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**iTeh STANDARD**  
**LTE,**  
**Evolved Universal Terrestrial Radio Access (E-UTRA);**  
**Medium Access Control (MAC) protocol specification**  
**(3GPP TS 36.321 version 16.7.0 Release 16)**

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# Contents

|   |    |
|---|----|
| Intellectual Property Rights .....                              | 2  |
| Legal Notice .....  | 2  |
| Modal verbs terminology.....                                    | 2  |
| Foreword.....   | 6  |
| 1 Scope .....   | 7  |
| 2 References .....  | 7  |
| 3 Definitions and abbreviations.....                            | 8  |
| 3.1 Definitions .....   | 8  |
| 3.2 Abbreviations .....   | 11 |
| 4 General .....   | 12 |
| 4.1 Introduction .....  | 12 |
| 4.2 MAC architecture.....                                       | 12 |
| 4.2.1 MAC Entities .....  | 13 |
| 4.3 Services .....  | 15 |
| 4.3.1 Services provided to upper layers .....                   | 15 |
| 4.3.2 Services expected from physical layer.....                | 15 |
| 4.4 Functions .....   | 15 |
| 4.5 Channel structure.....                                      | 16 |
| 4.5.1 Transport Channels.....                                   | 16 |
| 4.5.2 Logical Channels .....                                    | 17 |
| 4.5.3 Mapping of Transport Channels to Logical Channels .....   | 17 |
| 4.5.3.1 Uplink mapping.....                                     | 17 |
| 4.5.3.2 Downlink mapping.....                                   | 18 |
| 4.5.3.3 Sidelink mapping .....                                  | 19 |
| 5 MAC procedures .....  | 19 |
| 5.1 Random Access procedure.....                                | 19 |
| 5.1.1 Random Access Procedure initialization.....               | 19 |
| 5.1.2 Random Access Resource selection.....                     | 22 |
| 5.1.3 Random Access Preamble transmission .....                 | 24 |
| 5.1.4 Random Access Response reception.....                     | 25 |
| 5.1.5 Contention Resolution .....                               | 29 |
| 5.1.6 Completion of the Random Access procedure.....            | 31 |
| 5.2 Maintenance of Uplink Time Alignment.....                   | 31 |
| 5.3 DL-SCH data transfer.....                                   | 33 |
| 5.3.1 DL Assignment reception .....                             | 33 |
| 5.3.2 HARQ operation.....                                       | 35 |
| 5.3.2.1 HARQ Entity.....  | 35 |
| 5.3.2.2 HARQ process .....                                      | 36 |
| 5.3.3 Disassembly and demultiplexing .....                      | 37 |
| 5.4 UL-SCH data transfer.....                                   | 37 |
| 5.4.1 UL Grant reception .....                                  | 37 |
| 5.4.2 HARQ operation.....                                       | 41 |
| 5.4.2.1 HARQ entity .....                                       | 41 |
| 5.4.2.2 HARQ process .....                                      | 44 |
| 5.4.3 Multiplexing and assembly .....                           | 47 |
| 5.4.3.1 Logical channel prioritization .....                    | 47 |
| 5.4.3.2 Multiplexing of MAC Control Elements and MAC SDUs ..... | 49 |
| 5.4.4 Scheduling Request.....                                   | 49 |
| 5.4.5 Buffer Status Reporting .....                             | 51 |
| 5.4.5a Data Volume and Power Headroom Reporting .....           | 53 |
| 5.4.6 Power Headroom Reporting .....                            | 53 |
| 5.4.7 Preconfigured Uplink Resource.....                        | 56 |
| 5.4.7.1 Transmission using PUR.....                             | 56 |

