6.1.3.7-1 is identified by a MAC PDU subheader with LCID as specified in Table 6.2.1-4. This control element has a variable size. For each MTCH the fields below are included:

- LCID: this field indicates the Logical Channel ID of the MTCH. The length of the field is 5 bits;

- Stop MTCH: this field indicates the ordinal number of the subframe within the MCH scheduling period, counting only the subframes allocated to the MCH, where the corresponding MTCH stops. Value 0 corresponds to the first subframe. The length of the field is 11 bits. The special Stop MTCH value 2047 indicates that the corresponding MTCH is not scheduled. The value range 2043 to 2046 is reserved.



Figure 6.1.3.7-1: MCH Scheduling Information MAC control element

#### 6.1.3.7a Extended MCH Scheduling Information MAC Control Element

The Extended MCH Scheduling Information MAC control element illustrated in Figure 6.1.3.7-2 is identified by a MAC PDU subheader with LCID as specified in Table 6.2.1-4. This control element has a variable size.

For each MTCH the fields below are included:

- LCID: this field indicates the Logical Channel ID of the MTCH. The length of the field is 5 bits;

- Stop MTCH: this field indicates the ordinal number of the subframe within the MCH scheduling period, counting only the subframes allocated to the MCH, where the corresponding MTCH stops. Value 0 corresponds to the first subframe. The length of the field is 11 bits. The special Stop MTCH value 2047 indicates that the corresponding MTCH is not scheduled. The value range 2043 to 2046 is reserved.

For each MTCH the fields below may be included:

- LCID: this field indicates the Logical Channel ID of the MTCH. The length of the field is 5 bits. LCIDs x…x+y shall be equal to or a subset of the LCIDs 1…n;

- S: this field indicates that the transmission of the corresponding MTCH is to be suspended. The S field is set to 000. All other values are reserved.



Figure 6.1.3.7a-1: Extended MCH Scheduling Information MAC control element

#### 6.1.3.8 Activation/Deactivation MAC Control Elements

The Activation/Deactivation MAC control element of one octet is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a single octet containing seven C-fields and one R-field. The Activation/Deactivation MAC control element with one octet is defined as follows (figure 6.1.3.8-1).

The Activation/Deactivation MAC control element of four octets is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a four octets containing 31 C-fields and one R-field. The Activation/Deactivation MAC control element of four octets is defined as follows (figure 6.1.3.8-2).

For the case with no serving cell with a *ServCellIndex*, as specified in TS 36.331 [8] larger than 7, Activation/Deactivation MAC control element of one octet is applied, otherwise Activation/Deactivation MAC control element of four octets is applied.

For the case that Activation/Deactivation MAC control element is received and Hibernation MAC control element is not received:

- Ci: if there is an SCell configured with *SCellIndex* i as specified in TS 36.331 [8], this field indicates the activation/deactivation status of the SCell with *SCellIndex* i, else the MAC entity shall ignore the Ci field. When the Ci field is set to "1", SCell with *SCellIndex* i shall be activated if it is in already activated state or deactivated state, otherwise the Ci field set to "1" shall be ignored. The Ci field is set to "0" to indicate that the SCell with *SCellIndex* i shall be deactivated;

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

For the case that both Activation/Deactivation MAC control element and Hibernation MAC control element are received, see clause 6.1.3.15.



Figure 6.1.3.8-1: Activation/Deactivation MAC control element of one octet



Figure 6.1.3.8-2: Activation/Deactivation MAC control element of four octets

#### 6.1.3.9 Long DRX Command MAC Control Element

The Long DRX 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.

#### 6.1.3.10 Data Volume and Power Headroom Report MAC Control Element

The Data Volume and Power Headroom Report (DPR) MAC control element is identified by the MAC PDU subheader used for the CCCH MAC SDU, as specified in table 6.2.1-2. It does not add any additional subheader and is always placed before the CCCH MAC SDU. DPR MAC control element is not included in the calculation of the L field in the MAC PDU subheader for the CCCH MAC SDU.

It has a fixed size and consists of a single octet defined as follows (figures 6.1.3.10-1 and 6.1.3.10-1a):

- Data Volume (DV): The Data Volume field identifies the total amount of data available across all logical channels and of data not yet associated with a logical channel after all MAC PDUs for the TTI have been built. The amount of data is indicated in number of bytes. It shall include all data that is available for transmission in the RLC layer, in the PDCP layer, and in the RRC layer; the definition of what data shall be considered as available for transmission is specified in TS 36.322 [3], TS 36.323 [4] and TS 36.331 [8] respectively. The size of the RLC and MAC headers are not considered in the buffer size computation. The length of this field is 4 bits. The values taken by the Data Volume field are shown in Table 6.1.3.10-1;

- Power Headroom (PH): This field indicates the power headroom level. The length of the field is 2 bits or 4 bits. The reported PH and the corresponding power headroom and extended power headroom levels are shown in Table 6.1.3.10-2 and Table 6.1.3.10-2a, respectively, below (the corresponding measured values in dB can be found in TS 36.133 [9]);

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



Figure 6.1.3.10-1: Data Volume and Power Headroom Report MAC control element



Figure 6.1.3.10-1a: Data Volume and Power Headroom Report MAC control element for Extended Power Headroom level reporting

Table 6.1.3.10-1: Data Volume levels for DV

|  |  |  |  |
| --- | --- | --- | --- |
| **Index** | **Data Volume (DV) value [bytes]** | **Index** | **Data Volume (DV) value [bytes]** |
| 0 | DV = 0 | 8 | 67 < DV <= 91 |
| 1 | 0 < DV <= 10 | 9 | 91 < DV <= 125 |
| 2 | 10 < DV <= 14 | 10 | 125 < DV <= 171 |
| 3 | 14 < DV <= 19 | 11 | 171 < DV <= 234 |
| 4 | 19 < DV <= 26 | 12 | 234 < DV <= 321 |
| 5 | 26 < DV <= 36 | 13 | 321 < DV <= 768 |
| 6 | 36 < DV <= 49 | 14 | 768 < DV <= 1500 |
| 7 | 49 < DV <= 67 | 15 | DV > 1500 |

Table 6.1.3.10-2: Power Headroom levels for PH

|  |  |
| --- | --- |
| PH | Power Headroom Level |
| 0 | POWER\_HEADROOM\_0 |
| 1 | POWER\_HEADROOM\_1 |
| 2 | POWER\_HEADROOM\_2 |
| 3 | POWER\_HEADROOM\_3 |

Table 6.1.3.10-2a: Extended Power Headroom levels for PH

|  |  |
| --- | --- |
| PH | Extended Power Headroom Level |
| 0 | EXTENDED\_POWER\_HEADROOM\_0 |
| 1 | EXTENDED\_POWER\_HEADROOM\_1 |
| 2 | EXTENDED\_POWER\_HEADROOM\_2 |
| 3 | EXTENDED\_POWER\_HEADROOM\_3 |
| 4 | EXTENDED\_POWER\_HEADROOM\_4 |
| 5 | EXTENDED\_POWER\_HEADROOM\_5 |
| 6 | EXTENDED\_POWER\_HEADROOM\_6 |
| 7 | EXTENDED\_POWER\_HEADROOM\_7 |
| 8 | EXTENDED\_POWER\_HEADROOM\_8 |
| 9 | EXTENDED\_POWER\_HEADROOM\_9 |
| 10 | EXTENDED\_POWER\_HEADROOM\_10 |
| 11 | EXTENDED\_POWER\_HEADROOM\_11 |
| 12 | EXTENDED\_POWER\_HEADROOM\_12 |
| 13 | EXTENDED\_POWER\_HEADROOM\_13 |
| 14 | EXTENDED\_POWER\_HEADROOM\_14 |
| 15 | EXTENDED\_POWER\_HEADROOM\_15 |

#### 6.1.3.11 SPS confirmation MAC Control Element

The SPS confirmation MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2.

