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Technical Specification

**3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR;
Services provided by the physical layer
(Release 16)**



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Contents

| | |
|--|-----------|
| Foreword..... | 4 |
| 1 Scope..... | 5 |
| 2 References..... | 5 |
| 3 Definitions, symbols and abbreviations..... | 5 |
| 3.1 Definitions..... | 5 |
| 3.2 Symbols..... | 5 |
| 3.3 Abbreviations..... | 5 |
| 4 Services and functions of the physical layer..... | 6 |
| 4.1 General..... | 6 |
| 4.2 Overview of L1 functions..... | 6 |
| 5 Model of physical layer of the UE..... | 6 |
| 5.1 Uplink model..... | 7 |
| 5.1.1 Uplink shared channel..... | 7 |
| 5.1.2 Random access channel..... | 7 |
| 5.2 Downlink model..... | 8 |
| 5.2.1 Downlink shared channel..... | 8 |
| 5.2.2 Broadcast channel..... | 8 |
| 5.2.3 Paging channel..... | 9 |
| 5.3 Sidelink model..... | 10 |
| 5.3.1 Sidelink shared channel..... | 10 |
| 5.3.2 Broadcast channel..... | 11 |
| 6 Simultaneous transmission and reception of physical channels and physical signals..... | 12 |
| 6.1 Uplink..... | 12 |
| 6.2 Downlink..... | 13 |
| 6.3 Sidelink..... | 15 |
| 7 Measurements provided by the physical layer..... | 16 |
| 7.1 UE measurements..... | 16 |
| Annex A (informative): Change history..... | 17 |

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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- 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 is a technical specification of the services provided by the physical layer of 5G-NR to upper layers.

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 38.201: "NR; Physical Layer – General Description" |
| [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 38.306: "NR; User Equipment (UE) radio access capabilities" |

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP 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 3GPP TR 21.905 [1].

3.2 Symbols

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

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP 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 3GPP TR 21.905 [1].

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

| | |
|------|--------------------------------|
| ARQ | Automatic Repeat Request |
| BCH | Broadcast Channel |
| CA | Carrier Aggregation |
| CRC | Cyclic Redundancy Check |
| DC | Dual Connectivity |
| DL | Downlink |
| FEC | Forward Error Correction |
| GF | Grant-Free |
| MAC | Medium Access Control |
| MIMO | Multiple Input Multiple Output |
| PBCH | Physical Broadcast Channel |

| | |
|-------|------------------------------------|
| PCH | Paging Channel |
| PDCCH | Physical Downlink Control Channel |
| PDSCH | Physical Downlink Shared Channel |
| PRACH | Physical Random Access Channel |
| PUCCH | Physical Uplink Control Channel |
| PUSCH | Physical Uplink Shared Channel |
| RACH | Random Access Channel |
| RF | Radio Frequency |
| RNTI | Radio Network Temporary Identifier |
| SCH | Shared Channel |
| SI | System Information |
| SPS | Semi-Persistent Scheduling |
| SRS | Sounding Reference Signal |
| TPC | Transmit Power Control |
| UL | Uplink |

4 Services and functions of the physical layer

4.1 General

The physical layer offers data transport services to higher layers.

The access to these services is through the use of transport channels via the MAC sub-layer.

A transport block is defined as the data delivered by MAC layer to the physical layer and vice versa.

4.2 Overview of L1 functions

As mentioned in [2, TS 38.201], the physical layer is expected to perform the following functions to provide the data transport service:

- Error detection on the transport channel and indication to higher layers;
- FEC encoding/decoding of the transport channel;
- Hybrid ARQ soft-combining;
- Rate matching of the coded transport channel to physical channels;
- Mapping of the coded transport channel onto physical channels;
- Power weighting of physical channels;
- Modulation and demodulation of physical channels;
- Frequency and time synchronisation;
- Radio characteristics measurements and indication to higher layers;
- Multiple Input Multiple Output (MIMO) antenna processing;
- RF processing.

L1 functions are modelled for each transport channel in subclause 5.

5 Model of physical layer of the UE

The 5G-NR physical-layer model captures those characteristics of the 5G-NR physical-layer that are relevant from the point-of-view of higher layers. More specifically, the physical-layer model captures:

- The structure of higher-layer data being passed down to or up from the physical layer;

- The means by which higher layers can configure the physical layer;
- The different indications (error indications, channel-quality indications, etc.) that are provided by the physical layer to higher layers.

5.1 Uplink model

5.1.1 Uplink shared channel

The physical-layer model for Uplink Shared Channel transmission is described based on the corresponding PUSCH physical-layer-processing chain, see Figure 5.1.1-1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue.

