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Technical Specification

3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Physical layer; General description (Release 19)

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该技术规范的 PHY 层的基本内容

1、简单概述了物理层的功能

（针对多路访问，NTN 仅支持 FDD，在 38.101-5 中提到）

Keywords

3GPP, New Radio, Layer 1

图 1 是物理层周围的协议的架构（PHY、MAC、RRC）

2、38.200 其他协议的介绍（第五章）

图 2 是物理层规范之间的关系

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Foreword

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

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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x the first digit:

1 presented to TSG for information;

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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

1 Scope

The present document provides a general description of the physical layer of NR radio interface. The present document also describes the document structure of the 3GPP physical layer specifications, i.e. TS 38.200 series.

2 References

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

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TS 38.202: "NR; Services provided by the physical layer"

[3] 3GPP TS 38.211: "NR; Physical channels and modulation"

[4] 3GPP TS 38.212: "NR; Multiplexing and channel coding"

[5] 3GPP TS 38.213: "NR; Physical layer procedures for control"

[6] 3GPP TS 38.214: "NR; Physical layer procedures for data"

[7] 3GPP TS 38.215: "NR; Physical layer measurements"

[8] 3GPP TS 38.291: "NR; Ambient IoT Physical layer"

3 Definitions of terms, symbols and abbreviations

3.1 Terms

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].

Definition format

***<defined term>**: <definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format

<symbol> <Explanation>

3.3 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].

BPSK Binary Phase Shift Keying
CP Cyclic Prefix

DFT-s-OFDM	Discrete Fourier Transform-spread-Orthogonal Frequency Division Multiplexing
DU	Distributed Unit
E-UTRA	Evolved Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
FEC	Forward Error Correction
HARQ	Hybrid Automatic Repeat Request
IAB	Integrated Access and Backhaul
LDPC	Low Density Parity Check
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
MT	Mobile Termination
NCR	Network-Controlled Repeater
OFDM	Orthogonal Frequency Division Multiplexing
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRACH	Physical Random Access Channel
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSFCH	Physical Sidelink Feedback Channel
PSSCH	Physical Sidelink Shared Channel
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RLC	Radio Link Control
RRC	Radio Resource Control
SAP	Service Access Point
SRS	Sounding Reference Signal
TDD	Time Division Duplex
UE	User Equipment

4 General description of layer 1

4.1 Relation to other layers

4.1.1 General protocol architecture

The radio interface described in this specification covers the interface between the User Equipment (UE) and gNB, between gNBs, between IAB-node DU and IAB-node MT/UE, between gNB and NCR-MT, and between UEs. The radio interface is composed of the Layer 1, 2 and 3. The TS 38.200 series describes the Layer 1 (Physical Layer) specifications. Layers 2 and 3 are described in the 38.300 series.

本规范中描述的无线接口涵盖了用户设备（UE）与 gNB 之间、gNB 之间、IAB 节点 DU 与 IAB 节点 MT/UE 之间、gNB 与 NCR-MT 之间以及 UE 之间的接口。无线接口由第 1 层、2 层和 3 层组成。TS 38.200 系列描述了第 1 层（物理层）规范，第 2 层和第 3 层则在 38.300 系列中有所描述。

（IAB 是 Integrated Access and Backhaul（集成接入与回传）的缩写，它是一种网络架构，旨在通过在无线接入网络（RAN）中同时提供接入和回传功能来提高网络的效率。在 IAB 网络中，IAB 节点通过无线连接承载回传流量，同时提供接入服务给终端设备（如用户设备或 UE）。这种方式可以简化网络部署，尤其是在难以布设有线回传链路的地方。

NCR-MT 是 Non-Cellular Radio Mobile Terminal（非蜂窝无线移动终端）的缩写，它通常指不依赖传统蜂窝网络（如 LTE 或 5G NR）接入的终端设备。这类终端可能使用卫星通信、Wi-Fi 或其他非蜂窝技术进行连接。NCR-MT 在某些网络架构中可能用于特定场景，例如卫星接入或混合接入技术。）