|            |   |    |
|------------|---|----|
| 5.4.7.2    | Maintenance of PUR Uplink Time Alignment.....   | 56 |
| 5.4.8      | Access Stratum Release Assistance Indication.....                                       | 57 |
| 5.5        | PCH reception.....  | 57 |
| 5.6        | BCH reception.....  | 58 |
| 5.7        | Discontinuous Reception (DRX).....  | 58 |
| 5.7a       | Discontinuous Reception (DRX) for SC-PTM.....   | 62 |
| 5.8        | MAC reconfiguration.....  | 62 |
| 5.9        | MAC Reset.....  | 63 |
| 5.10       | Semi-Persistent Scheduling.....   | 63 |
| 5.10.1     | Downlink.....   | 64 |
| 5.10.2     | Uplink.....   | 64 |
| 5.11       | Handling of unknown, unforeseen and erroneous protocol data.....                        | 66 |
| 5.12       | MCH reception.....  | 66 |
| 5.13       | Activation/Deactivation of SCells.....  | 66 |
| 5.14       | SL-SCH Data transfer.....   | 68 |
| 5.14.1     | SL-SCH Data transmission.....   | 68 |
| 5.14.1.1   | SL Grant reception and SCI transmission.....  | 68 |
| 5.14.1.2   | Sidelink HARQ operation.....  | 74 |
| 5.14.1.2.1 | Sidelink HARQ Entity.....   | 74 |
| 5.14.1.2.2 | Sidelink process.....   | 74 |
| 5.14.1.3   | Multiplexing and assembly.....  | 75 |
| 5.14.1.3.1 | Logical channel prioritization.....   | 75 |
| 5.14.1.3.2 | Multiplexing of MAC SDUs.....   | 76 |
| 5.14.1.4   | Buffer Status Reporting.....  | 76 |
| 5.14.1.5   | TX carrier (re-)selection for V2X sidelink communication.....                           | 78 |
| 5.14.2     | SL-SCH Data reception.....  | 79 |
| 5.14.2.1   | SCI reception.....  | 79 |
| 5.14.2.2   | Sidelink HARQ operation.....  | 79 |
| 5.14.2.2.1 | Sidelink HARQ Entity.....   | 79 |
| 5.14.2.2.2 | Sidelink process.....   | 80 |
| 5.14.2.3   | Disassembly and demultiplexing.....   | 80 |
| 5.15       | SL-DCH data transfer.....   | 80 |
| 5.15.1     | SL-DCH data transmission.....   | 80 |
| 5.15.1.1   | Resource allocation.....  | 80 |
| 5.15.1.2   | Sidelink HARQ operation.....  | 81 |
| 5.15.1.2.1 | Sidelink HARQ Entity.....   | 81 |
| 5.15.1.2.2 | Sidelink process.....   | 81 |
| 5.15.2     | SL-DCH data reception.....  | 82 |
| 5.15.2.1   | Sidelink HARQ operation.....  | 82 |
| 5.15.2.1.1 | Sidelink HARQ Entity.....   | 82 |
| 5.15.2.1.2 | Sidelink process.....   | 83 |
| 5.16       | SL-BCH data transfer.....   | 83 |
| 5.16.1     | SL-BCH data transmission.....   | 83 |
| 5.16.2     | SL-BCH data reception.....  | 83 |
| 5.17       | Data inactivity monitoring.....   | 83 |
| 5.18       | Recommended Bit Rate.....   | 84 |
| 5.19       | Activation/Deactivation of CSI-RS resources.....  | 84 |
| 5.20       | Preallocated uplink grant.....  | 85 |
| 5.21       | SC-PTM Stop Indication.....   | 85 |
| 5.22       | Entering Dormant SCell state.....   | 85 |
| 5.23       | Autonomous Uplink.....  | 87 |
| 5.24       | Activation/Deactivation of PDCP duplication.....  | 87 |
| 5.25       | Transmission of Downlink Channel Quality Report.....                                    | 87 |
| 6          | Protocol Data Units, formats and parameters.....  | 88 |
| 6.1        | Protocol Data Units.....  | 88 |
| 6.1.1      | General.....  | 88 |
| 6.1.2      | MAC PDU (DL-SCH and UL-SCH except transparent MAC and Random Access Response, MCH)..... | 89 |
| 6.1.3      | MAC Control Elements.....   | 90 |
| 6.1.3.1    | Buffer Status Report MAC Control Elements.....  | 90 |
| 6.1.3.1a   | Sidelink BSR MAC Control Elements.....  | 93 |
| 6.1.3.2    | C-RNTI MAC Control Element.....   | 94 |