- Higher-layer data passed to/from the physical layer
- CRC and transport-block-error indication
- FEC and rate matching
- Data modulation
- Mapping to physical resource
- Multi-antenna processing
- Support of L1 control and Hybrid-ARQ-related signalling

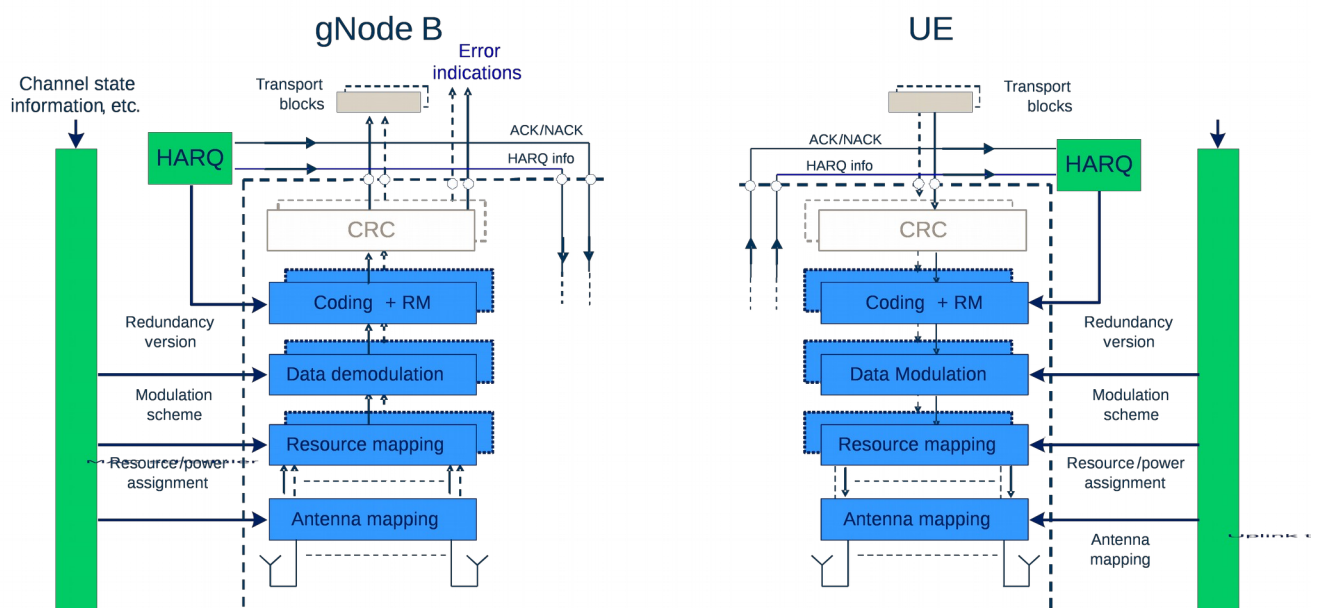


Figure 5.1.1-1: Physical-layer model for UL-SCH transmission

5.1.2 Random access channel

The physical-layer model for RACH transmission is characterized by a PRACH preamble format that consists of a cyclic prefix, a preamble, and a guard time during which nothing is transmitted.

5.2 Downlink model

5.2.1 Downlink shared channel

The physical-layer model for Downlink Shared Channel transmission is described based on the corresponding PDSCH physical-layer-processing chain, see Figure 5.2.1-1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue.

- Higher-layer data passed to/from the physical layer;
- CRC and transport-block-error indication;
- FEC and rate matching;
- Data modulation;
- Mapping to physical resource;
- Multi-antenna processing;
- Support of L1 control and Hybrid-ARQ-related signalling.