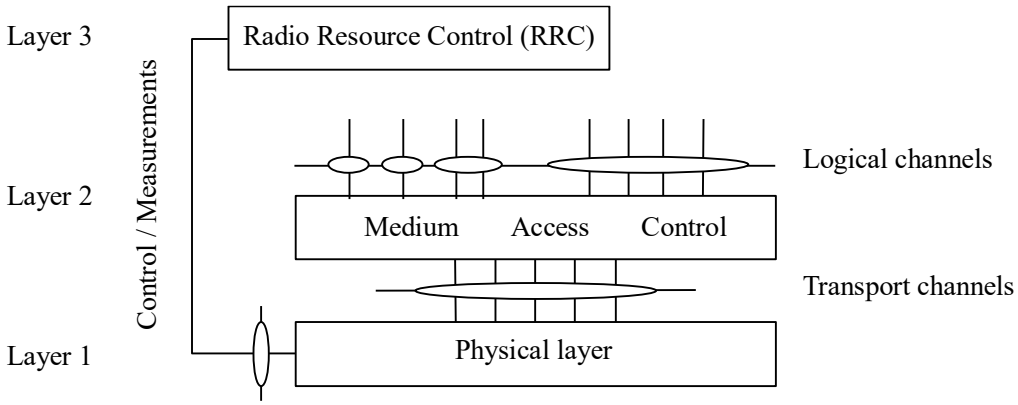

Figure 1: Radio interface protocol architecture around the physical layer

Figure 1 shows the NR radio interface protocol architecture around the physical layer (Layer 1). The physical layer interfaces the Medium Access Control (MAC) sub-layer of Layer 2 and the Radio Resource Control (RRC) Layer of Layer 3. The circles between different layer/sub-layers indicate Service Access Points (SAPs). The physical layer offers a transport channel to MAC. The transport channel is characterized by how the information is transferred over the radio interface. MAC offers different logical channels to the Radio Link Control (RLC) sub-layer of Layer 2. A logical channel is characterized by the type of information transferred.

图 1 显示了物理层（第 1 层）周围的 NR 无线接口协议架构。物理层与第 2 层的媒介接入控制（MAC）子层和第 3 层的无线资源控制（RRC）层相连接。不同层/子层之间的圆圈表示服务接入点（SAP）。物理层为 MAC 提供了一个传输信道。传输信道的特点是信息如何通过无线接口进行传输。MAC 为第 2 层的无线链路控制（RLC）子层提供不同的逻辑信道。逻辑信道的特点是传输的信息类型。

4.1.1A Protocol architecture for Ambient IoT

The radio interface described in this specification also covers the interface between device and reader. For the radio interface protocol architecture between device and reader, the physical layer interfaces the MAC sub-layer of Layer 2, and there is no RRC Layer of Layer 3. The physical layer offers two transport channels to MAC, one is for reader to device (R2D) and the other is for device to reader (D2R). Details are specified in [38.291, 38.391].

读卡器?

4.1.2 Service provided to higher layers

The physical layer offers data transport services to higher layers. The access to these services is through the use of a transport channel via the MAC sub-layer. Details are specified in [2].

物理层为更高层提供数据传输服务。访问这些服务是通过 MAC 子层使用传输信道来实现的。具体细节在 [2] 中进行了规定。

4.2 General description of layer 1

4.2.1 Multiple access

The multiple access scheme for the NR physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP). For uplink, Discrete Fourier Transform-spread-OFDM (DFT-s-OFDM) with a CP is also supported. To support transmission in paired and unpaired spectrum, both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are enabled.

The Layer 1 is defined in a bandwidth agnostic way based on resource blocks, allowing the NR Layer 1 to adapt to various spectrum allocations. A resource block spans 12 sub-carriers with a given sub-carrier spacing.

The radio frame has a duration of 10ms and consists of 10 sub-frames with a sub-frame duration of 1ms. A sub-frame is formed by one or multiple adjacent slots, each having 14 adjacent symbols. Further details on the frame structure are specified in [2].