|                               |  |            |
|-------------------------------|--|------------|
| 6.1.3.3                       | DRX Command MAC Control Element .....  | 95         |
| 6.1.3.4                       | UE Contention Resolution Identity MAC Control Element.....                       | 95         |
| 6.1.3.5                       | Timing Advance Command MAC Control Element.....                                  | 95         |
| 6.1.3.6                       | Power Headroom Report MAC Control Element .....                                  | 96         |
| 6.1.3.6a                      | Extended Power Headroom Report MAC Control Elements.....                         | 96         |
| 6.1.3.6b                      | Dual Connectivity Power Headroom Report MAC Control Element .....                | 99         |
| 6.1.3.7                       | MCH Scheduling Information MAC Control Element .....                             | 102        |
| 6.1.3.7a                      | Extended MCH Scheduling Information MAC Control Element .....                    | 102        |
| 6.1.3.8                       | Activation/Deactivation MAC Control Elements .....                               | 103        |
| 6.1.3.9                       | Long DRX Command MAC Control Element.....  | 104        |
| 6.1.3.10                      | Data Volume and Power Headroom Report MAC Control Element .....                  | 104        |
| 6.1.3.11                      | SPS confirmation MAC Control Element.....  | 105        |
| 6.1.3.12                      | SC-PTM Stop Indication MAC Control Element .....                                 | 105        |
| 6.1.3.13                      | Recommended bit rate MAC Control Element .....                                   | 106        |
| 6.1.3.14                      | Activation/Deactivation of CSI-RS resources MAC Control Element .....            | 107        |
| 6.1.3.15                      | Hibernation MAC Control Elements.....  | 108        |
| 6.1.3.16                      | AUL confirmation MAC Control Element .....                                       | 109        |
| 6.1.3.17                      | PDCP Duplication Activation/Deactivation MAC Control Element .....               | 110        |
| 6.1.3.18                      | Downlink Channel Quality Report Command MAC Control Element.....                 | 110        |
| 6.1.3.19                      | Downlink Channel Quality Report and AS RAI MAC Control Element.....              | 110        |
| 6.1.4                         | MAC PDU (transparent MAC).....   | 111        |
| 6.1.5                         | MAC PDU (Random Access Response).....  | 111        |
| 6.1.6                         | MAC PDU (SL-SCH).....  | 113        |
| 6.2                           | Formats and parameters.....  | 115        |
| 6.2.1                         | MAC header for DL-SCH, UL-SCH and MCH.....                                       | 115        |
| 6.2.2                         | MAC header for Random Access Response.....                                       | 118        |
| 6.2.3                         | MAC payload for Random Access Response.....                                      | 118        |
| 6.2.4                         | MAC header for SL-SCH .....  | 118        |
| 7                             | Variables and constants.....   | 120        |
| 7.1                           | RNTI values .....  | 120        |
| 7.2                           | Backoff Parameter values.....  | 121        |
| 7.3                           | PRACH Mask Index values.....   | 123        |
| 7.4                           | Subframe_Offset values .....   | 123        |
| 7.5                           | TTI_BUNDLE_SIZE values.....  | 123        |
| 7.6                           | DELTA_PREAMBLE values .....  | 123        |
| 7.7                           | HARQ RTT Timers.....   | 124        |
| 7.8                           | DL_REPETITION_NUMBER value.....  | 126        |
| 7.9                           | UL_REPETITION_NUMBER value.....  | 127        |
| <b>Annex A (normative):</b>   | <b>Handling of measurement gaps .....</b>  | <b>128</b> |
| <b>Annex B (normative):</b>   | <b>Contention resolution for RACH access.....</b>                                | <b>129</b> |
| <b>Annex C (informative):</b> | <b>Intended UE behaviour for DRX Timers .....</b>                                | <b>132</b> |
| <b>Annex D (normative):</b>   | <b>List of CRs Containing Early Implementable Features and Corrections .....</b> | <b>134</b> |
| <b>Annex E (informative):</b> | <b>Change history .....</b>  | <b>135</b> |
| History .....                 |  | 144        |

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# 1 Scope

The present document specifies the E-UTRA MAC protocol.