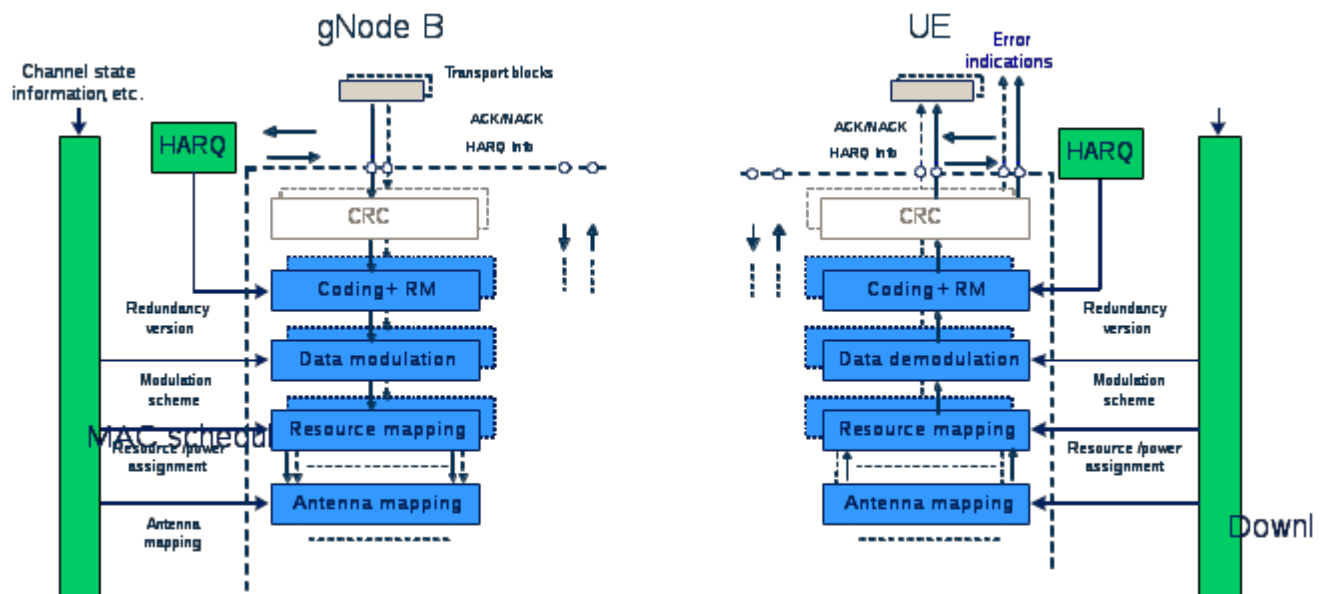


Figure 5.2.1-1: Physical-layer model for DL-SCH transmission

5.2.2 Broadcast channel

The physical-layer model for BCH transmission is characterized by a fixed pre-defined transport format. There is one transport block for the BCH every 80ms. The BCH physical-layer model is described based on the corresponding PBCH physical-layer-processing chain, see Figure 5.2.2-1:

- Higher-layer data passed to/from the physical layer;
- CRC and transport-block-error indication;
- FEC and rate matching;
- Data modulation;

- Mapping to physical resource;
- Multi-antenna processing.

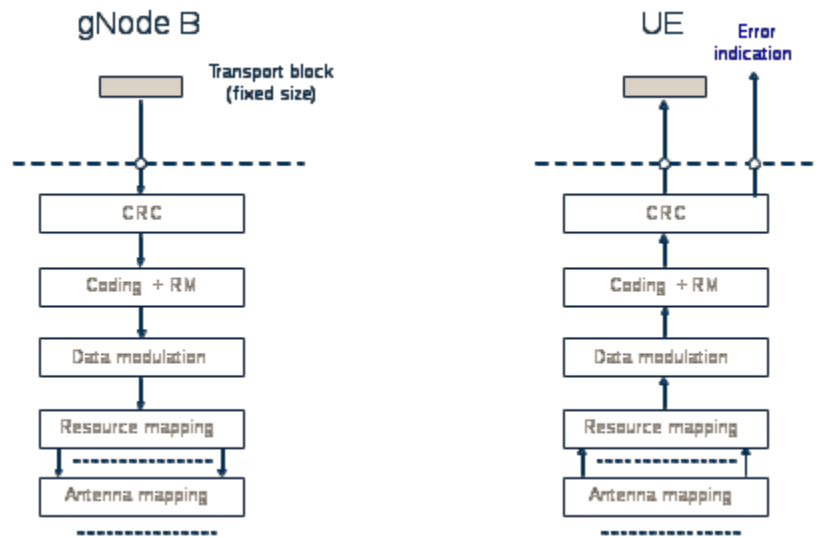


Figure 5.2.2-1: Physical-layer model for BCH transmission

5.2.3 Paging channel

The physical-layer model for PCH transmission is described based on the corresponding physical-layer-processing chain, see Figure 5.2.3-1. The PCH is carried on PDSCH. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue.

- Higher-layer data passed to/from the physical layer;
- CRC and transport-block-error indication;
- FEC and rate matching;
- Data modulation;
- Mapping to physical resource;
- Multi-antenna processing.