NR 物理层的多址接入方案基于正交频分复用（OFDM）与循环前缀（CP）。对于上行链路，也支持带有 CP 的离散傅里叶变换扩展正交频分复用（DFT-s-OFDM）。为了支持在配对和非配对频谱中的传输，启用了频分双工（FDD）和时分双工（TDD）技术。
第 1 层是以资源块为基础，以带宽无关的方式定义的，这使得 NR 第 1 层能够适应各种频谱分配。一个资源块跨越 12 个子载波，并具有给定的子载波间隔。
无线帧的持续时间为 10 毫秒，由 10 个子帧组成，每个子帧的持续时间为 1 毫秒。一个子帧由一个或多个相邻的时隙组成，每个时隙包含 14 个相邻符号。帧结构的更多细节在 [2] 中进行了规定。

4.2.2 Physical channels and modulation

The physical channels defined in the downlink are:

- the Physical Downlink Shared Channel (PDSCH), 物理下行共享信道
- the Physical Downlink Control Channel (PDCCH), 物理下行控制信道
- the Physical Broadcast Channel (PBCH), 物理广播信道

The physical channels defined in the uplink are:

- the Physical Random Access Channel (PRACH), 物理随机接入信道
- the Physical Uplink Shared Channel (PUSCH), 物理上行共享信道
- and the Physical Uplink Control Channel (PUCCH). 物理上行控制信道

The physical channels defined in the sidelink are:

- the Physical Sidelink Broadcast Channel (PSBCH), 物理侧链广播信道
- the Physical Sidelink Control Channel (PSCCH), 物理侧链控制信道
- the Physical Sidelink Feedback Channel (PSFCH), 物理侧链反馈信道
- and the Physical Sidelink Shared Channel (PSSCH). 物理侧链共享信道

In addition, signals are defined as reference signals, primary and secondary synchronization signals, wake-up signal and low-power synchronization signal.

The modulation schemes supported are

- in the downlink, QPSK, 16QAM, 64QAM, 256QAM, and 1024QAM,
- in the uplink, QPSK, 16QAM, 64QAM and 256QAM for OFDM with a CP and π/2-BPSK, QPSK, 16QAM, 64QAM and 256QAM for DFT-s-OFDM with a CP.

4.2.3 Channel coding

The channel coding scheme for transport blocks is quasi-cyclic LDPC codes with 2 base graphs and 8 sets of parity check matrices for each base graph, respectively. One base graph is used for code blocks larger than certain sizes or with initial transmission code rate higher than thresholds; otherwise, the other base graph is used. Before the LDPC coding, for large transport blocks, the transport block is segmented into multiple code blocks with equal size. The channel coding scheme for PBCH and control information is Polar coding based on nested sequences. Puncturing, shortening and repetition are used for rate matching. Further details of channel coding schemes are specified in [4].

传输块的信道编码方案是准循环 LDPC 码，具有 2 个基图和每个基图的 8 组奇偶校验矩阵。一个基图用于大于某些大小的码块或初始传输码率高于阈值的情况；否则，使用另一个基图。在 LDPC 编码之前，对于大传输

块，传输块被分段成多个大小相等的码块。PBCH 和控制信息的信道编码方案是基于嵌套序列的极化编码。使用打孔、缩短和重复进行速率匹配。信道编码方案的更多细节在 [4] 中进行了规定。

4.2.4 Physical layer procedures

There are several Physical layer procedures involved. Such procedures covered by the physical layer are;

- Cell search
- Power control
- Uplink synchronisation and Uplink timing control
- Random access related procedures
- HARQ related procedures
- Beam management and CSI related procedures
- Sidelink related procedures
- Channel access procedures

Through the control of physical layer resources in the frequency domain as well as in the time and power domains, implicit support of interference coordination is provided in NR.

物理层程序涉及多个物理层过程。物理层涵盖的过程包括:

- 小区搜索
- 功率控制
- 上行同步和上行定时控制
- 随机接入相关过程
- HARQ 相关过程
- 波束管理和 CSI 相关过程
- 侧链相关过程
- 信道接入过程

通过对频域、时域和功率域中的物理层资源的控制，NR 提供了隐式的干扰协调支持。

4.2.5 Physical layer measurements

Radio characteristics are measured by the UE and the network and reported to higher layers. These include, e.g. measurements for intra- and inter-frequency handover, inter RAT handover, timing measurements, and measurements for RRM.

Measurements for inter-RAT handover are defined in support of handover to E-UTRA.

