

ETSI TS 138 321 V15.4.0 (2019-04)



**5G;
NR;
Medium Access Control (MAC) protocol specification
(3GPP TS 38.321 version 15.4.0 Release 15)**

STANDARD PREVIEW
(standard: 3GPP)
Full standards: <https://standards.iteh.ai/catalog/standards/sist/c0b5263-82c6-48ee-8599-7f5e5b89ecee/etsi-ts-138-321-v15-4-0-2019-04>



Reference

RTS/TSGR-0238321vf40

Keywords

5G

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Contents

Intellectual Property Rights	2
Foreword.....	2
Modal verbs terminology.....	2
Foreword.....	6
1 Scope	7
2 References	7
3 Definitions, symbols and abbreviations	8
3.1 Definitions	8
3.2 Abbreviations	8
4 General	9
4.1 Introduction	9
4.2 MAC architecture	9
4.2.1 General.....	9
4.2.2 MAC Entities	9
4.3 Services	10
4.3.1 Services provided to upper layers	10
4.3.2 Services expected from physical layer.....	11
4.4 Functions	11
4.5 Channel structure.....	11
4.5.1 General.....	11
4.5.2 Transport Channels	11
4.5.3 Logical Channels	12
4.5.4 Mapping of Transport Channels to Logical Channels	12
4.5.4.1 General	12
4.5.4.2 Uplink mapping.....	12
4.5.4.3 Downlink mapping.....	12
5 MAC procedures	12
5.1 Random Access procedure	12
5.1.1 Random Access procedure initialization.....	12
5.1.2 Random Access Resource selection.....	15
5.1.3 Random Access Preamble transmission	18
5.1.4 Random Access Response reception.....	18
5.1.5 Contention Resolution	20
5.1.6 Completion of the Random Access procedure.....	22
5.2 Maintenance of Uplink Time Alignment.....	22
5.3 DL-SCH data transfer.....	23
5.3.1 DL Assignment reception	23
5.3.2 HARQ operation.....	25
5.3.2.1 HARQ Entity.....	25
5.3.2.2 HARQ process	25
5.3.3 Disassembly and demultiplexing	26
5.4 UL-SCH data transfer.....	26
5.4.1 UL Grant reception	26
5.4.2 HARQ operation.....	28
5.4.2.1 HARQ Entity.....	28
5.4.2.2 HARQ process	29
5.4.3 Multiplexing and assembly	30
5.4.3.1 Logical Channel Prioritization	30
5.4.3.1.1 General	30
5.4.3.1.2 Selection of logical channels	30
5.4.3.1.3 Allocation of resources.....	31
5.4.3.2 Multiplexing of MAC Control Elements and MAC SDUs	32
5.4.4 Scheduling Request.....	32
5.4.5 Buffer Status Reporting	33