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# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
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- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer Procedures".
- [3] 3GPP TS 36.322: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification".
- [4] 3GPP TS 36.323: "Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) Specification".
- [5] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".
- [6] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".  
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- [7] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation".
- [8] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".
- [9] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".
- [10] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".
- [11] 3GPP TS 36.216: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer for relaying operation".
- [12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".
- [13] 3GPP TS 23.303: "Proximity-based services (ProSe); Stage 2".
- [14] 3GPP TS 23.285: "Architecture enhancements for V2X services".
- [15] 3GPP TS 24.386: "User Equipment (UE) to V2X control function; protocol aspects; Stage 3".
- [16] 3GPP TS 26.114: "IP Multimedia Subsystem (IMS); Multimedia telephony; Media handling and interaction".
- [17] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".



- [18] 3GPP TS 38.213: "NR; Physical Layer Procedures for control".
- [19] 3GPP TS 38.133: "NR; Requirements for support of radio resource management".
- [20] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRAN); Overall description; Stage 2".
- [21] 3GPP TS 38.101-3: "NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios".
- [22] 3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities".
- [23] 3GPP TS 23.287: "Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services".
- [24] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification".
- [25] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

## 3 Definitions and abbreviations

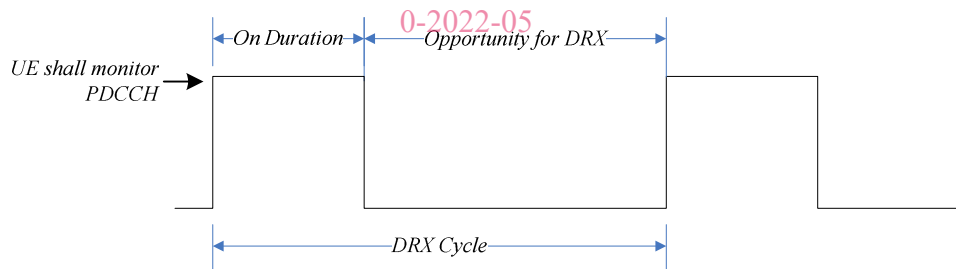
### 3.1 Definitions

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

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

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

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



**Figure 3.1-1: DRX Cycle**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- For serving cells operating according to Frame structure Type 3, all subframes represent PDCCH-subframes.
- For RNs with an RN subframe configuration configured and not suspended, in its communication with the E-UTRAN, all downlink subframes configured for RN communication with the E-UTRAN represent PDCCH-subframes.
- For SC-PTM reception on an FDD cell, all subframes except MBSFN subframes represent PDCCH-subframes, unless specified otherwise in this clause.
- For SC-PTM reception on a TDD cell, all downlink subframes and subframes including DwPTS of the TDD UL/DL configuration indicated by *tdd-Config*, as specified in TS 36.331 [8] of the cell except MBSFN subframes represent PDCCH-subframes, unless specified otherwise in this clause.
- For BL UE or UE in enhanced coverage, all subframes in which the UE is required to monitor MPDCCH represent PDCCH-subframes among all valid subframes regardless of whether the subframe is dropped, see clause 9.1.5 of TS 36.213 [2].
- For NB-IoT UE, all subframes that are part of the NPDCCH search space represent PDCCH-subframes among all NB-IoT downlink subframes, including those which the UE is not required to monitor as specified in clause 16.6 of TS 36.213 [2].