无线特性由 UE 和网络进行测量，并报告给更高层。这些包括例如用于频内和频间切换、异 RAT 切换、时序测量以及 RRM 测量等。
异 RAT 切换的测量是为了支持向 E-UTRA 的切换而定义的。

4.2.6 Physical layer of Ambient IoT

The physical channel defined for R2D is:

- the Physical Reader-to-Device Channel (PRDCH).

The physical channel defined for D2R is:

- the Physical Device-to-Reader Channel (PDRCH).

In addition, signals are defined as R2D timing acquisition signal (R-TAS), R2D postamble signal and D2R amble signal.

The modulation schemes supported are

- for R2D, line encoding with OOK modulation;
- for D2R, modulation of OOK or BPSK, resulting in small frequency shift.

The channel coding scheme for D2R is tail biting convolutional code.

Physical layer procedures for Ambient IoT are:

- PDRCH and D2R amble signal transmission;
- R-TAS reception;
- PRDCH reception;
- Monitoring of R2D.

5 Document structure of physical layer specification

5.1 Overview

The physical layer specification consists of a general document (TS 38.201), and seven documents (TS 38.202, 38.211 through 38.215, and 37.213). The relation between the physical layer specifications in the context of the higher layers is shown in Figure 2.

物理层规范由一份通用文档（TS 38.201）和七份文档（TS 38.202, 38.211 至 38.215, 以及 37.213）组成。图 2 展示了物理层规范与更高层的关系。

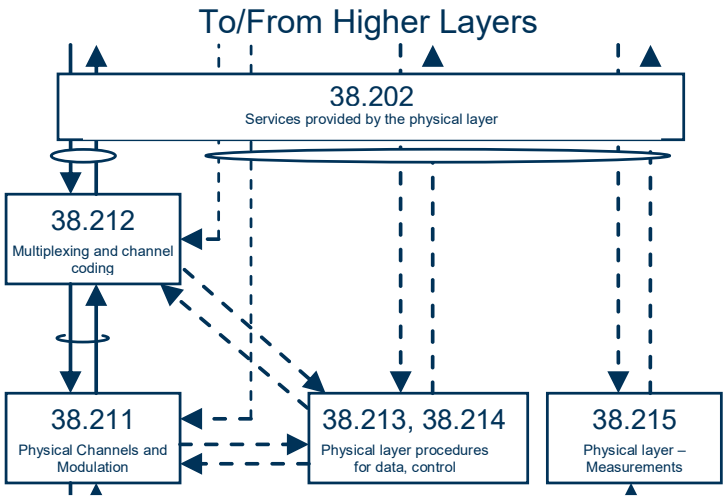

Figure 2: Relation between Physical Layer specifications

5.2 TS 38.201: Physical layer; General description

The scope is to describe:

- The contents of the Layer 1 documents (TS 38.200 series);
- Where to find information;

5.3 TS 38.202: Physical layer services provided by the physical layer

The scope is to describe services provided by the physical layer, and to specify:

- Services and functions of the physical layer;
- Model of physical layer of the UE;
- Parallel transmission of simultaneous physical channels and SRS;
- Measurements provided by the physical layer.

本规范的范围是描述物理层提供的服务，并规定：

- 物理层的服务和功能；
- UE 的物理层模型；
- 同时物理信道和 SRS 的并行传输；
- 物理层提供的测量。

5.4 TS 38.211: Physical channels and modulation

The scope is to establish the characteristics of the Layer-1 physical channels, generation of physical layer signals and modulation, and to specify:

- Definition of the uplink, downlink and sidelink physical channels;
- Frame structure and physical resources;
- Modulation mapping (BPSK, QPSK, etc);
- OFDM signal generation;
- Scrambling, modulation and upconversion;
- Layer mapping and precoding;
- Physical shared channel in uplink, downlink and sidelink;
- Reference signal in uplink, downlink and sidelink;
- Physical random access channel;
- Primary and secondary synchronization signals;
- Wake-up signal and low-power synchronization signal.