5.4.6	Power Headroom Reporting	35
5.5	PCH reception	37
5.6	BCH reception	37
5.7	Discontinuous Reception (DRX)	37
5.8	Transmission and reception without dynamic scheduling	40
5.8.1	Downlink	40
5.8.2	Uplink	40
5.9	Activation/Deactivation of SCells	42
5.10	Activation/Deactivation of PDCP duplication	43
5.11	MAC reconfiguration	43
5.12	MAC Reset	43
5.13	Handling of unknown, unforeseen and erroneous protocol data	44
5.14	Handling of measurement gaps	44
5.15	Bandwidth Part (BWP) operation	44
5.16	SUL operation	47
5.17	Beam Failure Detection and Recovery procedure	47
5.18	Handling of MAC CEs	48
5.18.1	General	48
5.18.2	Activation/Deactivation of Semi-persistent CSI-RS/CSI-IM resource set	48
5.18.3	Aperiodic CSI Trigger State subselection	49
5.18.4	Activation/Deactivation of UE-specific PDSCH TCI state	49
5.18.5	Indication of TCI state for UE-specific PDCCH	49
5.18.6	Activation/Deactivation of Semi-persistent CSI reporting on PUCCH	49
5.18.7	Activation/Deactivation of Semi-persistent SRS	49
5.18.8	Activation/Deactivation of spatial relation of PUCCH resource	50
5.18.9	Activation/Deactivation of semi-persistent ZP CSI-RS resource set	50
5.18.10	Recommended Bit Rate	50
5.19	Data inactivity monitoring	51
6	Protocol Data Units, formats and parameters	51
6.1	Protocol Data Units	51
6.1.1	General	51
6.1.2	MAC PDU (DL-SCH and UL-SCH except transparent MAC and Random Access Response)	51
6.1.3	MAC Control Elements (CEs)	53
6.1.3.1	Buffer Status Report MAC CEs	53
6.1.3.2	C-RNTI MAC CE	57
6.1.3.3	UE Contention Resolution Identity MAC CE	57
6.1.3.4	Timing Advance Command MAC CE	57
6.1.3.5	DRX Command MAC CE	58
6.1.3.6	Long DRX Command MAC CE	58
6.1.3.7	Configured Grant Confirmation MAC CE	58
6.1.3.8	Single Entry PHR MAC CE	58
6.1.3.9	Multiple Entry PHR MAC CE	59
6.1.3.10	SCell Activation/Deactivation MAC CEs	61
6.1.3.11	Duplication Activation/Deactivation MAC CE	62
6.1.3.12	SP CSI-RS / CSI-IM Resource Set Activation/Deactivation MAC CE	62
6.1.3.13	Aperiodic CSI Trigger State Subselection MAC CE	63
6.1.3.14	TCI States Activation/Deactivation for UE-specific PDSCH MAC CE	64
6.1.3.15	TCI State Indication for UE-specific PDCCH MAC CE	64
6.1.3.16	SP CSI reporting on PUCCH Activation/Deactivation MAC CE	65
6.1.3.17	SP SRS Activation/Deactivation MAC CE	65
6.1.3.18	PUCCH spatial relation Activation/Deactivation MAC CE	67
6.1.3.19	SP ZP CSI-RS Resource Set Activation/Deactivation MAC CE	68
6.1.3.20	Recommended bit rate MAC CE	68
6.1.4	MAC PDU (transparent MAC)	69
6.1.5	MAC PDU (Random Access Response)	69
6.2	Formats and parameters	70
6.2.1	MAC subheader for DL-SCH and UL-SCH	70
6.2.2	MAC subheader for Random Access Response	71
6.2.3	MAC payload for Random Access Response	72
7	Variables and constants	72

7.1 RNTI values72
7.2 Backoff Parameter values.....73
7.3 DELTA_PREAMBLE values74
7.4 PRACH Mask Index values.....74

Annex A (informative): Change history75
History78

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1 Scope

The present document specifies the NR MAC protocol.

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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- [1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
- [2] 3GPP TS 38.300: "NR; Overall description; Stage 2".
- [3] 3GPP TS 38.322: "NR; Radio Link Control (RLC) protocol specification".
- [4] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) protocol specification".
- [5] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".
- [6] 3GPP TS 38.213: "NR; Physical Layer Procedures for control".
- [7] 3GPP TS 38.214: "NR; Physical Layer Procedures for data".
- [8] 3GPP TS 38.211: "NR; Physical channels and modulation".
- [9] 3GPP TS 38.212: "NR; Multiplexing and channel coding".
- [10] Void.
- [11] 3GPP TS 38.133: "NR; Requirements for support of radio resource management".
- [12] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".
- [13] 3GPP TS 26.114: "Technical Specification Group Services and System Aspects; IP Multimedia Subsystem (IMS); Multimedia Telephony; Media handling and interaction".
- [14] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".
- [15] 3GPP TS 38.101-2: "NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".
- [16] 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".
- [17] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer Procedures".

3 Definitions, symbols 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].

HARQ information: HARQ information for DL-SCH or for UL-SCH transmissions consists of New Data Indicator (NDI), Transport Block size (TBS), Redundancy Version (RV), and HARQ process ID.

Msg3: Message transmitted on UL-SCH containing a C-RNTI MAC CE or CCCH SDU, submitted from upper layer and associated with the UE Contention Resolution Identity, as part of a Random Access procedure.