It has a fixed size of zero bits.

#### 6.1.3.12 SC-PTM Stop Indication MAC Control Element

The SC-PTM Stop Indication MAC control element is applicable to NB-IoT UEs and BL UEs or UEs in enhanced coverage and indicates that the SC-MTCH transmission for a specific G-RNTI is stopped. It 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.

#### 6.1.3.13 Recommended bit rate MAC Control Element

The recommended bit rate MAC control element is identified by a MAC PDU subheader with LCID as specified in tables 6.2.1-1 and 6.2.1-2 for bit rate recommendation message from the eNB to the UE and bit rate recommendation query message from the UE to the eNB, respectively. It has a fixed size and consists of two octets defined as follows (figure 6.1.3.13-1):

- LCID: This field indicates the identity of the logical channel (as described in Table 6.1.3.13-2) for which the recommended bit rate or the recommended bit rate query is applicable. The length of the field is 4 bits;

- Uplink/Downlink (UL/DL): This field indicates whether the recommended bit rate or the recommended bit rate query applies to uplink or downlink. The length of the field is 1 bit. The UL/DL field set to "0" indicates downlink. The UL/DL field set to "1" indicates uplink;

- Bit Rate: This field indicates an index to Table 6.1.3.13-1. The length of the field is 6 bits. For bit rate recommendation the value indicates the recommended bit rate. For bit rate recommendation query the value indicates the desired bit rate;

- X: Bit rate multiplier. For UEs supporting recommended bit rate multiplier, when *bitRateMultiplier* is configured for the logical channel indicated by LCID field, X field set to "1" indicates the actual value of bit rate is the value corresponding to the index indicated by the Bit Rate field multiplied by *bitRateMultiplier* as specified in TS 36.331 [8];

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



Figure 6.1.3.13-1: Recommended bit rate MAC control element

Table 6.1.3.13-1: Values (kbit/s) for Bit Rate field

|  |  |  |  |
| --- | --- | --- | --- |
| Index | Recommended Bit Rate value [kbit/s] | Index | Recommended Bit Rate value [kbit/s] |
| 0 | Note 1 | 32 | 700 |
| 1 | 0 | 33 | 800 |
| 2 | 8 | 34 | 900 |
| 3 | 10 | 35 | 1000 |
| 4 | 12 | 36 | 1100 |
| 5 | 16 | 37 | 1200 |
| 6 | 20 | 38 | 1300 |
| 7 | 24 | 39 | 1400 |
| 8 | 28 | 40 | 1500 |
| 9 | 32 | 41 | 1750 |
| 10 | 36 | 42 | 2000 |
| 11 | 40 | 43 | 2250 |
| 12 | 48 | 44 | 2500 |
| 13 | 56 | 45 | 2750 |
| 14 | 72 | 46 | 3000 |
| 15 | 88 | 47 | 3500 |
| 16 | 104 | 48 | 4000 |
| 17 | 120 | 49 | 4500 |
| 18 | 140 | 50 | 5000 |
| 19 | 160 | 51 | 5500 |
| 20 | 180 | 52 | 6000 |
| 21 | 200 | 53 | 6500 |
| 22 | 220 | 54 | 7000 |
| 23 | 240 | 55 | 7500 |
| 24 | 260 | 56 | 8000 |
| 25 | 280 | 57 | Reserved |
| 26 | 300 | 58 | Reserved |
| 27 | 350 | 59 | Reserved |
| 28 | 400 | 60 | Reserved |
| 29 | 450 | 61 | Reserved |
| 30 | 500 | 62 | Reserved |
| 31 | 600 | 63 | Reserved |
| Note1: For bit rate recommendation message this index is used for indicating that no recommendation on bit rate is given. | | | |

Table 6.1.3.13-2: Values of identity of the logical channel for LCID field

|  |  |
| --- | --- |
| Codepoint/Index | Identity of the logical channel (i.e. *logicalChannelIdentity* as specified in TS 36.331 [8]) |
| 0000 | Reserved |
| 0001 | 32 |
| 0010 | 33 |
| 0011-1010 | 3-10 |
| 1011 | 34 |
| 1100 | 35 |
| 1101 | 36 |
| 1110 | 37 |
| 1111 | 38 |

#### 6.1.3.14 Activation/Deactivation of CSI-RS resources MAC Control Element

The Activation/Deactivation of CSI-RS resources MAC control element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has variable size as the number of CSI process configured with *csi-RS-NZP-Activation* by RRC, see TS 36.331 [8], (N) and the N number of octets with A fields are included in ascending order of CSI process ID, i.e., *CSI-ProcessId*, as defined in Figure 6.1.3.14-1. Activation/Deactivation CSI-RS command is defined in Figure 6.1.3.14-2 and activates or deactivates CSI-RS resources for a CSI process. For a UE configured with transmission mode 9, N equals 1. Activation/Deactivation of CSI-RS resources MAC control element applies to the serving cell on which the UE receives the Activation/Deactivation of CSI-RS resources MAC control element.

The Activation/Deactivation of CSI-RS resources MAC control elements is defined as follows:

- Ai: this field indicates the activation/deactivation status of the CSI-RS resources configured by upper layers for the CSI process. A1 corresponds to the 1st entry in the list of CSI-RS specified by *csi-RS-ConfigNZP-ApList* as configured by upper layers, A2 corresponds to the 2nd entry in this list and so on. The Ai field is set to "1" to indicate that ith entry in the list of CSI-RS specified by *csi-RS-ConfigNZP-ApList* shall be activated. The Ai field is set to "0" to indicate that ith entry in the list shall be deactivated. For each CSI process, the number of Ai fields (i=1, 2,…, 8) which are set to "1" shall be equal to the value of the higher-layer parameter *activatedResources* in TS 36.331 [8].



Figure 6.1.3.14-1: Activation/Deactivation of CSI-RS resources MAC Control Element



Figure 6.1.3.14-2: Activation/Deactivation CSI-RS command

#### 6.1.3.15 Hibernation MAC Control Elements

The Hibernation MAC control element of one octet is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a single octet containing seven C-fields and one R-field. The Hibernation MAC control element with one octet is defined as follows (figure 6.1.3.15-1).

The Hibernation MAC control element of four octets is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a four octets containing 31 C-fields and one R-field. The Hibernation MAC control element of four octets is defined as follows (figure 6.1.3.15-2).

For the case with no serving cell with a *ServCellIndex* (TS 36.331 [8]) larger than 7, Hibernation MAC control element of one octet is applied, otherwise Hibernation MAC control element of four octets is applied.

For the case that Hibernation MAC control element is received and Activation/Deactivation MAC control element is not received:

- Ci: if there is an SCell configured with *SCellIndex* i as specified in TS 36.331 [8], this field indicates the dormant/activated status of the SCell with *SCellIndex* i, else the MAC entity shall ignore the Ci field.The Ci field is set to "1" to indicate that the SCell with *SCellIndex i* shall enter dormant state. When the Ci field is set to "0", the SCell with *SCellIndex i* shall be activated if it is in already activated state or dormant state, otherwise the Ci field set to "0" shall be ignored.

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

For the case that both Activation/Deactivation MAC control element and Hibernation MAC control element are received:

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

- Ci: if there is an SCell configured with *SCellIndex* i as specified in TS 36.331 [8], these fields indicate possible state transitions of the SCell with *SCellIndex* i, else the MAC entity shall ignore the Ci fields. The Ci fields of the two MAC control elements are interpreted according to Table 6.1.3.15-1.