本规范的范围是建立第 1 层物理信道的特性、物理层信号的生成与调制，并规定：

- 上行链路、下行链路和侧链物理信道的定义；

- 帧结构和物理资源；
- 调制映射（BPSK、QPSK 等）；
- OFDM 信号生成；
- 扰码、调制和上变频；
- 层映射和预编码；
- 上行链路、下行链路和侧链中的物理共享信道；
- 上行链路、下行链路和侧链中的参考信号；
- 物理随机接入信道；
- 主同步信号和次同步信号；
- 唤醒信号和低功耗同步信号。

5.5 TS 38.212: Multiplexing and channel coding

The scope is to describe the transport channel and control channel data processing, including multiplexing, channel coding and interleaving, and to specify:

- Channel coding schemes;
- Rate matching;
- Uplink transport channels and control information;
- Downlink transport channels and control information;
- Sidelink transport channels and control information.

本规范的范围是描述传输信道和控制信道的数据处理，包括复用、信道编码和交织，并规定：

- 信道编码方案；
- 速率匹配；
- 上行传输信道和控制信息；
- 下行传输信道和控制信息；
- 侧链传输信道和控制信息。

5.6 TS 38.213: Physical layer procedures for control

The scope is to establish the characteristics of the physical layer procedures for control, and to specify:

- Synchronization procedures;
- Uplink power control;
- Random access procedure;
- UE procedure for reporting control information;
- UE procedure for receiving control information.

本规范的范围是建立控制的物理层过程特性，并规定：

- 同步过程；
- 上行功率控制；
- 随机接入过程；
- UE 报告控制信息的过程；
- UE 接收控制信息的过程。

5.7 TS 38.214: Physical layer procedures for data

The scope is to establish the characteristics of the physical layer procedures for data, and to specify:

- Power control;
- Physical downlink shared channel related procedures;
- Physical uplink shared channel related procedure;
- Physical sidelink shared channel related procedure.

本规范的范围是建立数据的物理层过程特性，并规定：

- 功率控制；
- 物理下行共享信道相关过程；
- 物理上行共享信道相关过程；
- 物理侧链共享信道相关过程。

5.8 TS 38.215: Physical layer measurements

The scope is to establish the characteristics of the physical layer measurements, and to specify:

- Control of UE/NG-RAN measurements;
- Measurement capabilities for NR.

本规范的范围是建立物理层测量的特性，并规定：

- UE/NG-RAN 测量的控制；
- NR 的测量能力。

5.9 TS 37.213: Physical layer procedures for shared spectrum channel access

The scope is to establish the characteristics of the physical layer procedures for shared spectrum channel, and to specify:

- Downlink channel access procedures;
- Uplink channel access procedures;
- Sidelink channel access procedures.

本规范的范围是建立共享频谱信道的物理层过程特性，并规定：

- 下行链路信道接入过程;
- 上行链路信道接入过程;
- 侧链信道接入过程。

5.10 TS 38.291: Ambient IoT Physical layer

The scope is to establish the characteristics of the physical layer of Ambient IoT, and to specify:

- Time and frequency domain structures;
- Physical channels and signals generation;
- Physical layer procedures.

本规范的范围是建立环境物联网（Ambient IoT）物理层的特性，并规定：

- 时间和频率域结构；
- 物理信道和信号的生成；
- 物理层过程。

(环境物联网（Ambient IoT） 是指通过将物联网技术嵌入到日常环境中，使得环境能够感知、连接和响应周围的设备和用户，从而实现智能化、自动化的管理和交互。这种物联网的理念侧重于“无处不在”的连接和智能化功能，即设备和传感器能够在不干扰人们日常活动的情况下，自动感知环境变化并做出响应。

在环境物联网中，设备通过传感器收集数据（如温度、湿度、光照等），并通过网络与其他设备或系统进行交互和数据传输。这种互联互通的方式不仅限于智能家居设备，还可能包括智能城市、智能交通、健康监测等领域，旨在通过环境中的智能设备和技术提升生活质量和工作效率。)

Annex A (informative): Preferred mathematical notations

The following table contains the preferred mathematical notations used in L1 documentation.