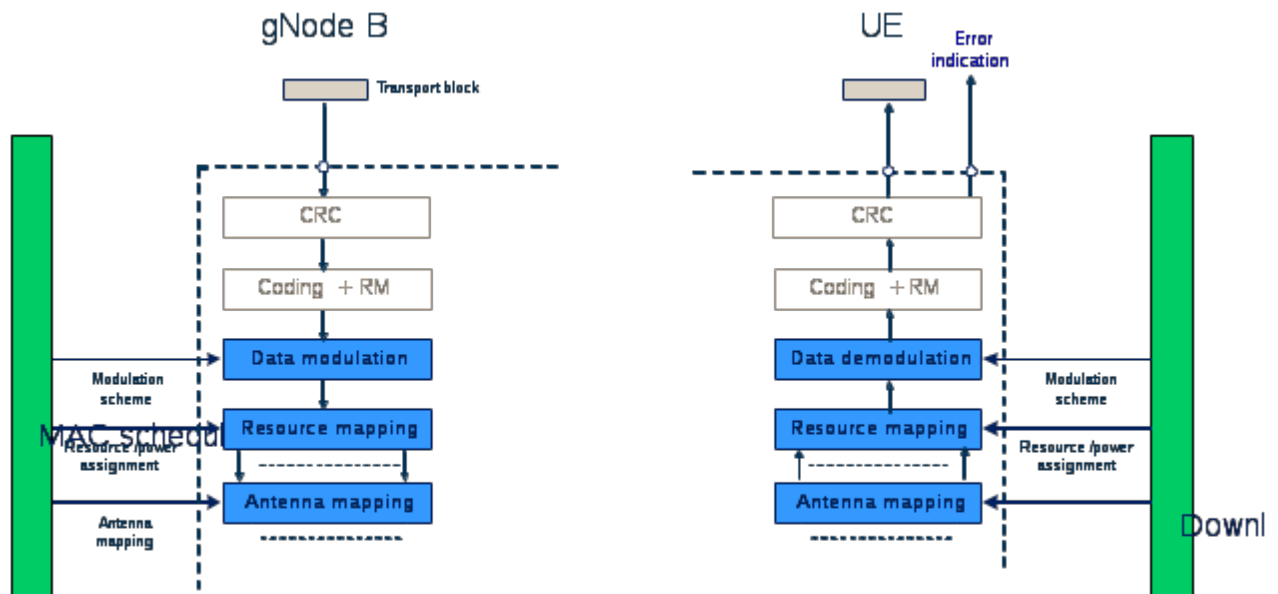


Figure 5.2.3-1: Physical-layer model for PCH transmission

5.3 Sidelink model

5.3.1 Sidelink shared channel

The physical-layer model for Sidelink Shared Channel transmission is described based on the corresponding SL-SCH physical-layer-processing chain, see Figure 5.3.1-1. Processing steps that are relevant for the physical-layer model, e.g. in the sense that they are configurable by higher layers, are highlighted in blue.

- Higher-layer data passed to/from the physical layer;
- CRC and transport-block-error indication;
- FEC and rate matching;
- Data modulation;
- Mapping to physical resource;
- Multi-antenna processing;
- Support of L1 control and Hybrid-ARQ-related signalling.