Figure 6.1.3.15-1: Hibernation MAC control element of one octet



Figure 6.1.3.15-2: Hibernation MAC control element of four octets

Table 6.1.3.15-1: MAC control elements for SCell state transitions

|  |  |  |
| --- | --- | --- |
| Hibernation MAC control element Ci | Activation/Deactivation MAC control element Ci | SCell shall be |
| 0 | 0 | Deactivated |
| 0 | 1 | Activated |
| 1 | 0 | Reserved MAC control element combination |
| 1 | 1 | Dormant |

#### 6.1.3.16 AUL confirmation MAC Control Element

The AUL confirmation MAC control element of one octet is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a fixed size and consists of a single octet containing seven C-fields and one R-field. The AUL confirmation MAC control element with one octet is defined as follows (figure 6.1.3.16-1).

The AUL confirmation MAC control element of four octets is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a fixed size and consists of a four octets containing 31 C-fields and one R-field. The AUL confirmation MAC control element of four octets is defined as follows (figure 6.1.3.16-2).

For the case with no serving cell with a *ServCellIndex* (TS 36.331 [8]) larger than 7, AUL confirmation MAC control element of one octet is applied, otherwise AUL confirmation MAC control element of four octets is applied.

- Ci: if there is an SCell configured with *SCellIndex* i as specified in TS 36.331 [8], this field indicates whether a PDCCH containing AUL activation or AUL release of the autonomous uplink configuration in the SCell with *SCellIndex* i has been received, else the MAC entity shall ignore the Ci field. The Ci field is set to "1" to indicate that a PDCCH containing AUL activation or AUL release of the autonomous uplink configuration in the SCell with *SCellIndex* i has been received in the TTI in which AUL confirmation has been triggered. The Ci field is set to "0" to indicate that a PDCCH containing AUL activation or AUL release of the autonomous uplink configuration in the SCell with *SCellIndex* i has not been received in the TTI in which AUL confirmation has been triggered;

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



Figure 6.1.3.16-1: AUL confirmation MAC Control Element of one octet



Figure 6.1.3.16-2: AUL confirmation MAC Control Element of four octets

#### 6.1.3.17 PDCP Duplication Activation/Deactivation MAC Control Element

PDCP Duplication Activation/Deactivation 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, consists of a single octet containing eight D-fields, and is defined, for a MAC entity, as follows (figure 6.1.3.17-1):

- Di: this field refers to the i-th DRB in the ascending order of the DRB identity among the established DRB(s) configured with duplication and with RLC entity(ies) associated with this MAC entity. Di field set to "1" indicates that the duplication shall be activated and Di field set to "0" indicates that the duplication shall be deactivated.



Figure 6.1.3.17-1: PDCP Duplication Activation/Deactivation MAC Control Element

#### 6.1.3.18 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.

#### 6.1.3.19 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 6.1.3.19-1):

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

- AS RAI: The field corresponds to Access Stratum Release Assistance Indication as shown in Table 6.1.3.19-1. The length of the field is 2 bits;

- Quality Report: For a NB-IoT UE, if *npdsch-16QAM-Config* is not configured, the report mapping is defined in Table 9.1.22.15-1 in TS 36.133 [9] and if *npdsch-16QAM-Config* is configured the report mapping is defined in Table 9.1.22.17-1 in TS 36.133 [9]. For a BL UE or UE in CE, the field corresponds to DL channel quality report as defined in TS 36.133 [9]. The length of the field is 4 bits.



Figure 6.1.3.19-1: DCQR and AS RAI MAC control element

Table 6.1.3.19-1: 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 |

#### 6.1.3.20 Timing Advance Report MAC Control Element

The Timing Advance MAC CE is identified by MAC subheader with LCID as specified in Table 6.2.1-2.

It has a fixed size and consists of two octets defined as follows (Figure 6.1.3.20-1):

- R: Reserved bit, set to 0;

- Timing Advance: The Timing Advance field indicates the least integer number of subframes greater than or equal to the Timing Advance value (see TS 36.211 [7] clause 8.1). The length of the field is 14 bits.



Figure 6.1.3.20-1: Timing Advance MAC CE

#### 6.1.3.21 Differential Koffset MAC Control Element

The Differential Koffset MAC CE is identified by MAC subheader with LCID as specified in Table 6.2.1-1.

It has a fixed size and consists of a single octet defined as follows (Figure 6.1.3.21-1):

- R: Reserved bit, set to 0;

- Differential Koffset: This field indicates the differential Koffset in subframes (see TS 36.213 [2]). The length of the field is 6 bits.



Figure 6.1.3.21-1: Differential Koffset MAC CE

#### 6.1.3.xx GNSS Measurement Command MAC Control Element

The GNSS Measurement Command MAC Control Element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-1.

Editor’s note: FFS on the figure of GNSS Measurement Command MAC CE.

#### 6.1.3.yy GNSS Validity Duration Report MAC Control Element

The GNSS Validity Duration Report MAC Control Element is identified by a MAC PDU subheader with LCID as specified in table 6.2.1-2.

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

- R: Reserved bit, set to 0;

- GNSS Validity Duration: the field corresponds to the remaining GNSS validity duration defined in the TS 36.331 [8].



Figure 6.1.3.yy-1: GNSS Validity Duration Report MAC control element

Editor’s note: RAN2 will wait for more input from RAN1 for the detailed format of UL MAC CE for GNSS validity duration reporting and DL MAC CE for GNSS measurement.

Next change

### 6.1.4 MAC PDU (transparent MAC)

A MAC PDU consists solely of a MAC Service Data Unit (MAC SDU) whose size is aligned to a TB; as described in figure 6.1.4-1. This MAC PDU is used for transmissions on PCH, BCH, DL-SCH including BCCH, BR-BCCH, SL-DCH and SL-BCH.



Figure 6.1.4-1: Example of MAC PDU (transparent MAC)

### 6.1.5 MAC PDU (Random Access Response)

A MAC PDU consists of a MAC header and zero or more MAC Random Access Responses (MAC RAR) and optionally padding as described in figure 6.1.5-4.

The MAC header is of variable size.

A MAC PDU header consists of one or more MAC PDU subheaders; each subheader corresponding to a MAC RAR except for the Backoff Indicator subheader. If included, the Backoff Indicator subheader is only included once and is the first subheader included within the MAC PDU header.

A MAC PDU subheader consists of the three header fields E/T/RAPID (as described in figure 6.1.5-1) but for the Backoff Indicator subheader which consists of the five header field E/T/R/R/BI (as described in figure 6.1.5-2).

A MAC RAR consists of the following fields R/Timing Advance Command/UL Grant/(R/ER)/Temporary C-RNTI (as described in figures 6.1.5-3, 6.1.5-3a, 6.1.5-3b and 6.1.5-3c). For BL UEs and UEs in enhanced coverage in enhanced coverage level 2 or 3 (see clause 6.2 in TS 36.213 [2]) the MAC RAR in figure 6.1.5-3a is used, for NB-IoT UEs (see clause 16.3.3 in TS 36.213 [2]) the MAC RAR in figure 6.1.5-3b is used, except for NB-IoT UEs using preamble format 2, the MAC RAR in figure 6.1.5-3c is used. Otherwise the MAC RAR in figure 6.1.5-3 is used.

Padding may occur after the last MAC RAR. Presence and length of padding is implicit based on TB size, size of MAC header and number of RARs.