item	notation
multiply product	cross sign, e.g. $a \times b$
matrix product	dot sign, e.g. $a \cdot b$
scalar product (product of a matrix by a scalar)	dot sign, scalar should precede matrix e.g. $(1+j)\cdot\begin{bmatrix} u \\ v \end{bmatrix}$
matrix dimensioning	number of rows × number of column, e.g.: $R \times C$
Kronecker product	$a \otimes b$
bracketing of sets (all elements of same type, not ordered elements)	curly brackets {}, e.g. {a_1, a_2, …,a_p}, or $\{a_i\}_{i\in\{1,2,\ldots,p\}}$
bracketing of lists (all elements not necessary of same type, ordered elements)	round brackets (), e.g. (A, u, x)
bracketing of sequences (all elements of same type, ordered elements)	angle brackets, e.g. <a_1, a_2, …,a_p> or $\langle a_i \rangle_{i\in\{1,2,\ldots,p\}}$
bracketing of function argument	round brackets, e.g. f(x)
bracketing of array index	square brackets, e.g. a[x]
bracketing of matrix or vector	square brackets [], e.g. $\begin{bmatrix} x \\ y \end{bmatrix}$, $\begin{bmatrix} x & y \end{bmatrix}$, or $\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
Separation of indexes	use a comma : e.g. $N_{i,j}$
use of italic for symbols	a symbol should be either in italic or in normal font, but mixing up should be avoided.
bracketing of arithmetic expression to force precedence of operations	round brackets : e.g. $(a+b)\times c$
necessity of bracketing arithmetic expressions	When only + and × bracketing is not necessary. When the **mod** operator is used explicit bracketing of mod operands and possibly result should be done.
number type	in a context of non negative integer numbers, some notes should stress when a number is signed, or possibly fractional.
binary **xor** and **and**	respectively use + or ·. If no "mod 2" is explicitly in the expression some text should stress that the operation is modulo 2.
matrix or vector transpose	v^T
1×1 matrices	implicitly cast to its unique element.
vector dot product	$u^T \cdot v$ for column vectors, and $u \cdot v^T$ for line vectors
complex conjugate	v^*
matrix or vector Hermitian transpose	v^H
real part and imaginary part of complex numbers.	Re(x) and Im(x)
Modulo operation (including negative value) $r \equiv a \bmod N$	Let q be the integer quotient of a and N, Z is integer, r is remainder then $\begin{cases} q \in Z \\ a = N \times q + r \\ 0 \le r < \lvert N \rvert \end{cases}$, where $q = \lfloor a/N \rfloor$ for all a and N (Note that $\lfloor \bullet \rfloor$ is floor operation to round the elements of $\bullet$ to the nearest integers towards minus infinity)

Annex B (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-05	RAN1#89	R1-1708435				Draft skeleton	0.0.0
2017-07	AH_1706	R1-1712012				Inclusion of agreements up to and including RAN1 NR Ad-Hoc #2	0.0.1
2017-08	RAN1#90	R1-1713894				Updates according to email discussion " [NRAH2-03-201] TS 38.201"	0.0.2
2017-08	RAN1#90	R1-1715069				Clean version	0.1.0
2017-08	RAN1#90	R1-1715319				Inclusion of agreements up to and including RAN1 #90	0.1.1
2017-09	RAN #77	RP-171998				For information to RAN	1.0.0
2017-11	RAN1#90b	R1-1719242				Inclusion of agreements up to and including RAN1#90bis	1.0.1
2017-11	RAN1#91	R1-1721046				Endorsed version by RAN1#90bis (email thread)	1.1.0
2017-12	RAN1#91	R1-1721339				Editorial update - Endorsed version by RAN1#91 (email thread)	1.2.0
2017-12	RAN#78	RP-172530				Endorsed version for approval by plenary.	2.0.0
2017-12	RAN#78					Approved by plenary – Rel-15 spec under change control	15.0.0
2019-12	RAN#86	RP-192661	0001	-	B	Introduction of V2X, NR-based access to unlicensed spectrum, integrated access backhaul for NR and remote interference management	16.0.0
2021-12	RAN#94-e	RP-212982	0002	-	B	Introduction of DL 1024QAM	17.0.0
2023-09	RAN#101	RP-232469	0003	-	B	Introduction of sidelink channel access procedures for Rel-18 NR sidelink evolution	18.0.0
2023-09	RAN#101	RP-232479	0004	-	B	Introduction of Rel-18 network-controlled repeaters	18.0.0
2025-06	RAN#108	RP-251577	0005	-	B	Introduction of low-power wake-up signal and receiver for NR (LP-WUS/WUR)	19.0.0
2025-06	RAN#108	RP-251586	0006	-	B	Introduction of Ambient IoT	19.0.0