ETSI TS 138 321 V16.22.0 (2026-02)

TECHNICAL SPECIFICATION

5G;
NR;
Medium Access Control (MAC) protocol specification
(3GPP TS 38.321 version 16.22.0 Release 16)

Reference
RTS/TSGR-0238321vgm0

Keywords
5G

ETSI

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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

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- z the third digit is incremented when editorial only changes have been incorporated in the document.

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.
- For a specific reference, subsequent revisions do not apply.
- 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 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".

[18] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access".

[19] 3GPP TS 23.287: "Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services ".

[20] 3GPP TS 23.285: "Architecture enhancements for V2X services".

[21] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".

[22] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC); Protocol specification".

[23] 3GPP TS 37.355: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP)".

[24] 3GPP TS 38.215: "NR; Physical layer measurements".

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].

Dormant BWP: The dormant BWP is one of downlink BWPs configured by the network via dedicated RRC signalling. In the dormant BWP, the UE stop monitoring PDCCH on/for the SCell, but continues performing CSI measurements, Automatic Gain Control (AGC) and beam management, if configured.

DRX group: A group of Serving Cells that is configured by RRC and that have the same DRX Active Time.

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

IAB-donor: gNB that provides network access to UEs via a network of backhaul and access links.

IAB-node: RAN node that supports NR access links to UEs and NR backhaul links to parent nodes and child nodes.

Listen Before Talk: A procedure according to which transmissions are not performed if the channel is identified as being occupied, see TS 37.213 [18].

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.

NR backhaul link: NR link used for backhauling between an IAB-node and an IAB-donor, and between IAB-nodes in case of a multi-hop backhauling.

NR sidelink communication: AS functionality enabling at least V2X Communication as defined in TS 23.287 [19], between two or more nearby UEs, using NR technology but not traversing any network node.

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].

Sidelink transmission information: Sidelink transmission information included in an SCI for an SL-SCH transmission as specified in clause 8.3 and 8.4 of TS 38.212 [9] consists of Sidelink HARQ information including NDI, RV, Sidelink process ID, HARQ feedback enabled/disabled indicator, Sidelink identification information including cast type indicator, Source Layer-1 ID and Destination Layer-1 ID, and Sidelink other information including CSI request, a priority, a communication range requirement and Zone ID.

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.

V2X sidelink communication: AS functionality enabling V2X Communication as defined in TS 23.285 [20], between nearby UEs, using E-UTRA technology but not traversing any network node.

NOTE 1: 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 it is stopped or expires (e.g. due to BWP switching). When the MAC entity applies zero value for a timer, the timer shall be started and immediately expire unless explicitly stated otherwise.

NOTE 2: In this version of the specification, the SRS in the procedural description includes Positioning SRS and Positioning SRS is treated the same as SRS by the UE unless explicitly stated otherwise.

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].

AP	Aperiodic
BFR	Beam Failure Recovery
BSR	Buffer Status Report
BWP	Bandwidth Part
CE	Control Element
CG	Cell Group
CI-RNTI	Cancellation Indication RNTI
CSI	Channel State Information
CSI-IM	CSI Interference Measurement
CSI-RS	CSI Reference Signal
CS-RNTI	Configured Scheduling RNTI
DAPS	Dual Active Protocol Stack
DCP	DCI with CRC scrambled by PS-RNTI
DL-PRS	DownLink-Positioning Reference Signal
IAB	Integrated Access and Backhaul
INT-RNTI	Interruption RNTI
LBT	Listen Before Talk
LCG	Logical Channel Group
LCP	Logical Channel Prioritization
MCG	Master Cell Group
MPE	Maximum Permissible Exposure
NUL	Normal Uplink
NZP CSI-RS	Non-Zero Power CSI-RS
PDB	Packet Delay Budget
PHR	Power Headroom Report
PS-RNTI	Power Saving RNTI
PTAG	Primary Timing Advance Group
QCL	Quasi-colocation
RS	Reference Signal
SCG	Secondary Cell Group
SFI-RNTI	Slot Format Indication RNTI
SI	System Information
SL-RNTI	Sidelink RNTI
SL-CS-RNTI	Sidelink Configured Scheduling RNTI
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 Signal-RNTI
UCI	Uplink Control Information
V2X	Vehicle-to-Everything
ZP CSI-RS	Zero Power CSI-RS

4 General

4.1 Introduction

The objective of this clause 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 clause 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.