Figure 6.1.5-1: E/T/RAPID MAC subheader



Figure 6.1.5-2: E/T/R/R/BI MAC subheader



Figure 6.1.5-3: MAC RAR



Figure 6.1.5-3a: MAC RAR for PRACH enhanced coverage level 2 or 3



Figure 6.1.5-3b: MAC RAR for NB-IoT UEs



Figure 6.1.5-3c: MAC RAR for NB-IoT UEs using PRACH preamble format 2



Figure 6.1.5-4: Example of MAC PDU consisting of a MAC header and MAC RARs

### 6.1.6 MAC PDU (SL-SCH)

A MAC PDU consists of a MAC header, one or more MAC Service Data Units (MAC SDU), and optionally padding; as described in Figure 6.1.6-4.

Both the MAC header and the MAC SDUs are of variable sizes.

A MAC PDU header consists of one SL-SCH subheader, one or more MAC PDU subheaders; each subheader except SL-SCH subheader corresponds to either a MAC SDU or padding.

The SL-SCH subheader consists of the seven header fields V/R/R/R/R/SRC/DST.

A MAC PDU subheader consists of the six header fields R/R/E/LCID/F/L but for the last subheader in the MAC PDU. The last subheader in the MAC PDU consists solely of the four header fields R/R/E/LCID. A MAC PDU subheader corresponding to padding consists of the four header fields R/R/E/LCID.



Figure 6.1.6-1: R/R/E/LCID/F/L MAC subheader



Figure 6.1.6-2: R/R/E/LCID MAC subheader



Figure 6.1.6-3: SL-SCH MAC subheader for V ="0001" and "0010"



Figure 6.1.6-3a: SL-SCH MAC subheader for V="0011"

MAC PDU subheaders have the same order as the corresponding MAC SDUs and padding.

Padding occurs at the end of the MAC PDU, except when single-byte or two-byte padding is required. Padding may have any value and the MAC entity shall ignore it. When padding is performed at the end of the MAC PDU, zero or more padding bytes are allowed.

When single-byte or two-byte padding is required, one or two MAC PDU subheaders corresponding to padding are placed after the SL-SCH subheader and before any other MAC PDU subheader.

A maximum of one MAC PDU can be transmitted per TB.



Figure 6.1.6-4: Example of MAC PDU consisting of MAC header, MAC SDUs and padding

## 6.2 Formats and parameters

### 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". A short DCQR may be included in the MAC PDU subheader with LCID set to "00000", "01011", "01100" or "01101". 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: Except when this field is used for short DCQR, the Format2 field indicates the size of the Length field as indicated in table 6.2.1-3. For short DCQR, the mapping of F2 field to short DCQR value is described in table 6.2.1-5. There is one F2 field per MAC PDU subheader. The size of the F2 field is 1 bit. Except when this field is used for short DCQR, 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: Except when this field is used for short DCQR, reserved bit, set to "0". For short DCQR, the mapping of R field to short DCQR value is described in table 6.2.1-5.

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 |
| 01011-01101 | Reserved |
| 01110 | GNSS Measurement Command |
| 01111 | Differential Koffset |
| 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, Differential Koffset, GNSS Measurement 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 | GNSS Validity Duration Report |
| 01111 | Timing Advance Report |
| 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, Timing Advance Report, GNSS Validity Duration Report 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. | |

Table 6.2.1-5: Values of R and F2 fields for short DCQR

|  |  |  |
| --- | --- | --- |
| Index of R | Index of F2 | Short DCQR value |
| 0 | 0 | No short DCQR |
| 0 | 1 | Short DCQR 1 |
| 1 | 0 | Short DCQR 2 |
| 1 | 1 | Short DCQR 3 |

Editor’s note: The use of DL for GNSS Measurement Command and UL LCID for GNSS Validity Duration Report needs further discussion.Next change

### 6.2.2 MAC header for Random Access Response

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

- 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 at least another set of E/T/RAPID fields follows. The E field is set to "0" to indicate that a MAC RAR or padding starts at the next byte;

- T: The Type field is a flag indicating whether the MAC subheader contains a Random Access ID or a Backoff Indicator. The T field is set to "0" to indicate the presence of a Backoff Indicator field in the subheader (BI). The T field is set to "1" to indicate the presence of a Random Access Preamble ID field in the subheader (RAPID);

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

- BI: The Backoff Indicator field identifies the overload condition in the cell. The size of the BI field is 4 bits;

- RAPID: The Random Access Preamble IDentifier field identifies the transmitted Random Access Preamble (see clause 5.1.3). The size of the RAPID field is 6 bits.

The MAC header and subheaders are octet aligned.

NOTE: For NB-IoT, the Random Access Preamble IDentifier field corresponds to the start subcarrier index.

### 6.2.3 MAC payload for Random Access Response

The MAC RAR is of fixed size and consists of the following fields:

- R: Reserved bit, set to "0". For a BL UE or a UE in CE, this bit is set to "1" to indicate that an UL Grant in Random Access Response is for EDT;

- Timing Advance Command: The Timing Advance Command field indicates the index value *TA* (0, 1, 2… 1282) used to control the amount of timing adjustment that the MAC entity has to apply (see clause 4.2.3 of TS 36.213 [2]), except for NB-IoT UEs using preamble format 2, where the Timing Advance Command field indicates the index value *TA* (0, 1, 2… 1536). The size of the Timing Advance Command field is 11 bits;

- UL Grant: The Uplink Grant field indicates the resources to be used on the uplink (see clause 6.2 of TS 36.213 [2], or for NB-IoT UEs, see clause 16.3.3 of TS 36.213 [2]). The size of the UL Grant field is 20 bits, except for NB-IoT UEs, where the size of UL grant field is 15 bits, and except for BL UEs and UEs in enhanced coverage level 2 or 3, where the size of the UL grant field is 12 bits.

- ER: Extended RAPID bits, indicating the two least significant bits of extended RAPID used when PRACH preamble format 2 is transmitted.

- Temporary C-RNTI: The Temporary C-RNTI field indicates the temporary identity that is used by the MAC entity during Random Access. The size of the Temporary C-RNTI field is 16 bits.

The MAC RAR is octet aligned.

### 6.2.4 MAC header for SL-SCH

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

- V: The MAC PDU format version number field indicates which version of the SL-SCH subheader is used. In this version of the specification three format versions are defined, and this field shall therefore be set to "0001", "0010", and "0011". If the DST field is 24 bits this field shall be set to "0011". The V field size is 4 bits;

- SRC: The Source Layer-2 ID field carries the identity of the source. It is set to the ProSe UE ID. The SRC field size is 24 bits;

- DST: The DST field can be 16 bits or 24 bits. If it is 16 bits, it carries the 16 most significant bits of the Destination Layer-2 ID. If it is 24 bits, it is set to the Destination Layer-2 ID. For sidelink communication, the Destination Layer-2 ID is set to the ProSe Layer-2 Group ID or Prose UE ID. For V2X sidelink communication, the Destination Layer-2 ID is set to the identifier provided by upper layers as defined in TS 23.285 [14]. If the V field is set to "0001", this identifier is a groupcast identifier. If the V field is set to "0010", this identifier is a unicast identifier;

- LCID: The Logical Channel ID field uniquely identifies the logical channel instance within the scope of one Source Layer-2 ID and Destination Layer-2 ID pair of the corresponding MAC SDU or padding as described in table 6.2.4-1. There is one LCID field for each MAC SDU 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. The values of LCID from "01011" to "10100" identify the logical channels used to send duplicated RLC SDUs from logical channels of which the values of LCID from "00001" to "01010" respectively in sequential order. The LCID field size is 5 bits;

- L: The Length field indicates the length of the corresponding MAC SDU in bytes. There is one L field per MAC PDU subheader except for the last subheader. The size of the L field is indicated by the F field;

- F: The Format field indicates the size of the Length field as indicated in table 6.2.4-2. There is one F field per MAC PDU subheader except for the last subheader. The size of the F field is 1 bit. If the size of the MAC SDU is less than 128 bytes, the value of the F field is set to 0, otherwise it is set to 1;

- 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/R/E/LCID fields. The E field is set to "0" to indicate that either a MAC SDU or padding starts at the next byte;

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

The MAC header and subheaders are octet aligned.