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

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

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

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

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

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

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

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

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

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

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

**Serving Cell:** A Primary or a Secondary Cell, see TS 36.331 [8].

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

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

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

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

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

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

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

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

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

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

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

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

## 3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

|            |  |
|------------|--|
| AS         | Access Stratum   |
| AUL        | Autonomous Uplink  |
| BL         | Bandwidth reduced Low complexity                               |
| BR         | Bandwidth Reduced  |
| BSR        | Buffer Status Report   |
| C-RNTI     | Cell RNTI  |
| CBR        | Channel Busy Ratio   |
| CC-RNTI    | Common Control RNTI  |
| CG         | Cell Group   |
| CQI        | Channel Quality Indicator                                      |
| CRI        | CSI-RS Resource Indicator                                      |
| CSI        | Channel State Information                                      |
| DAPS       | Dual Active Protocol Stack                                     |
| DCQR       | Downlink Channel Quality Report                                |
| DRB        | Data Radio Bearer  |
| EDT        | Early Data Transmission  |
| eIMTA      | Enhanced Interference Management and Traffic Adaptation        |
| eIMTA-RNTI | Enhanced Interference Management and Traffic Adaptation - RNTI |
| E-UTRA     | Evolved UMTS Terrestrial Radio Access                          |
| E-UTRAN    | Evolved UMTS Terrestrial Radio Access Network                  |
| G-RNTI     | Group RNTI   |
| H-SFN      | Hyper SFN  |
| MAC        | Medium Access Control  |
| MCG        | Master Cell Group  |
| M-RNTI     | MBMS RNTI  |
| MPDCCH     | MTC Physical Downlink Control Channel                          |
| LCG        | Logical Channel Group  |
| NB-IoT     | Narrow Band Internet of Things                                 |
| NPDCCH     | Narrowband Physical Downlink Control Channel                   |
| NPDSCH     | Narrowband Physical Downlink Shared channel                    |
| NPRACH     | Narrowband Physical Random Access Control Channel              |
| NPUSCH     | Narrowband Physical Uplink Shared channel                      |

|                |   |
|----------------|---|
| PCell          | Primary Cell  |
| PSCell         | Primary Secondary Cell                                      |
| PHR            | Power Headroom Report                                       |
| PMI            | Precoding Matrix Index                                      |
| PPPP           | ProSe Per-Packet Priority                                   |
| P-RNTI         | Paging RNTI   |
| ProSe          | Proximity-based Services                                    |
| pTAG           | Primary Timing Advance Group                                |
| PTI            | Precoding Type Indicator                                    |
| PUR            | Preconfigured Uplink Resource                               |
| RA-RNTI        | Random Access RNTI  |
| RAI            | Release Assistance Indication                               |
| RI             | Rank Indicator  |
| RN             | Relay Node  |
| RNTI           | Radio Network Temporary Identifier                          |
| SCell          | Secondary Cell  |
| SC-FDM         | Single-Carrier Frequency Division Multiplexing              |
| SCG            | Secondary Cell Group  |
| SCI            | Sidelink Control Information                                |
| SC-N-RNTI      | Single Cell Notification RNTI                               |
| SC-PTM         | Single Cell Point to Multipoint                             |
| SC-RNTI        | Single Cell RNTI  |
| SI-RNTI        | System Information RNTI                                     |
| SL             | Sidelink  |
| SL-RNTI        | Sidelink RNTI   |
| SL-V-RNTI      | Sidelink V2X RNTI   |
| SR             | Scheduling Request  |
| SRS            | Sounding Reference Symbols                                  |
| SRS-TPC-RNTI   | Sounding Reference Symbols-Transmit Power Control-RNTI      |
| SpCell         | Special Cell  |
| sTAG           | Secondary Timing Advance Group                              |
| sTTI           | Slot or subslot TTI   |
| TAG            | Timing Advance Group  |
| TB             | Transport Block   |
| TPC-PUCCH-RNTI | Transmit Power Control-Physical Uplink Control Channel-RNTI |
| TPC-PUSCH-RNTI | Transmit Power Control-Physical Uplink Shared Channel-RNTI  |
| V2X            | Vehicle-to-Everything                                       |

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## 4 General

### 4.1 Introduction

The objective is to describe the MAC architecture and the MAC entity from a functional point of view. Functionality specified for the UE equally applies to the RN for functionality necessary for the RN. There is also functionality which is only applicable to the RN, in which case the specification denotes the RN instead of the UE. RN-specific behaviour is not applicable to the UE. For TDD operation, UE behaviour follows the TDD UL/DL configuration indicated by *tdd-Config* unless specified otherwise.

The introduction of short TTI allows for more than a single instance of a TTI to occur within a 1ms subframe and as such the use of the term "for each TTI" shall be read as meaning that the associated actions shall be executed for all TTIs also in the case of overlapping TTIs (e.g. a UE may read multiple instances of PDCCH in a downlink subframe).

### 4.2 MAC architecture

The description in this clause is a model and does not specify or restrict implementations.

RRC is in control of configuration of MAC.