PDCCH occasion: A time duration (i.e. one or a consecutive number of symbols) during which the MAC entity is configured to monitor the PDCCH.

Serving Cell: A PCell, a PSCell, or an SCell in TS 38.331 [5].

Special Cell: For Dual Connectivity operation the term Special Cell 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. Otherwise the term Special Cell refers to the PCell. A Special Cell supports PUCCH transmission and contention-based Random Access, and is always activated.

Timing Advance Group: A group of Serving Cells that is configured by RRC and that, for the cells with a UL configured, using the same timing reference cell and the same Timing Advance value. A Timing Advance Group containing the SpCell of a MAC entity is referred to as Primary Timing Advance Group (PTAG), whereas the term Secondary Timing Advance Group (STAG) refers to other TAGs.

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. The duration of a timer is not updated until they are stopped or expires (e.g. due to BWP switching).

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].

BSR	Buffer Status Report
BWP	Bandwidth Part
CE	Control Element
CSI	Channel State Information
CSI-IM	CSI Interference Measurement
CSI-RS	CSI Reference Signal
CS-RNTI	Configured Scheduling RNTI
INT-RNTI	Interruption RNTI
LCG	Logical Channel Group
LCP	Logical Channel Prioritization
MCG	Master Cell Group
NUL	Normal Uplink
NZP CSI-RS	Non-Zero Power CSI-RS
PHR	Power Headroom Report
PTAG	Primary Timing Advance Group
QCL	Quasi-colocation
RS	Reference Signal
SCG	Secondary Cell Group
SFI-RNTI	Slot Format Indication RNTI
SI	System Information
SpCell	Special Cell
SP	Semi-Persistent
SP-CSI-RNTI	Semi-Persistent CSI RNTI

SPS	Semi-Persistent Scheduling
SR	Scheduling Request
SS	Synchronization Signals
SSB	Synchronization Signal Block
STAG	Secondary Timing Advance Group
SUL	Supplementary Uplink
TAG	Timing Advance Group
TCI	Transmission Configuration Indicator
TPC-SRS-RNTI	Transmit Power Control-Sounding Reference Symbols-RNTI
ZP CSI-RS	Zero Power CSI-RS

4 General

4.1 Introduction

The objective of this section is to describe the MAC architecture and the MAC entity of the UE from a functional point of view.

4.2 MAC architecture

4.2.1 General

This subclause describes a model of the MAC i.e. it does not specify or restrict implementations.

RRC is in control of the MAC configuration.

4.2.2 MAC Entities

The MAC entity of the UE handles 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);

When the UE is configured with SCG, two MAC entities are configured to the UE: one for the MCG and one for the SCG.

The functions of the different MAC entities in the UE operate independently unless otherwise specified. The timers and parameters used in each MAC entity are configured independently unless otherwise specified. 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 unless otherwise specified.

If the MAC entity is configured with one or more SCells, there are multiple DL-SCH and there may be multiple UL-SCH as well as multiple 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.

If the MAC entity is not configured with any SCell, there is one DL-SCH, one UL-SCH, and one RACH per MAC entity.

Figure 4.2.2-1 illustrates one possible structure of the MAC entity when SCG is not configured.