Table 6.2.4-1 Values of LCID for SL-SCH

|  |  |
| --- | --- |
| Index | LCID values |
| 00000 | Reserved |
| 00001-01010 | Identity of the logical channel |
| 01011-10100 | Identity of the logical channel which is used for duplication |
| 10101-11011 | Reserved |
| 11100 | PC5-S messages that are not protected |
| 11101 | PC5-S messages "Direct Security Mode Command" and "Direct Security Mode Complete" |
| 11110 | Other PC5-S messages that are protected |
| 11111 | Padding |

Table 6.2.4-2 Values of F field:

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

# 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 |
| 0001-0960  0001-1000 (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-RNTI |
| 0961-FFF3  1001-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 |

## 7.2 Backoff Parameter values

Backoff Parameter values are presented in Table 7.2-1 except for NB-IoT where Table 7.2-2 shall be used.

Table 7.2-1: Backoff Parameter values.

|  |  |
| --- | --- |
| Index | Backoff Parameter value (ms) |
| 0 | 0 |
| 1 | 10 |
| 2 | 20 |
| 3 | 30 |
| 4 | 40 |
| 5 | 60 |
| 6 | 80 |
| 7 | 120 |
| 8 | 160 |
| 9 | 240 |
| 10 | 320 |
| 11 | 480 |
| 12 | 960 |
| 13 | Reserved |
| 14 | Reserved |
| 15 | Reserved |

The reserved values of the backoff parameter if received by the current release version UEs shall be taken as 960 ms.

Table 7.2-2: Backoff Parameter values for NB-IoT.

|  |  |
| --- | --- |
| Index | Backoff Parameter value (ms) |
| 0 | 0 |
| 1 | 256 |
| 2 | 512 |
| 3 | 1024 |
| 4 | 2048 |
| 5 | 4096 |
| 6 | 8192 |
| 7 | 16384 |
| 8 | 32768 |
| 9 | 65536 |
| 10 | 131072 |
| 11 | 262144 |
| 12 | 524288 |
| 13 | Reserved |
| 14 | Reserved |
| 15 | Reserved |

The reserved values of the backoff parameter if received by the current release version NB-IoT UEs shall be taken as 524288 ms.

## 7.3 PRACH Mask Index values

Table 7.3-1: PRACH Mask Index values

|  |  |  |
| --- | --- | --- |
| PRACH Mask Index | Allowed PRACH (FDD) | Allowed PRACH (TDD) |
| 0 | All | All |
| 1 | PRACH Resource Index 0 | PRACH Resource Index 0 |
| 2 | PRACH Resource Index 1 | PRACH Resource Index 1 |
| 3 | PRACH Resource Index 2 | PRACH Resource Index 2 |
| 4 | PRACH Resource Index 3 | PRACH Resource Index 3 |
| 5 | PRACH Resource Index 4 | PRACH Resource Index 4 |
| 6 | PRACH Resource Index 5 | PRACH Resource Index 5 |
| 7 | PRACH Resource Index 6 | Reserved |
| 8 | PRACH Resource Index 7 | Reserved |
| 9 | PRACH Resource Index 8 | Reserved |
| 10 | PRACH Resource Index 9 | Reserved |
| 11 | Every, in the time domain, even PRACH opportunity  1st PRACH Resource Index in subframe | Every, in the time domain, even PRACH opportunity  1st PRACH Resource Index in subframe |
| 12 | Every, in the time domain, odd PRACH opportunity  1st PRACH Resource Index in subframe | Every, in the time domain, odd PRACH opportunity  1st PRACH Resource Index in subframe |
| 13 | Reserved | 1st PRACH Resource Index in subframe |
| 14 | Reserved | 2nd PRACH Resource Index in subframe |
| 15 | Reserved | 3rd PRACH Resource Index in subframe |

## 7.4 Subframe\_Offset values

Subframe\_Offset values are presented in Table 7.4-1.

Table 7.4-1: Subframe\_Offset values

|  |  |  |
| --- | --- | --- |
| TDD UL/DL configuration | Position of initial Semi-Persistent grant | Subframe\_Offset value (ms) |
| 0 | N/A | 0 |
| 1 | Subframes 2 and 7 | 1 |
| Subframes 3 and 8 | -1 |
| 2 | Subframe 2 | 5 |
| Subframe 7 | -5 |
| 3 | Subframes 2 and 3 | 1 |
| Subframe 4 | -2 |
| 4 | Subframe 2 | 1 |
| Subframe 3 | -1 |
| 5 | N/A | 0 |
| 6 | N/A | 0 |

## 7.5 TTI\_BUNDLE\_SIZE value

The parameter TTI\_BUNDLE\_SIZE is 4.

## 7.6 DELTA\_PREAMBLE values

Except for NB-IoT, the DELTA\_PREAMBLE preamble format based power offset values are presented in Table 7.6-1.

Table 7.6-1: DELTA\_PREAMBLE values.

|  |  |
| --- | --- |
| Preamble Format | DELTA\_PREAMBLE value |
| 0 | 0 dB |
| 1 | 0 dB |
| 2 | -3 dB |
| 3 | -3 dB |
| 4 | 8 dB |

Where the Preamble Format is given by *prach-ConfigIndex*, as specified in TS 36.211 [7].

For NB-IoT, the DELTA\_PREAMBLE preamble format based power offset values are presented in Table 7.6-2.

Table 7.6-2: DELTA\_PREAMBLE values for NB-IoT.

|  |  |  |
| --- | --- | --- |
| Preamble Format | DELTA\_PREAMBLE value | |
| Frame Structure Type 1 | Frame Structure Type 2 |
| 0, 1 | 0 dB | 0dB |
| 0a, 1a | - | 0dB |
| 2 | 10\*log10(1/3) dB | 0dB |

Where Preamble Format is specified in TS 36.211 [7].

## 7.7 HARQ RTT Timers

The parameters RTToffset and DLoffset provides offsets for determining the HARQ round trip time. The parameter RTToffset is set to 0 in terrestrial networks and RTToffset is set to UE-eNB RTT in Non-terrestrial networks. The parameter DLoffset is set to 0 in terrestrial networks and DLoffset is set to Koffset + *k-Mac* in Non-terrestrial networks where Koffset is defined in TS 36.213 [2].

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 Timer 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 Timer 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 Timer 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, when single TB is scheduled by PDCCH the HARQ RTT Timer corresponds to 7 + N subframes plus DLoffset, where N is the used PUCCH repetition factor, where only valid (configured) UL subframes as configured by upper layers in *fdd-UplinkSubframeBitmapBR* are counted for N. In case of TDD, HARQ RTT Timer corresponds to 3 + k + N subframes plus RTToffset, 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 for N as indicated in clauses 10.1 and 10.2 of TS 36.213 [2].

For BL UEs and UEs in enhanced coverage, when multiple TBs are scheduled by PDCCH and HARQ-ACK bundling is not configured, the HARQ RTT Timer corresponds to 7 + m \* N subframes plus DLoffset, where N is the used PUCCH repetition factor and m is the number of scheduled TBs as indicated in PDCCH, where only valid (configured) UL subframes as configured by upper layers in *fdd-UplinkSubframeBitmapBR* are counted for m \* N.