When the UE is configured with DAPS handover, two MAC entities are used by the UE: one for the source cell (source MAC entity) and one for the target cell (target MAC entity).

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 and for each MAC entity during DAPS handover.

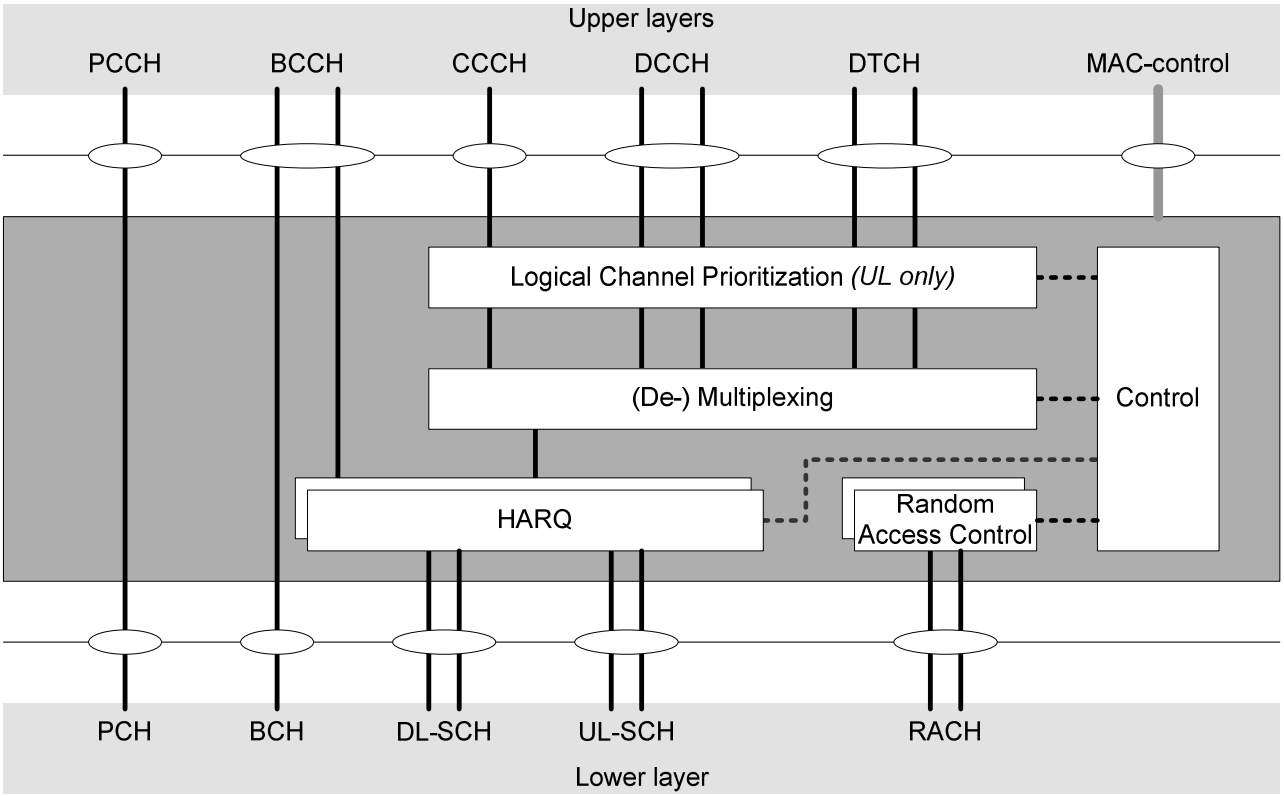

Figure 4.2.2-1: MAC structure overview

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

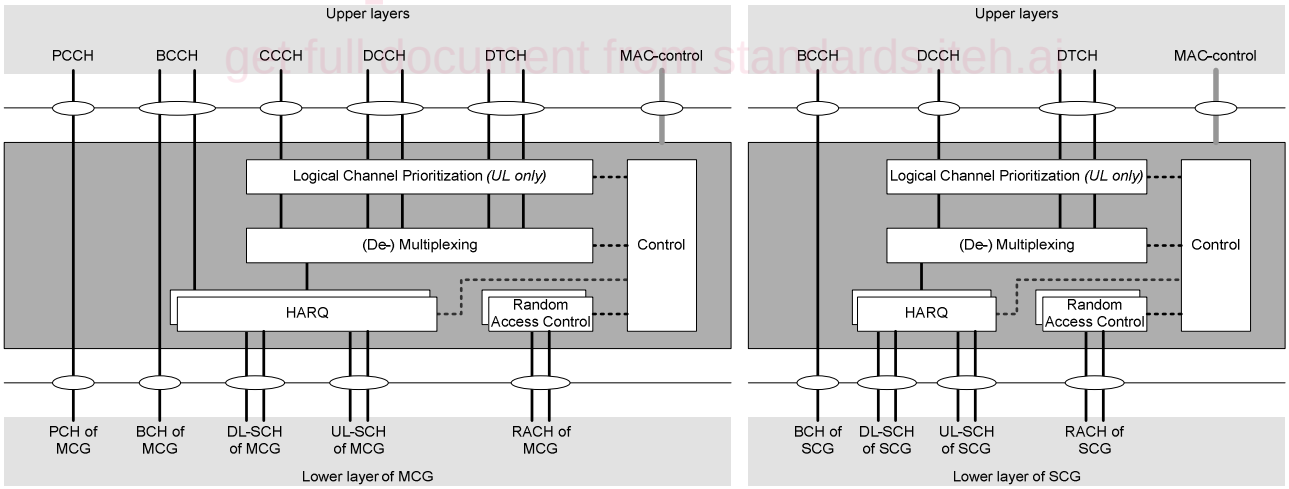

Figure 4.2.2-2: MAC structure overview with two MAC entities

In addition, the MAC entity of the UE handles the following transport channel for sidelink:

- Sidelink Shared Channel (SL-SCH);
- Sidelink Broadcast Channel (SL-BCH).

Figure 4.2.2-3 illustrates one possible structure for the MAC entity when sidelink is configured.

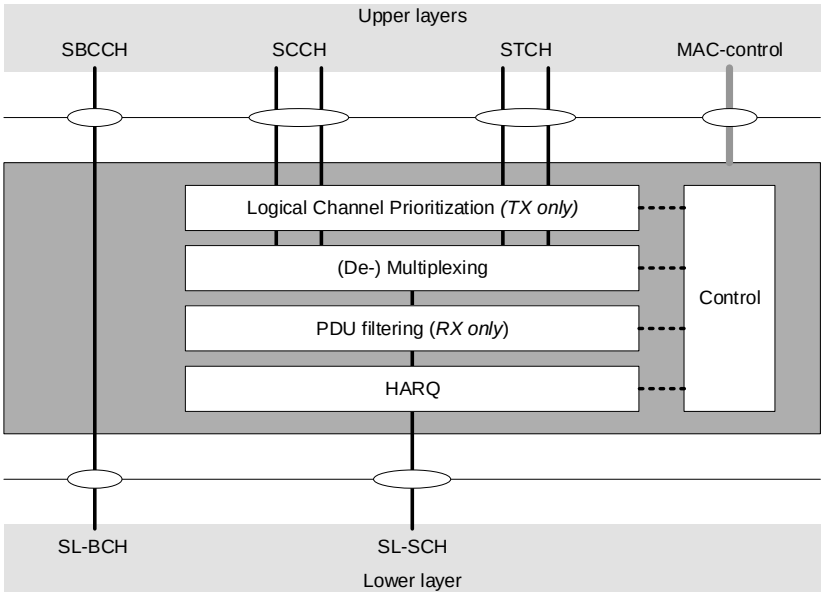

Figure 4.2.2-3: MAC structure overview for sidelink

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 prioritization;

- priority handling between overlapping resources of one UE;
- radio resource selection.

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

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

MAC function	Downlink	Uplink	Sidelink TX	Sidelink RX
Mapping between logical channels and transport channels	X	X	X	X
Multiplexing		X	X	
Demultiplexing	X			X
Scheduling information reporting		X	X	
Error correction through HARQ	X	X	X	X
Logical Channel prioritization		X	X	
Radio resource selection			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	Sidelink
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	
Sidelink Broadcast Channel	SL-BCH			X
Sidelink Shared Channel	SL-SCH			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.