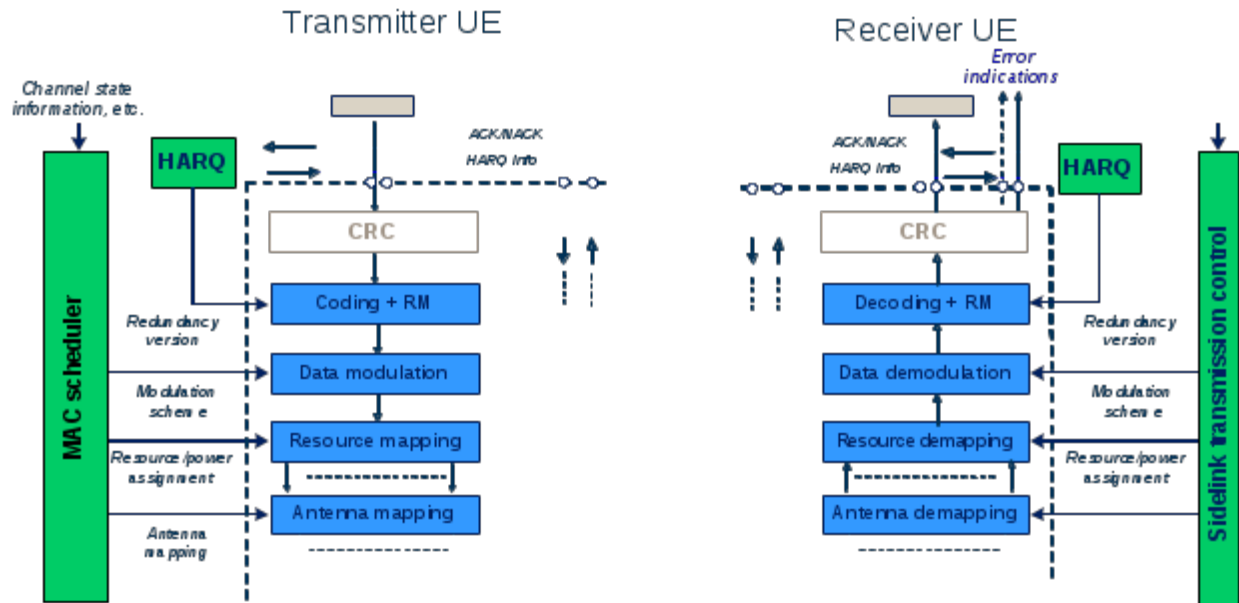


Figure 5.3.1-1: Physical-layer model for SL-SCH transmission

5.3.2 Broadcast channel

The physical-layer model for Sidelink Broadcast Channel transmission is characterized by a fixed pre-defined transport format. There is one transport block for every slot in which the UE transmits SL-BCH, if the UE is configured to transmit on SL-BCH. The SL-BCH physical-layer model is described based on the corresponding SL-BCH physical-layer-processing chain, see Figure 5.3.2-1:

- Higher-layer data passed to/from the physical layer;
- CRC and transport-block-error indication;
- FEC and rate matching;
- Data modulation;
- Mapping to physical resource;
- Multi-antenna processing.

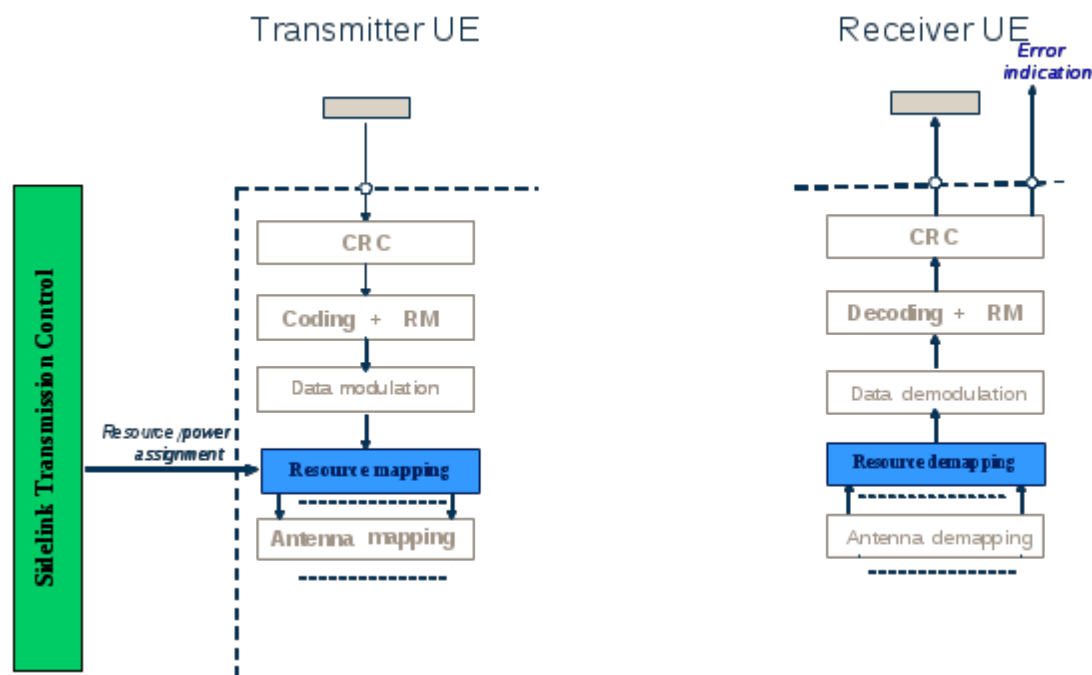


Figure 5.3.2-1: Physical-layer model for SL-BCH transmission

6 Simultaneous transmission and reception of physical channels and physical signals

This clause describes the requirements from the UE to send and receive multiple physical channels and physical signals simultaneously depending on the capabilities and service requirements. The following notation is used between both the uplink and downlink subclauses below.

- p is the number of uplink carriers configured for the UE on which physical channels can be transmitted
- p' is the number of uplink carriers configured for the UE on which SRS can be transmitted
- q is the number of downlink carriers configured for the UE
- j is the number of cell groups configured for the UE.
- k is the number of PUCCH groups configured for the UE.

6.1 Uplink

The tables 6.1-1 and 6.1-2 describe the possible combinations of physical channels and SRS that can be sent in simultaneously in the uplink by one UE. Table 6.1-1 introduces notation for a "Transmission Type" which represents a physical channel or sounding reference signal, and any associated transport channel. Table 6.1-2 describes the combinations of these "Transmission Types" which are supported by the UE depending on capabilities [8, TS 38.306], and enumerates how many of each can be transmitted simultaneously.