For BL UEs and UEs in enhanced coverage, when multiple TBs are scheduled by PDCCH and HARQ-ACK bundling is configured the HARQ RTT Timer corresponds to 7 + M \* N subframes plus DLoffset, where N is the used PUCCH repetition factor and M is the number of TB bundles as specified in clause 7.3 of TS 36.213 [2], where only valid (configured) UL subframes as configured by upper layers in *fdd-UplinkSubframeBitmapBR* are counted for M \* N.

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 subframes plus RTToffset + deltaPDCCH, 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 plus RTToffset 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 subframes plus RTToffset + deltaPDCCH 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 plus RTToffset 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 plus RTToffset for FDD and Frame Structure Type 3, and set to kULHARQRTT subframes plus RTToffset 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 subframes plus RTToffset + deltaPDCCH, where deltaPDCCH is the interval starting from the subframe following the last subframe of the PUSCH transmission plus 3 subframes plus RTToffset 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 subframe plus RTToffset + deltaPDCCH, where deltaPDCCH is the interval starting from the subframe following the last subframe of the PUSCH transmission plus 1 subframe plus RTToffset 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 Timer 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/DL Configuration** | **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/DL Configuration** | **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/DL Configuration** | **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/DL Configuration** | **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/DL Configuration** | **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 1: Void

NOTE 2: Void

## 7.8 DL\_REPETITION\_NUMBER value

The parameter DL\_REPETITION\_NUMBER value is received from lower layers and corresponds to the repetition level as specified in TS 36.213 [2].

## 7.9 UL\_REPETITION\_NUMBER value

The parameter UL\_REPETITION\_NUMBER value is received from lower layers and corresponds to the repetition level as specified in TS 36.213 [2].

End of changes

# Annex – Agreements

### RAN2#119-e

**Disabling of HARQ feedback**

* Disabling DL HARQ feedback is supported for NB-IoT and eMTC NTN. FFS on UE capability
* For UL HARQ operation, introduce two HARQ modes, i.e., HARQ mode A and HARQ mode B in IoT NTN (both NB-IoT and eMTC NTN), similarly to NR NTN
* From RAN2 perspective, at least for eMTC, enabling/disabling HARQ feedback can be configured per DL HARQ process at least via UE specific RRC signalling. FFS for NB-IoT (and especially for CP solution for NB-IOT).

**Mobility Enhancements**

* IoT NTN can use the mechanism for neighbour cell measurements in connected mode (specified in Rel-17 for NB-IoT). FFS if any enhancements are needed (e.g. triggers) for both NB-IoT and eMTC.
* RAN2 to continue working on a new time-based trigger for triggering intra and inter frequency measurements in connected mode, e.g. the serving cell is going to stop covering the current area, for both earth-moving and earth-fixed cell (FFS on distance-based trigger)
* CHO enhancements for eMTC NTN (i.e. time/timer based solution) are introduced based on the R17 NR NTN solution. FFS on location-based solution
* Measurement results reporting is not supported in Rel-18 NB-IoT NTN.

### RAN2#119bis-e

**Disabling of HARQ feedback**

* For NB-IoT, enabling/disabling HARQ feedback can be configured per DL HARQ process at least via UE specific RRC signaling (e.g. RRCConnectionSetup). This does not preclude other options (e.g. DCI-based). We can also revert this decision if requested by RAN1.
* Disabling HARQ feedback is supported for NB-IoT with single HARQ process, and it is up to eNB implementation whether to disable the HARQ feedback
* Working Assumption:Blind retransmission can be used in IoT NTN when HARQ feedback is disabled and when HARQ mode B is used (RAN2 assumes there is no spec change for this)
* HARQ mode A/B for uplink transmission may be configured per UL HARQ process at least via UE specific RRC signalling for eMTC and NB-IOT NTN. We can also revert this decision if requested by RAN1
* RAN2 agree to take R17 NR NTN DRX solution as baseline for IoT NTN, e.g. for HARQ process with DL HARQ feedback disabled, the UE will not start the corresponding DL HARQ RTT timer.
* For NB-IoT NTN with single HARQ process when the HARQ feedback is disabled, the UE will start/restart drx-inactivity timer in the subframe containing the last repetition of the corresponding PDSCH reception (can still check whether the alternative to set the HARQ RTT timer to 0 also works)
* RAN2 agree to take R17 NR NTN DRX solution as baseline for IoT NTN, e.g. for HARQ process in HARQ mode B, the UE will not start the corresponding UL HARQ RTT timer.
* For NB-IoT NTN with single HARQ process in HARQ mode B, the UE will start/restart drx-inactivity timer in the subframe containing the last repetition of the corresponding PUSCH transmission (can still check whether other alternatives also work)
* The solutions of LCP restriction on allowed HARQ mode in NR NTN can be reused for eMTC NTN.

**Mobility Enhancements**

* For eMTC over NTN, for both earth-moving and earth-fixed cell scenarios, we introduce location based CHO triggering events

### RAN2#120

**Disabling of HARQ feedback**

* For NB-IoT NTN with single HARQ process when the HARQ feedback is disabled, the UE will start/restart drx-inactivity timer in the subframe containing the last repetition of the corresponding PDSCH reception plus 12 subframes.
* RAN2 understands that something needs to be added to consider the processing time also for inactivity timer of HARQ mode B. Continue the discussion on the details in the next meeting
* For eMTC, the following LCH to HARQ process mapping rules are supported:

1) LCH is mapped only to a HARQ process configured with HARQ mode A;

2) LCH is mapped only to a HARQ process configured with HARQ mode B;

3) If an LCH is not configured with a mapping rule, it may be mapped to any HARQ process (HARQ mode A or B).

4) If UL HARQ mode is not configured, LCH mapping rules are not supported (legacy behaviour)

* For eMTC, introduce allowedHARQ-mode for each logical channel, e.g. included in LogicalChannelConfig IE.
* An optional UE capability is introduced to indicate whether the UE supports disabling HARQ feedback for downlink transmission.
* An optional UE capability is introduced to indicate whether the UE supports HARQ Mode B and, for eMTC, the corresponding LCP restrictions for uplink transmission

**Mobility Enhancements**

* For NB-IoT we support a trigger for neighbour cell measurements based on T-service (in the quasi-Earth fixed case) (this does not preclude anything for eMTC discussion)
* At least for NB-IoT NTN, for quasi-earth fixed cells, UE shall start intra/inter frequency measurement in connected mode before the t-Service if present. The exact time to start measurements in connected mode before t-Service can be left to UE implementation” (can revisit if we agree other proposal based on neighbour cell coverage)
* RAN2 will not specify the condition of stopping UE measurement before t-Service
* For earth-moving cell, the UE derives when loss of coverage of current cell happens (how to derive this information is FFS)
* For earth-moving cell, UE shall start intra/inter frequency measurements in RRC connected mode before losing coverage. The exact time to start measurements can be left to UE implementation
* CHO time trigger event is defined as time duration [t1, t2] associated for each CHO candidate cell. The UE shall execute CHO to that candidate cell during the time duration, if all other configured CHO execution conditions will apply and there is only one triggered candidate cell.: UE is allowed to perform HO only during T1 to T2.
* For eMTC NTN, introduce a location-based conditional reconfiguration trigger based on condEventD1 in NR, where the event will be satisfied if the distance between the UE and a first reference location (e.g. within the serving cell) is above a threshold, and the distance between the UE and a second reference location (e.g. within a neighbour cell) is below a threshold. (similar to condEventD1 in NR)
* For eMTC NTN, introduce event A4 based conditional trigger (similar to condEventA4 in NR).
* FFS whether time and location-based trigger conditions may be configured independently (i.e., without a jointly configured event A4 measurement condition) for eMTC NTN.

