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1 Scope

The present document describes a general description of the physical layer of the Verizon 5G radio access air interface. The present document also describes the document structure of the physical layer specifications, i.e. TS V5G.200 series

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 V5G document, a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1]: TS V5G.211: "Verizon 5G Radio Access (V5G RA); Physical channels and modulation".
[2]: TS V5G.212: "Verizon 5G Radio Access (V5G RA); Multiplexing and channel coding".
[3]: TS V5G.213: "Verizon 5G Radio Access (V5G RA); Physical layer procedures".

3 Symbols and abbreviations

3.1 Symbols

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

Symbol format

<symbol> <Explanation>

3.2 Abbreviations

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

5G Node-B	5G Node B
5G RA	5G Radio Access
BPSK	Binary Phase Shift Keying

CP	Cyclic Prefix
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CSI	Channel State Information
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic Repeat Request
LTE	Long Term Evolution
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplexing
QAM	Quadrature Amplitude Modulation
QPP	Quadratic Permutation Polynomial
QPSK	Quadrature Phase Shift Keying
RLC	Radio Link Control
RRC	Radio Resource Control
RSSI	Received Signal Strength Indicator
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
SAP	Service Access Point
TDD	Time Division Duplex
TX Diversity	Transmit Diversity
UE	User Equipment
xPBCH	5G Physical Broadcast Channel
xPDSCH	5G Physical Downlink Shared Channel
xPDCCH	5G Physical Downlink Control Channel
xPRACH	5G Physical Random Access Channel
xPUCCH	5G Physical Uplink Control Channel
xPUSCH	5G Physical Uplink Shared Channel

4 General description of Verizon 5G RA 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 the network. The radio interface is composed of the Layer 1, 2 and 3. The TS V5G.200 series describes the Layer 1 (Physical Layer) specifications. Layers 2 and 3 are described in the TS V5G.300 series.

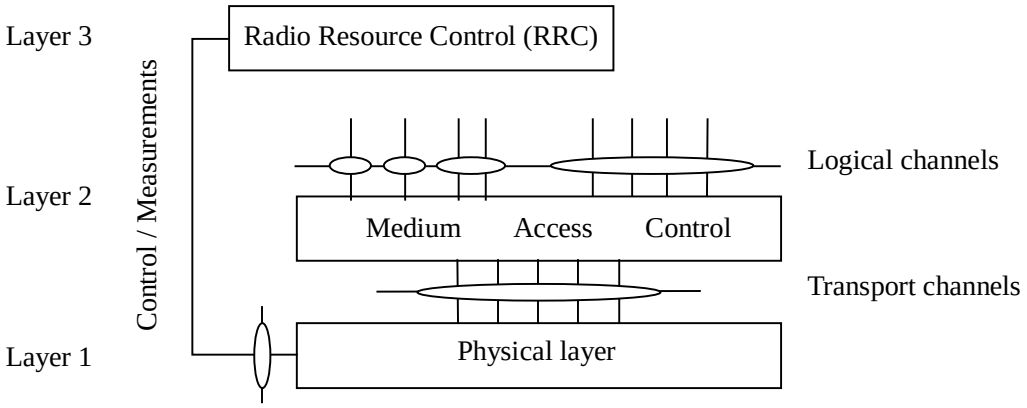

Figure 4.1.1-1: Radio interface protocol architecture around the physical layer

Figure 4.1.1-1 shows the Verizon 5G RA air 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.

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. The physical layer is expected to perform the following functions in order 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
- Transmit Diversity (TX diversity)
- Digital and Analog Beamforming
- RF processing

4.2 General description of Layer 1

4.2.1 Multiple Access

The multiple access scheme for the Verizon 5G RA physical layer is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink and uplink. Half duplex operation is supported using Time Division Duplex (TDD).
A single component carrier bandwidth of 100MHz is supported. A resource block spans 12 sub-carriers with a sub-carrier bandwidth of 75kHz over a duration of 0.1 ms.
The radio frame consists of 50 subframes and has a length of 10 ms. Each subframe has a length of 0.2ms and link direction (downlink or uplink) for data transmission can be dynamically switched on a subframe basis. A subframe can be configured as one of following combinations of DL control/data and UL control/data:

- a subframe including DL control and DL data
- a subframe including DL control, DL data and UL control
- a subframe including DL control and UL data
- a subframe including DL control, UL data and UL control

Further details on the frame structure are specified in [1].
Analog beamforming is supported and its beam direction is dynamically switched for mobility support. Digital precoding is supported with MIMO transmission. MIMO configurations in the downlink with up to 8 transmit antennas are supported, which allows for multi-layer downlink transmissions with up to 8 streams (up to 2 streams per UE). Multi-layer uplink transmissions with up to 2 streams per UE are supported. Aggregation of multiple cells is supported in the uplink and downlink with up to 8 serving cells.