Table 6.1-1: Uplink "Transmission Types"

| "Transmission Type" | Physical Channel or SRS | Associated Transport Channel | Comment |
|--|-------------------------|------------------------------|----------------|
| A | PRACH | RACH | Note 1, Note 3 |
| B | PUCCH | N/A | |
| C | PUSCH | UL-SCH | Note 2, Note 3 |
| D | SRS | N/A | |
| Note 1: RACH corresponds to contention based. | | | |
| Note 2: UCI on PUSCH without UL-SCH is possible. | | | |
| Note 3: For SCell, MsgA PRACH and MsgA PUSCH is not supported. | | | |

Table 6.1-2: Uplink "Transmission Type" combinations

| Supported Combinations | Comment |
|--|----------------|
| $j \times A$ | Note 1 |
| $k \times B$ | Note 2 |
| $p \times C$ | Note 3, Note 4 |
| $p' \times D$ | Note 3, Note 5 |
| $\tilde{j} \times A + \tilde{k} \times B$ | Note 6 |
| $\tilde{j} \times A + \tilde{p} \times C$ | Note 6 |
| $\tilde{j} \times A + \tilde{p}' \times D$ | Note 6 |
| $\hat{k} \times B + \hat{p} \times C$ | Note 8 |
| $\tilde{k} \times B + \tilde{p}' \times D$ | Note 7 |
| $\tilde{p} \times C + \tilde{p}' \times D$ | Note 7 |

Note 1: The number of cell groups j in the supported combination is subject to UE capability.

Note 2: The number of PUCCH groups k in the supported combination is subject to UE capability.

Note 3: The number of carriers p , and p' in the supported combinations are subject to UE capability.

Note 4: In the case there is one SUL carrier, then $p-1$ would be supported.

Note 5: UE may be configured with p' but may also have capability to simultaneously sound less than this number.

Note 6: Simultaneous PRACH with PUCCH (or PUSCH or SRS) is supported only in the case of inter-band CA, with $\tilde{j} \leq j$, $\tilde{k} \leq k$, $\tilde{p} \leq p$, and $\tilde{p}' \leq p'$ depending on the configuration, and subject to UE capability for parallel transmission.

Note 7: Simultaneous SRS with PUCCH (or PUSCH) is supported only in the case of inter-band CA, with $\tilde{k} \leq k$, $\tilde{p} \leq p$, and $\tilde{p}' \leq p'$ depending on the configuration, and subject to UE capability for parallel transmission.

Note 8: Simultaneous PUCCH and PUSCH(s) is supported only in the case that multiple PUCCH groups are configured and the respective PUCCH and PUSCH(s) are transmitted in the different PUCCH groups, with $\hat{k} < k$ and $\hat{p} \leq p$. k and p are subject to UE capability for supported number of PUCCH groups and UL carriers, respectively. \tilde{k} and \tilde{p} depend on configuration.

6.2 Downlink

The tables 6.2-1, 6.2-2 describe the possible combinations of physical channels that can be received simultaneously in the downlink by one UE. Table 6.2-1 introduces notation for a "Reception Type" which represents a physical channel and any associated transport channel. Table 6.2-2 describes the combinations of these "Reception Types" which are supported by the UE depending on capabilities [8, TS 38.306], and enumerates how many of each can be received simultaneously. The UE shall be able to receive all TBs according to the indication on PDCCH. Any subset of the combinations specified in table 6.2-2 is also supported.

Table 6.2-1: Downlink "Reception Types"

| "Reception Type" | Physical Channel(s) | Monitored RNTI | Associated Transport Channel | Comment |
|---|---------------------|--|------------------------------|----------------|
| A | PBCH | N/A | BCH | |
| B | PDCCH+PDSCH | SI-RNTI | DL-SCH | Note 1 |
| C0 | PDCCH | P-RNTI | N/A | Note 1, Note 2 |
| C1 | PDCCH+PDSCH | P-RNTI | PCH | Note 1 |
| D0 | PDCCH+PDSCH | RA-RNTI or Temporary C-RNTI or MsgB-RNTI | DL-SCH | Note 3 |
| D1 | PDCCH+PDSCH | C-RNTI, CS-RNTI, MCS-C-RNTI | DL-SCH | |
| D2 | PDCCH | C-RNTI, CS-RNTI, MCS-C-RNTI | DL-SCH | |
| E | PDCCH | C-RNTI | N/A | Note 4 |
| F0 | PDCCH | Temporary C-RNTI | UL-SCH | Note 3 |
| F1 | PDCCH | C-RNTI, CS-RNTI, MCS-C-RNTI | UL-SCH | |
| G | PDCCH | SFI-RNTI | N/A | |
| H | PDCCH | INT-RNTI | N/A | |
| J0 | PDCCH | TPC-PUSCH-RNTI | N/A | |
| J1 | PDCCH | TPC-PUCCH-RNTI | N/A | |
| J2 | PDCCH | TPC-SRS-RNTI | N/A | |
| K | PDCCH | SP-CSI-RNTI | N/A | |
| L0 | PDCCH | SL-RNTI | SL-SCH | |
| L1 | PDCCH | SLCS-RNTI | SL-SCH | |
| M | PDCCH | SL Semi-Persistent Scheduling V-RNTI | SL-SCH | Note 5 |
| N | PDCCH | PS-RNTI | N/A | |
| O | PDCCH | AI-RNTI | N/A | |
| Note 1: These are received from PCell only. Note 2: In some cases UE is only required to monitor the short message within the DCI for P-RNTI. Note 3: These are received from PCell or PSCell. Note 4: This corresponds to PDCCH-ordered PRACH. Note 5: This corresponds to PDCCH scheduling LTE PC5. | | | | |