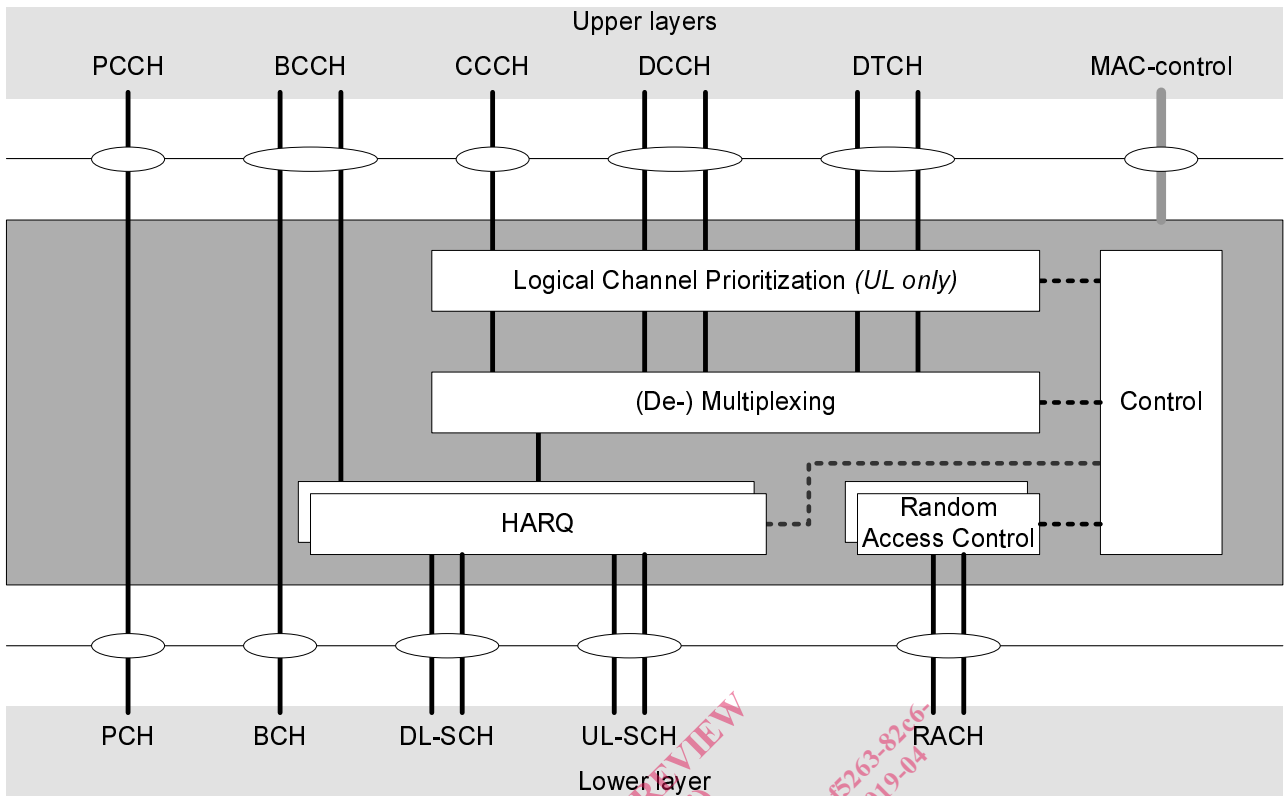


Figure 4.2.2-1: MAC structure overview

Figure 4.2.2-2 illustrates one possible structure for the MAC entities when MCG and SCG are configured.