### RAN2#121

**GNSS operation enhancements**

* For UE to report GNSS position fix time duration for measurement during the initial access, at least the following Msg5 message can be used:

RRCConnectionSetupComplete, RRCConnectionSetupComplete-NB,

RRCConnectionResumeComplete, RRCConnectionResumeComplete-NB,

FFS for RRCreestablishmentComplete and RRCConnectionReconfigurationComplete.

FS for Msg3

* FFS whether the UE can stay in RRC\_CONNECTED state when current GNSS position becoming out-of-date if the UE has initiated a new measurement
* The value range {10s, 20s, 30s, 40s, 50s, 60s, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min, 60 min, 90 min, 120 min, infinity} introduced in R17 is reused for connected UE GNSS validation duration report, unless modified by RAN1.
* UE reports GNSS validity duration after GNSS measurement. FFS whether the UE reports every time or only if the validity duration changes. FFS if the duration is the remaining validity duration or the whole duration

**Mobility Enhancements**

* Location-based connected mode measurement initiation is supported in quasi-Earth-fixed cell (UE is not required to update the GNSS location for this). A serving cell reference location and a distance threshold/radius for detecting when to trigger connected mode measurements will be broadcast for quasi-Earth-fixed cell. FFS on whether the R17 IEs are reused or not. FFS if the same mechanism can also be used in idle (like in NR-NTN)
* Location-based connected mode measurement initiation is supported in earth-moving cell (UE is not required to update the GNSS location for this). A serving cell reference location and a distance threshold/radius for detecting when to trigger connected mode measurements will be broadcast for earth-moving cell. FFS on whether the R17 IEs are reused or not. FFS on whether additional information needs to be broadcast to inform the UE how the reference location moves over time or if this can be derived from other information (e.g. Epoch time and ephemeris). FFS if the same mechanism can also be used in idle (like in NR-NTN)
* We don’t introduce any new low mobility criterion for enhanced mobility in Rel-18

**Enhancements to discontinuous coverage**

* RAN2 can continue to check whether dedicated RRC signalling can be used for providing satellite information corresponding to discontinuous coverage.
* RAN2 will support enhancements in paging and eDRX, in alignment with the work in SA2 and CT1. FFS on the details
* RAN2 may consider enhancements for connected UE upon detecting discontinuous coverage (e.g., suspend RLM, RLF detection, and RRC re-establishment process)
* Companies supporting the store and forward approach can bring a proposal to the plenary for TEI18 or for updating the WID

### RAN2#121bis-e

**Disabling of HARQ feedback**

* RAN2#121’s agreement is revised to “For NB-IoT NTN with single HARQ process when the HARQ feedback is disabled, the UE will start/restart drx-inactivity timer in the subframe containing the last repetition of the corresponding PDSCH reception plus 12 subframes plus deltaPDCCH” (Can further check in the NB-IoT session if anything needs to be done for legacy NB-IoT as well, as some timers don’t take deltaPDCCH into account)
* Wait for RAN1’s decision on the RRC signalling of enabling DCI-based solution to indicate HARQ feedback enabled/disabled, and the signalling granularity, e.g. per UE or per HARQ process
* On DCI indication overriding RRC configuration for the HARQ feedback enabled/disabled, wait for RAN1’s progress on DCI-based solution before discussing related DRX impact in RAN2.
* On DL multiple TB scheduling, wait for RAN1’s progress before discussing related DRX impact in RAN2.
* P4 in R2-2302557 is not agreed, i.e. no special handling for single HARQ process for eMTC.
* For eMTC NTN, a parameter harq-FeedbackEnablingforSPSactive could be configured for a UE. If harq-FeedbackEnablingforSPSactive is configured to enable HARQ feedback, UE reports ACK/NACK for the first SPS PDSCH after activation, regardless of if HARQ feedback is enabled or disabled corresponding to the first SPS PDSCH after activation.
* For a NB-IoT UE configured with a single HARQ process in HARQ mode B, send LS to RAN1 and ask for the “processing time for starting drx-InactivityTimer (i.e. start to monitor NPDCCH)”. (can further check the detailed wording of the question)
* Network implementation resolves the issue of ambiguity on start of DRX inactivity timer after the PUSCH transmission by not scheduling the NPDCCH back-to-back during the ambiguity period (i.e., Koffset – UE’s TA)
* Send LS to RAN1 to check for UL multiple TB scheduling, which UL HARQ mode combination(s) are to be supported.
* In the LS to RAN1, we don’t include a question on whether RAN1 intends to introduce the DCI-based solution for the UL HARQ mode
* UL transmission using SPS can be configured with HARQ mode B
* P1 in R2-2303713 is not agreed, i.e. do not enhance the LCP restriction based on uplinkHARQ-Mode for different RLC PDU types
* Send LS to RAN1 informing RAN2’s agreements and also including potential questions to be checked with RAN1
* Add one more question in the LS to check with RAN1 which of the below understandings is correct for the RAN1 agreement.
* Understanding 1: For a DL HARQ process with disabled HARQ feedback in NB-IoT, UE is not required to monitor NPDCCH for the same HARQ process in a period of Y=12(ms) from the end of reception of the NPDSCH.
* Understanding 2: For a DL HARQ process with disabled HARQ feedback in NB-IoT, UE is not required to monitor NPDCCH for all the HARQ processes in a period of Y=12(ms) from the end of reception of the NPDSCH.
* RAN2 further discuss whether UL transmission using PUR can be configured with HARQ mode B.

**GNSS operation enhancements**

* RLM is suspended during the GNSS measurement gap while the UE is measuring GNSS
* UE can stay in RRC\_CONNECTED state when current GNSS position becomes out-of-date if the UE enters a GNSS measurement gap. FFS whether the new GNSS measurement shall be started before, upon or after the current GNSS validity duration expiry
* For a UEs that cannot acquire system information and GNSS position at the same time, acquisition of SIB31 may be postponed until GNSS measurement is completed if the UE cannot complete acquisition of SIB31 before the start of GNSS measurement gap
* For the NB-IoT CP solution, UE will report the GNSS validity duration by using a MAC CE
* GNSS validity duration UE reported after GNSS measurement is the remaining validity duration

**Mobility Enhancements**

* New SIBxx is introduced to broadcast the neighbor cell/satellite information.
* Common TA parameters are broadcast as assistance information for neighbor cell measurements.
* Kmac is broadcast as neighbor cell assistance information.
* For moving cell, the UE can derive the trajectory of serving cell with rough accuracy based on serving satellite ephemeris and epochTime, with the assumption that the serving cell reference location broadcast by the network is the one at Epoch time (like in NR-NTN)
* Introduce satellite ID for the satellite in a list in new SIB-xx. FFS on the details of the new IE
* For eMTC NTN, for fixed cell, location-based measurement initiation can also be used in RRC\_IDLE for cell re-selection purposes (like in NR-NTN)
* For eMTC NTN, for moving cell, location-based measurement initiation can also be used in RRC\_IDLE for cell re-selection purposes (like in NR-NTN). FFS whether to consider solution that does not require UE to update the GNSS for this same as in connected mode
* SIB3 is extended to include the reference location and distanceThresh

**Enhancements to discontinuous coverage**

* RAN2 will not introduce any enhancement to allow a UE in RRC Connected to stay in RRC\_CONNECTED during/after a coverage gap (e.g. suspend RLM/RLF, activation time in RRC Reconfiguration, CHO enhancement)
* RAN2 to introduce enhancement to RRC Release using one of the following options (FFS which one):

- Explicit RRC Release using a new RRC Release cause

- UE Autonomous release (e.g. timer based or upon detection of coverage gap)

### RAN2#122

**GNSS operation enhancements**

* Confirm the working assumption that GNSS validity duration UE reports is the remaining validity duration.
* The UE triggers GNSS measurement reporting every time upon completing the GNSS fix operation.
* When network triggers GNSS measurement initiation is up to network implementation.
* Add a note to state some AS operations are suspended when UE is performing GNSS measurement during GNSS measurement gap.
* GNSS fix time duration should be reported in 1) and 2):

1)RRCConnectionReestablishmentComplete and RRCConnectionReestablishmentComplete-NB

2) RRCConnectionReconfigurationComplete for HO case

(FFS whether there are some scenarios where this is not needed or whether there has to be some explicit NW indication to do so)

Working Assumptions:

* An UL MAC CE for GNSS validity duration reporting is used for NB-IoT user plane solution and eMTC UE as well, in addition to previously agreed NB-IoT control plane solution
* A new DL MAC CE is introduced to trigger connected UE to perform GNSS measurement.