Table 6.2-2: Downlink "Reception Type" combinations

| Supported Combinations | | | Comment |
|--|--|---|--|
| PCell | PSCell | SCell | |
| 1. RRC_IDLE | | | |
| A + (B and/or C1 and/or D0) + F0 | | | Note 1 |
| 2. RRC_INACTIVE | | | |
| A + (B and/or C1 and/or D0) + F0 | | | Note 1 |
| 3. RRC_CONNECTED | | | |
| (A + C0 + (B and/or (D0 or (m1*D1+m2*D2))) + E + F0 + n*F1 + G + H + J0 + J1 + J2 + K + O + [L0 + L1 + M]) or ((A+B+C0+[D0]) [and/or] N) | (A + (D0 or (m1*D1+m2*D2)) + E + F0 + n*F1 + G + H + J0 + J1 + J2 + K + O + [L0 + L1 + M]) or ((A+B+C0+[D0]) [and/or] N) | m1*D1 + m2*D2 + E + n*F1 + G + H + J0 + J1 + J2 + K + O + [L0 + L1 + M] | Note 2, Note 3, Note 4, Note 5, Note 6, Note 7, Note 8 |

| | |
|---------|---|
| Note 1: | UE is not required to decode more than two PDSCH simultaneously, and decoding prioritization when more than two are received is up to UE implementation. |
| Note 2: | For PCell, UE is not required to decode SI-RNTI PDSCH simultaneously with C-RNTI PDSCH, unless in FR1. |
| Note 3: | Supported combinations are subject to UE capabilities for dual connectivity, carrier aggregation, receiving of group TPC commands, pre-emption indication and dynamic SFI monitoring. |
| Note 4: | The values of $m2 \geq 0$ and $n \geq 0$ in the supported combinations are subject to the UE capability. |
| Note 5: | Support of monitoring PDCCH with SL-RNTI, SLCS-RNTI, SL Semi-Persistent Scheduling V-RNTI are subject to UE capability. |
| Note 6: | The values of $m1 \geq 1$ in the supported combinations are subject to the UE capability [for receiving multi-DCI-based multi-TRP/multi-panel transmissions]. |
| Note 7: | In Active time, a UE is not expected to monitor the DCI format for the PDCCH scrambled by PS-RNTI. |
| Note 8: | The PDCCH scrambled by PS-RNTI can only be configured on the PCell and PSCell. |

6.3 Sidelink

The tables 6.3-1 and 6.3-2 describe the possible combinations of physical channels that can be sent simultaneously in the sidelink by a UE. Table 6.3-1 introduces notation for a sidelink "Transmission Type" which represents a physical channel, and any associated transport channel. Table 6.3-2 describes the combinations of these "Transmission Types" which are supported by the UE depending on capabilities [8, TS 38.306], and enumerates how many of each can be transmitted simultaneously.

Table 6.3-1: Sidelink "Transmission Types"

| "Transmission Type" | Physical Channel | Associated Transport Channel | Comment |
|---------------------|------------------|------------------------------|---------|
| A | PSBCH | SL-BCH | |
| B | PSSCH | SL-SCH | |
| C | PSCCH | SL-SCH | |
| D | PSFCH | N/A | |

Table 6.3-2: Sidelink "Transmission Type" combinations

| Supported Combinations | Comment |
|------------------------|---|
| A | |
| B | |
| C | |
| $N \times D$ | |
| B+C | |
| Note: | Depending on the UE capability, the UE may be able to perform simultaneous Uplink and Sidelink transmissions. If the simultaneous transmission of Sidelink and Uplink is beyond the UE capability, the one not prioritized can be dropped according to [TS 38.321]. |

The tables 6.3-3 and 6.3-4 describe the possible combinations of physical channels that can be received simultaneously in the sidelink by a UE. Table 6.3-3 introduces notation for a sidelink "Reception Type" which represents a physical channel, and any associated transport channel. Table 6.3-4 describes the combinations of these "Transmission Types" which are supported by the UE depending on capabilities [8, TS 38.306], and enumerates how many of each can be received simultaneously.