## 4.2.1 MAC Entities

E-UTRA defines two MAC entities; one in the UE and one in the E-UTRAN. These MAC entities handle the following transport channels:

- Broadcast Channel (BCH);
- Downlink Shared Channel(s) (DL-SCH);
- Paging Channel (PCH);
- Uplink Shared Channel(s) (UL-SCH);
- Random Access Channel(s) (RACH);
- Multicast Channel(s) (MCH);
- Sidelink Broadcast Channel (SL-BCH);
- Sidelink Discovery Channel (SL-DCH);
- Sidelink Shared Channel (SL-SCH).

The exact functions performed by the MAC entities are different in the UE from those performed in the E-UTRAN.

The RN includes both types of MAC entities; one type for communication with UEs and one type for communication with the E-UTRAN.

In Dual Connectivity, two MAC entities are configured in the UE: one for the MCG and one for the SCG. In DAPS handover, two MAC entities are configured in the UE: one MAC entity for the source cell (source MAC entity) and one MAC entity for the target cell (target MAC entity). Each MAC entity is configured by RRC with a serving cell supporting PUCCH transmission and contention based Random Access. In this specification, the term SpCell refers to such cell, whereas the term SCell refers to other serving cells. The term SpCell either refers to the PCell of the MCG or the PSCell of the SCG depending on if the MAC entity is associated to the MCG or the SCG, respectively. A Timing Advance Group containing the SpCell of a MAC entity is referred to as pTAG, whereas the term sTAG refers to other TAGs.

The functions of the different MAC entities in the UE operate independently, if not otherwise indicated. The timers and parameters used in each MAC entity are configured independently if not otherwise indicated. The Serving Cells, C-RNTI, radio bearers, logical channels, upper and lower layer entities, LCGs, and HARQ entities considered by each MAC entity refer to those mapped to that MAC entity if not otherwise indicated.

If the MAC entity is configured with one or more SCells, there are multiple DL-SCH and there may be multiple UL-SCH and RACH per MAC entity; one DL-SCH, one UL-SCH, and one RACH on the SpCell, one DL-SCH, zero or one UL-SCH and zero or one RACH for each SCell.

The physical layer may perform a listen-before-talk procedure, according to which transmissions are not performed if the channel is identified as being occupied or the physical layer may monitor for PUSCH trigger, as specified in TS 36.213 [2], according to which transmissions are not performed if PUSCH trigger B is not received. In both cases a MAC entity considers the transmission to have been performed anyway, unless stated otherwise.

Figure 4.2.1-1 illustrates one possible structure for the UE side MAC entity when SCG is not configured and for each MAC entity during DAPS handover, and it should not restrict implementation.