4.2.2 Physical channels and modulation

The physical channels defined in the downlink are:

- the 5G Physical Downlink Shared Channel (xPDSCH),
- the 5G Physical Downlink Control Channel (xPDCCH),
- the 5G Physical Broadcast Channel (xPBCH),
- and the 5G Extended Physical Broadcast Channel (ePBCH).

The physical channels defined in the uplink are:

- the 5G Physical Random Access Channel (xPRACH),
- the 5G Physical Uplink Shared Channel (xPUSCH),
- and the 5G Physical Uplink Control Channel (xPUCCH).

In addition, signals are defined as reference signals and synchronization signals.

The modulation schemes supported are:
- QPSK, 16QAM and 64QAM in the downlink and uplink.

4.2.3 Channel coding and interleaving

The following channel coding schemes can be applied:
- Tail biting convolutional coding;
- LDPC coding;
- Turbo coding (optional)

4.2.4 Physical layer procedures

There are several Physical layer procedures involved with Verizon 5G RA operation. 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 acquisition.

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 Verizon 5G RA.

4.2.5 Physical layer measurements

Radio characteristics are measured by the UE and the 5G Node-B and reported to higher layers in the network.

5 Document structure of Verizon 5G radio access physical layer specification

5.1 Overview

The physical layer specification consists of a general document (TS V5G.201), and five documents (TSs V5G.211, V5G.212, and V5G.213). The relation between the physical layer specifications in the context of the higher layers is shown in Figure 5.1-1.

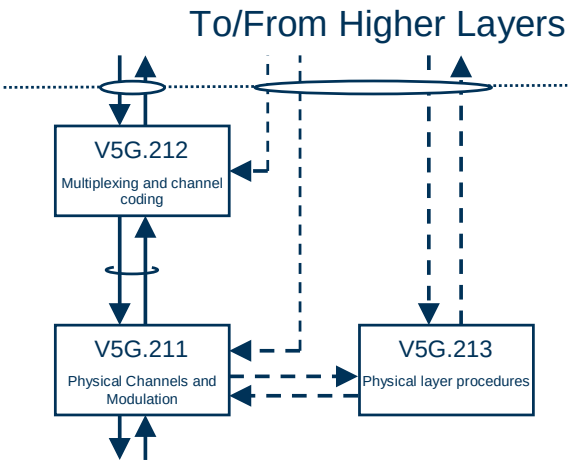

Figure 5.1-1: Relation between Physical Layer specifications

5.2 TS V5G.201: Physical layer – General description

The scope is to describe:

- The contents of the Layer 1 documents (TS V5G.200 series);
- Where to find information;
- A general description of Verizon 5G RA Layer 1.

5.3 TS V5G.211: Physical channels and modulation

The scope of this specification 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 and downlink physical channels;
- The structure of the physical channels, frame format, physical resource elements, etc.;
- Modulation mapping (BPSK, QPSK, etc);
- Physical shared channel in uplink and downlink;
- Reference signals in uplink and downlink;
- Random access channel;
- Primary and secondary synchronization signals;
- OFDM signal generation in uplink and downlink;
- Scrambling, modulation and up conversion;
- Uplink-downlink timing relations;
- Layer mapping and precoding in uplink and downlink.

5.4 TS V5G.212: Multiplexing and channel coding

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

- Channel coding schemes;
- Coding of Layer 1 / Layer 2 control information;
- Interleaving;
- Rate matching.

5.5 TS V5G.213: Physical layer procedures

The scope of this specification is to establish the characteristics of the physical layer procedures, and to specify:

- Synchronisation procedures, including cell search procedure and timing synchronisation;
- Power control procedure;
- Random access procedure;
- Physical downlink shared channel related procedures, including CSI feedback reporting;
- Physical uplink shared channel related procedures, including UE sounding and HARQ ACK/NACK detection;
- Physical shared control channel procedures, including assignment of shared control channels;
- Beam acquisition procedures.