Table 6.3-3: Sidelink "Reception Types"

| "Transmission Type" | Physical Channel | Associated Transport Channel | Comment |
|---------------------|------------------|------------------------------|---------|
| A | PSBCH | SL-BCH | |
| B | PSSCH | SL-SCH | |
| C | PSCCH | SL-SCH | |
| D | PSFCH | N/A | |

Table 6.3-4: Sidelink "Reception Type" combinations

| Supported Combinations | Comment |
|--|---------|
| A | |
| B | Note 1 |
| C | Note 1 |
| $M \times D$ | |
| B+C | Note 1 |
| Note 1: Corresponds to simultaneous reception within one sub-channel | |

7 Measurements provided by the physical layer

7.1 UE measurements

The list and detailed definition of UE measurements is provided in [7, TS 38.215].

Annex A (informative): Change history

| Change history | | | | | | | |
|----------------|----------|------------|------|-----|-----|--|-------------|
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2017-05 | RAN1#89 | R1-1712013 | | | | Draft skeleton | 0.0.0 |
| 2017-07 | AH_1706 | R1-1712013 | | | | Update for agreements from meetings up to RAN1 NR AH2 | 0.0.1 |
| 2017-08 | RAN1#90 | R1-1713371 | | | | Update for agreements from meetings up to RAN1 NR AH2 | 0.0.2 |
| 2017-08 | RAN1#90 | R1-1714655 | | | | Update with change marks removed for RAN1 #90 endorsement | 0.1.0 |
| 2017-09 | RAN1#90 | R1-1715320 | | | | Updated with minor editorial changes for review after RAN1 #90 | 0.1.1 |
| 2017-09 | RAN#77 | RP-172006 | | | | For information to plenary | 1.0.0 |
| 2017-10 | RAN1#90b | R1-1719229 | | | | Updated for agreements from meetings up to RAN1 #90b | 1.0.1 |
| 2017-11 | RAN1#91 | R1-1721047 | | | | Updated after email discussion | 1.1.0 |
| 2017-12 | RAN1#91 | R1-1721340 | | | | Updated to reflect agreements from RAN1 #91 | 1.2.0 |
| 2017-12 | RAN#78 | RP-172630 | | | | 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 |
| 2018-03 | RAN#79 | RP-180200 | 0001 | - | F | CR capturing the Jan18 ad-hoc and RAN1#92 meeting agreements | 15.1.0 |
| 2018-06 | RAN#80 | RP-181172 | 0002 | 1 | F | CR to 38.202 capturing the RAN1#92bis and RAN1#93 meeting agreements | 15.2.0 |
| 2018-06 | RAN#80 | RP-181257 | 0003 | - | B | CR to 38.202 capturing the RAN1#92bis and RAN1#93 meeting agreements related to URLLC | 15.2.0 |
| 2018-09 | RAN#81 | RP-181789 | 0004 | - | B | CR to 38.202 capturing RAN1#94 meeting agreements | 15.3.0 |
| 2018-12 | RAN#82 | RP-182523 | 0005 | - | F | CR to 38.202 capturing RAN1#95 meeting agreements | 15.4.0 |
| 2019-06 | RAN#84 | RP-191277 | 0006 | - | F | Correction to simultaneous reception of DL Channels | 15.5.0 |
| 2019-06 | RAN#84 | RP-191277 | 0007 | - | F | CR on inclusion of TC-RNTI for monitored RNTI for UL-SCH and inclusion of monitoring PDCCH ordering PRACH on SCell | 15.5.0 |
| 2019-12 | RAN#86 | RP-192623 | 0008 | 1 | F | CR on simultaneous transmission of UL channels | 15.6.0 |
| 2019-12 | RAN#86 | RP-192635 | 0009 | - | B | Introduction of two-step RACH | 16.0.0 |
| 2019-12 | RAN#86 | RP-192637 | 0010 | - | B | Introduction of integrated access and backhaul for NR | 16.0.0 |
| 2019-12 | RAN#86 | RP-192638 | 0011 | - | B | Introduction of V2X | 16.0.0 |
| 2019-12 | RAN#86 | RP-192639 | 0012 | - | B | Introduction of Physical Layer Enhancements for URLLC | 16.0.0 |
| 2019-12 | RAN#86 | RP-192641 | 0013 | - | B | Introduction of MIMO enhancements | 16.0.0 |
| 2019-12 | RAN#86 | RP-192642 | 0014 | - | B | Introduction of UE Power Savings | 16.0.0 |