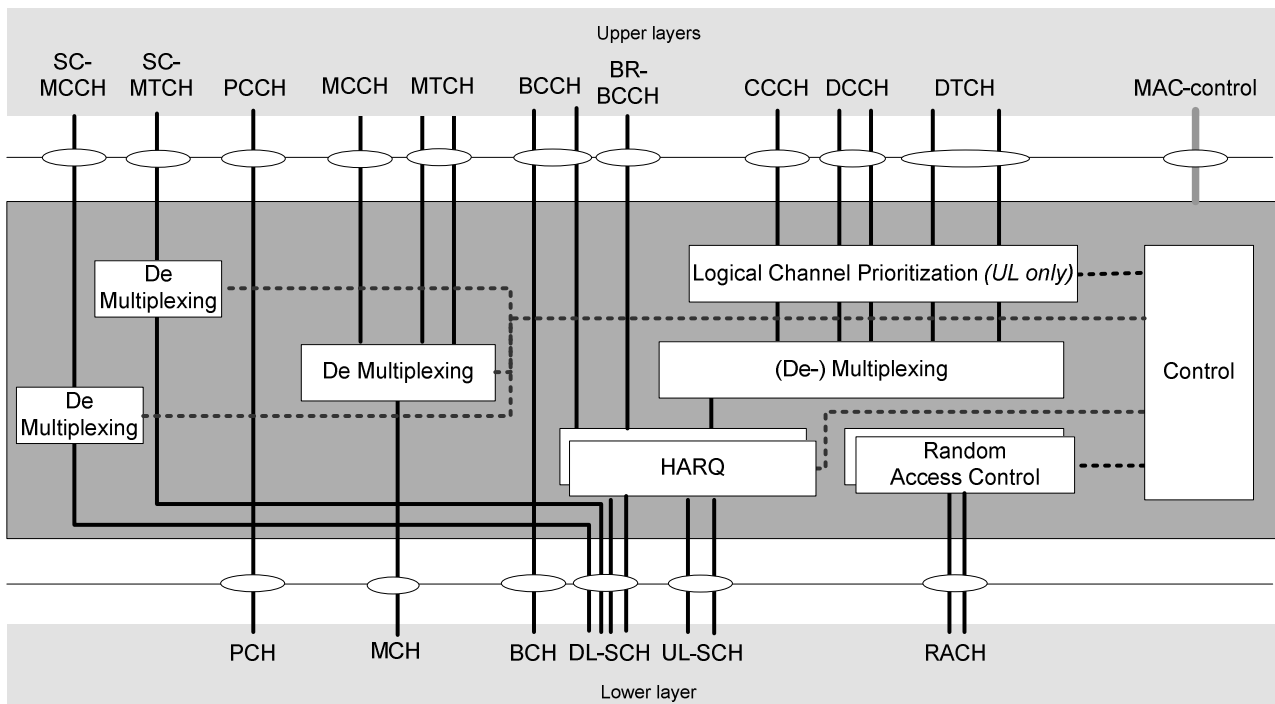


Figure 4.2.1-1: MAC structure overview, UE side

Figure 4.2.1-2 illustrates one possible structure for the UE side MAC entities when MCG and SCG are configured, and it should not restrict implementation. MBMS reception and SC-PTM reception are excluded from this figure for simplicity.

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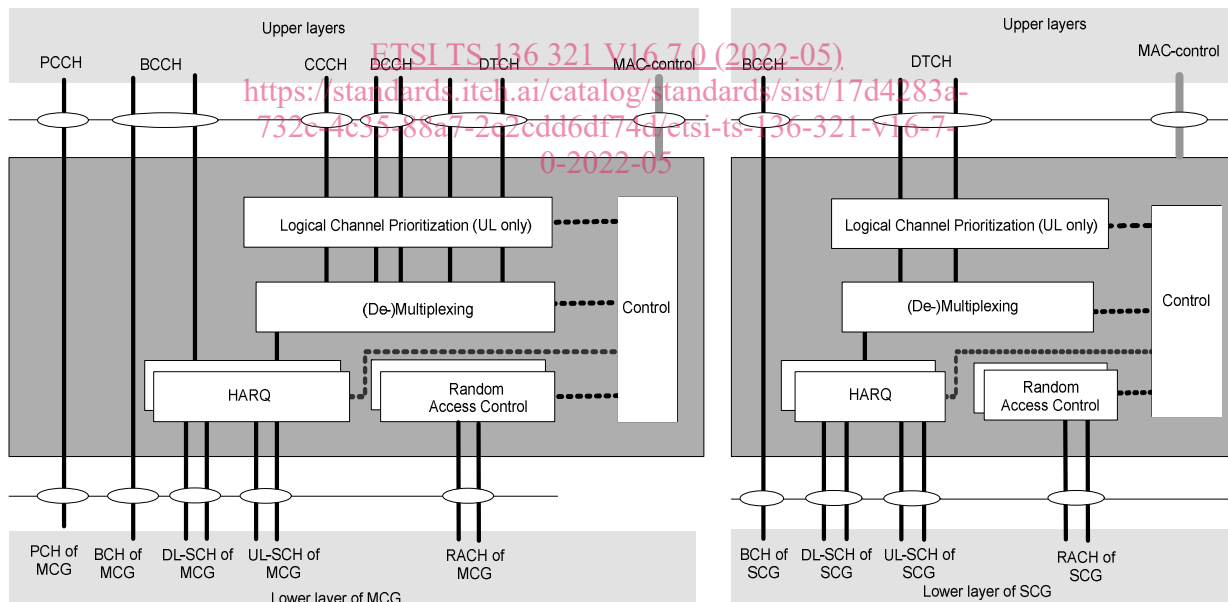


Figure 4.2.1-2: MAC structure overview with two MAC entities, UE side

Figure 4.2.1-3 illustrates one possible structure for the UE side MAC entity when sidelink is configured, and it should not restrict implementation.