**Mobility Enhancements**

* Extend the neighbour cell information in existing SIBs (not SIB31) to include satellite ID
* The system Information modification procedure is not triggered for an update of new SIB on neighbor-cell assistance information.
* For NB-IoT, SIBxx is not an essential SIB. UE does not need to consider the cell barred if it is unable to acquire the SIB when scheduled. FFS for eMTC
* In RRC IDLE, how to (re-)acquire neighbour cell assistance information is up to UE’s implementation.
* The satellite ID in the new SIB is an integer of X bits wherein X depends on the maximum number of satellites to be considered for mobility.
* The satellite ID is defined as Radio resource control information element to be used in other configurations.
* If a parameter in the common TA parameters is absent, then the value of the parameter is assumed zero.
* If Kmac is absent, then the value of Kmac for the neighbor satellite in the list is assumed zero. FFS on further optimization on signaling, e.g., signalling explicit value 0 of Kmac.
* Reference location and distanceThresh in SIB31. A change of reference location does not trigger SI modification. A UE does not need to get a new reference location as long as ephemeris and Epoch time are valid (in Connected mode the UE relies on T317)
* For earth-fixed cells, introduce t-ServiceStart for neighbor cells. If UE is aware of the t-ServiceStart of the neighbour cell then may be used (up to UE implementation) to determine when to start measurements of that neighbor cell
* If the serving cell t-service expires, stop T310 (if running) and start T311 (i.e. perform cell search and re-establishment without attempting to recover on the current cell for the duration of T310). FFS on discontinuous coverage
* R18 location and time based trigger for measurements (for connected mode and for idle) apply to both NB-IoT and eMTC.

### RAN2#123

**Disabling of HARQ feedback**

* For eMTC NTN, it can be left to eNB’s implementation to configure either HARQ mode A or HARQ mode B for all HARQ process (or no HARQ mode) if mpdcch-UL-HARQ-ACK-FeedbackConfig is configured.
* For NB-IoT NTN and eMTC NTN for CE Mode B, to configure/indicate enabling/disabling of HARQ feedback for downlink transmission:

• Introduce an RRC bitmap with a value per HARQ process to indicate the HARQ feedback enabling/disabling for each HARQ process. (Similar to NR)

• Introduce a single flag in RRC signaling to indicate whether DCI-based solution is enabled or not

* HARQ feedback shall always be sent for DL SPS deactivation (i.e. regardless of HARQ feedback enabled/disabled).
* For NB-IoT, UL HARQ mode configuration is based on RRC signalling (similar like NR NTN).
* For a NB-IoT UE configured with a single HARQ process, if the HARQ process is configured with HARQ mode B, UE (re)starts drx-InactivityTimer in the subframe containing the last repetition of the corresponding PUSCH transmission plus 1 subframe plus deltaPDCCH.
* HARQ mode B is not applicable for UL transmission using PUR. FFS whether HARQ mode can be configured for PUR.
* In the case mpdcch-UL-HARQ-ACK-FeedbackConfig is configured, for a HARQ process configure with HARQ mode B, the corresponding drx-ULRetransmissionTimer is not started after the last repetition of the corresponding PUSCH transmission if an UL HARQ-ACK feedback has not been received on MPDCCH until the last repetition of the corresponding PUSCH transmission
* For eMTC, UL HARQ mode configuration is based on RRC signalling (similar like NR NTN).
* RAN2 confirms working assumption 2 in LS R2-2307016 (R1-2306245) is feasible

**GNSS operation enhancements**

* An UL MAC CE for GNSS validity duration reporting is used for NB-IoT user plane solution and eMTC UE as well and A new DL MAC CE is introduced to trigger connected UE to perform GNSS measurement.
* RAN2 will wait for more input foRAN1 for the detailed format of UL MAC CE for GNSS validity duration reporting and DL MAC CE for GNSS measurement wait for more input from RAN1.
* T318 is restarted after GNSS position fix
* Capture the following NOTE in Stage 2 (can further fix the wording):

NOTE: The AS operations (e.g. RLM related timers, dataInactivityTimer, CHO execution, neighbour cell measurement, RACH, SR, and BSR) are suspended when UE is performing GNSS measurement during GNSS measurement gap.

FFS whether we need to state something about AS resumption

* UE assumes the GNSS location is valid upon successful GNSS measurement
* Network enables the reporting of GNSS position fix duration, in SIB2 and in dedicated signalling for the HO case
* UE autonomously trigger GNSS measurement can be configured via RRC dedicated signalling
* UE can autonomously start GNSS measurement during the inactive state of C-DRX.
* The exact time of starting GNSS measurement during the inactive state of C-DRX can be left for UE implementation.
* The priority of GNSS validity duration MAC CE is higher than BSR. The exact priority can be further checked during MAC running CR review.
* RRC layer needs to send indication to trigger MAC to report the remaining GNSS measurement validity duration.
* RRC layer sends such indication to MAC layer upon RRC layer receives indication that GNSS becomes valid.
* MAC layer should guarantee the reported remaining GNSS measurement validity duration is the latest value.
* If UE failed to autonomously re-acquire the GNSS position fix and the GNSS position is still valid during the inactive state of C-DRX, UE does not move to RRC\_IDLE. There is no specification impact. FFS if we still allow the UE not to move to Idle in case GNSS position is outdated
* If there is neither network aperiodically trigger nor network configuration of UE autonomously GNSS measurement, UE moves to RRC\_IDLE after GNSS becomes invalid. It’s FFS how to decide GNSS valid or invalid considering duration X and Y.

**Mobility Enhancements**

* For eMTC, the new SIB (SIBxx) is not an essential SIB. UE does not need to consider the cell barred if it is unable to acquire the SIB when scheduled.
* RAN2 will not consider to include cell stop time of neighbor cell in the new SIB (SIBxx) in this release.
* for NB-IoT NTN, location-based measurement initiation can also be optionally used in RRC\_IDLE for cell re-selection purposes (like in NR-NTN), with the assumption that it is up to the UE to update GNSS location.
* validity duration is optional, and if this field is absent, the UE uses validity duration from the serving cell
* For re-acquisition of SIBXX the UE may rely on T317/T318 in connected mode
* For CHO in NTN (both NR NTN and eMTC NTN, time and location-based trigger conditions may be configured independently (i.e., without a jointly configured measurement condition). We add a description/note saying in which scenarios this is reasonable, e.g. at least hard-switch case where gap is assumed to be zero/negligible

**Enhancements to discontinuous coverage**

* RAN2 understands that UE may directly go to RRC\_IDLE after RLF is triggered, if there is not enough time for the UE to finish the procedure of RRC re-establishment due to the discontinuous coverage (FFS whether this needs to be captured in the specs, e.g. a NOTE)