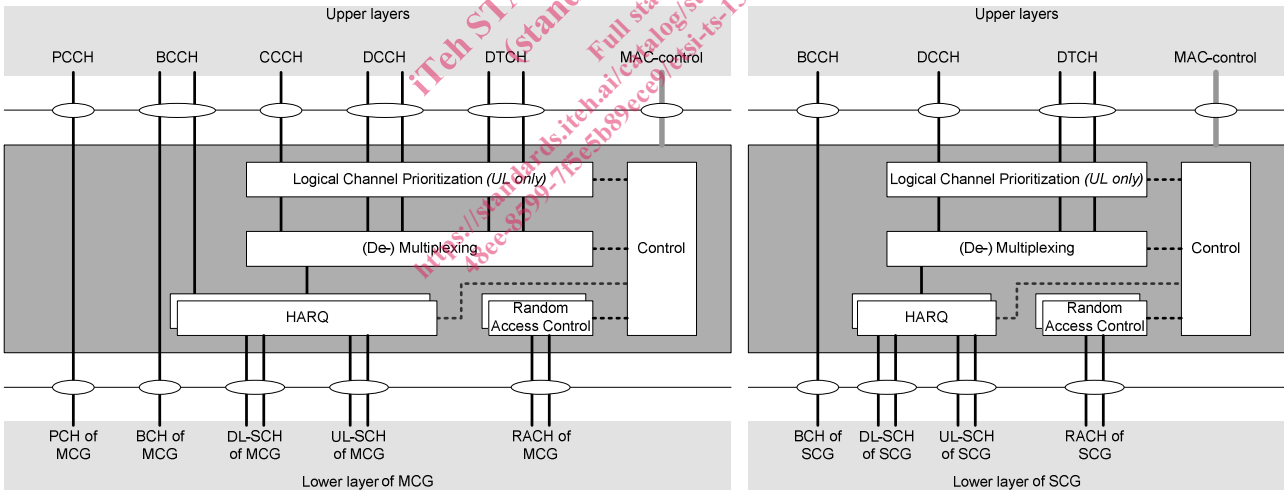


Figure 4.2.2-2: MAC structure overview with two MAC entities

4.3 Services

4.3.1 Services provided to upper layers

The MAC sublayer provides the following services to upper layers:

- data transfer;
- radio resource allocation.

4.3.2 Services expected from physical layer

The MAC sublayer expects the following services from the physical layer:

- data transfer services;
- signalling of HARQ feedback;
- signalling of Scheduling Request;
- measurements (e.g. Channel Quality Indication (CQI)).

4.4 Functions

The MAC sublayer supports the following functions:

- mapping between logical channels and transport channels;
- multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels;
- demultiplexing of MAC SDUs to one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels;
- scheduling information reporting;
- error correction through HARQ;
- logical channel prioritisation.

The relevance of MAC functions for uplink and downlink is indicated in Table 4.4-1.

Table 4.4-1: The link direction association of MAC functions.

MAC function	Downlink	Uplink
Mapping between logical channels and transport channels	X	X
Multiplexing		X
Demultiplexing	X	
Scheduling information reporting		X
Error correction through HARQ	X	X
Logical Channel prioritisation		X

4.5 Channel structure

4.5.1 General

The MAC sublayer operates on the channels defined below; transport channels are SAPs between MAC and Layer 1, logical channels are SAPs between MAC and RLC.

4.5.2 Transport Channels

The MAC sublayer uses the transport channels listed in Table 4.5.2-1 below.

Table 4.5.2-1: Transport channels used by MAC

Transport channel name	Acronym	Downlink	Uplink
Broadcast Channel	BCH	X	
Downlink Shared Channel	DL-SCH	X	
Paging Channel	PCH	X	
Uplink Shared Channel	UL-SCH		X
Random Access Channel	RACH		X

4.5.3 Logical Channels

The MAC sublayer provides data transfer services on logical channels. To accommodate different kinds of data transfer services, multiple types of logical channels are defined i.e. each supporting transfer of a particular type of information.

Each logical channel type is defined by what type of information is transferred.

The MAC sublayer provides the control and traffic channels listed in Table 4.5.3-1 below.

Table 4.5.3-1: Logical channels provided by MAC.

Logical channel name	Acronym	Control channel	Traffic channel
Broadcast Control Channel	BCCH	X	
Paging Control Channel	PCCH	X	
Common Control Channel	CCCH	X	
Dedicated Control Channel	DCCH	X	
Dedicated Traffic Channel	DTCH		X

4.5.4 Mapping of Transport Channels to Logical Channels

4.5.4.1 General

Both for uplink and downlink, the MAC entity is responsible for mapping logical channels onto transport channels. This mapping depends on the multiplexing that is configured by RRC.

4.5.4.2 Uplink mapping

The uplink logical channels can be mapped as described in Table 4.5.4.2-1.

Table 4.5.4.2-1: Uplink channel mapping.

Logical channel \ Transport channel	UL-SCH	RACH
CCCH	X	
DCCH	X	
DTCH	X	

4.5.4.3 Downlink mapping

The downlink logical channels can be mapped as described in Table 4.5.4.3-1.

Table 4.5.4.3-1: Downlink channel mapping.

Logical channel \ Transport channel	BCH	PCH	DL-SCH
BCCH	X		X
PCCH		X	
CCCH			X
DCCH			X
DTCH			X

5 MAC procedures

5.1 Random Access procedure

5.1.1 Random Access procedure initialization

The Random Access procedure described in this subclause is initiated by a PDCCH order, by the MAC entity itself, or by RRC for the events in accordance with TS 38.300 [2]. There is only one Random Access procedure ongoing at any