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| **Change Request** | | | | | | | |
| **Document** | **ORAN-WG6.AAL-GAnP** | **ver** | **00.01.00** | **CR** | **NVD-001** | **rev** | **2** | |

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| ***Title:*** | O-DU AAL profiles for 5G eMBB Physical layer | | |
| ***Source to WG:*** | NVIDIA | | |
| ***Target WG :*** | **WG6** | | |
| ***Category:*** | **B** | ***CR Creation Date*** | October 14, 2020 |
|  | *Use one of the following* ***categories****:* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)* ***F*** *(correction)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | |

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| ***Reason for Change:*** | To include 5G eMBB PHY layer channels from which the set of accelerated functions defining an O-DU AAL profile (relevant to 5G NR) can be drawn |
| ***Summary of change:*** | New text and figure are proposed and can be reviewed by track change in the text below |
| ***Consequences if not aproved:*** | If not included, O-DU AAL will profiles will lack a harmonized way of defining accelerated functions |

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| ***Clauses affected:*** | <list specific document sections impacted by the CR> | | | | |
|  | **Y** | **N** |  | |  |
| ***Other specs*** |  | **X** | Other core specifications: | <fill in related CRs if “Y”> | |
| ***affected:*** |  | **x** | Test specifications: | <fill in related CRs if “Y”> | |
| ***(show related CRs)*** |  | **X** | O&M Specifications: | <fill in related CRs if “Y”> | |
| ***Supporting material:***  ***Other comments:*** | <provide file name or URL of any material supporting this CR> | | | | |

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| ***Status:*** |  | ***CR Closed Date:*** |  |
| ***Outcome:*** |  | ***Duplication:*** |  |
| ***Outcome explanation:*** |  | | |

The proposed changes are indicated by Track Changes in the text below.

# AAL Profiles

An AAL profile specifies a set of Accelerated Functions that a Hardware Accelerator processes on behalf on an application within an O-RAN Cloudified Network Function (e.g. O-DU, O-CU etc.). Accordingly, AAL profiles can be categorized as O-DU AAL profiles, O-CU AAL profiles and so on. The following sections describes these different AAL profile categories in further details.

## O-DU AAL Profiles

An O-DU AAL profile can specify a set of Accelerated Functions within the O-DU protocol stack. These functions may belong to a single layer (e.g., PHY) or span across multiple layers (e.g., PHY and MAC) within O-DU. The current O-DU AAL Profiles being studied by ORAN WG6 are focusing on Accelerated functions from PHY layer of O-DU.

Figure 4.1 illustrates the building blocks for processing various O-DU PHY layer Downlink (DL) channels and signals (with 7.2-x functional split between O-DU and O-RU) defined by 3GPP [ref. 38.211] as part of 5G NR specification.



**Figure 4.1 O-DU PHY processing blocks for 5G NR (DL)**

The O-DU PHY layer in downlink consists of the following physical channels and reference signals:

* Physical Downlink Shared Channel (PDSCH) and associated Demodulation Reference Signal (PDSCH DM-RS).
* Physical Downlink Control Channel (PDCCH) and associated Demodulation Reference Signal (PDCCH DM-RS).
* Synchronization Signal Block (SSB) consisting of
  + Physical Broadcast Channel (PBCH) and associated DMRS (PBCH DM-RS).
  + Primary Synchronization Signal (PSS).
  + Secondary Synchronization Signal (SSS).
* Channel State Information-Reference Signal (CSI-RS) and Tracking Reference Signal (TRS).
* Phase Tracking Reference Signal (PT-RS) for DL.

The downlink physical channels (PDSCH, PDCCH, PBCH) carry information originating from higher layers (i.e. layer 2 and above).

The downlink physical layer processing of data channel (PDSCH) carrying transport blocks consists of the following steps:

**TB CRC attachment**: Error detection is provided on each transport block (TB) through a Cyclic Redundancy Check (CRC). Refer to Subclause 7.2.1 in [TS38.212] for details.

**CB segmentation and CRC attachment**: The transport block is segmented when it exceeds the code block (CB) size specified by 3GPP [Ref. TS38.212]. Code block segmentation and code block CRC attachment are performed according to Subclauses 7.2.3 and 5.2.2 of [TS38.212].

**LDPC encoding**: Refer to Subclauses 7.2.4 and 5.3.2 in [TS38.212] for details.

**Rate matching**: Refer to Subclauses 7.2.5 and 5.4.2 in [TS38.212] for details.

**CB concatenation**: Refer to Subclauses 7.2.6 and 5.5 in [TS38.212] for details.

**Scrambling**: Refer to Subclause 7.3.1.1 in [TS38.211] for details.

**Modulation**: Refer to Subclause 7.3.1.2 in [TS38.211] for details.

**Layer mapping**: Refer to Subclause 7.3.1.3 in [TS38.211] for details.

**RE mapping**: Refer to Subclause 7.3.1.5 and 7.3.1.6 in [TS38.211] for details on Resource Element (RE) mapping.

The downlink physical layer processing of control channel (PDCCH) carrying Downlink Control Information (DCI) consists of the following steps:

**CRC attachment**: Error detection is provided on DCI transmissions through a Cyclic Redundancy Check (CRC). Refer to Subclause 7.3.2 in [TS38.212] for details.

**Polar encoding**: Refer to Subclauses 7.3.3 and 5.3.1 in [TS38.212] for details.

**Rate matching**: Refer to Subclauses 7.3.4 and 5.4.1 in [TS38.212] for details.

**Scrambling**: Refer to Subclause 7.3.2.3 in [TS38.211] for details.

**Modulation**: Refer to Subclause 7.3.2.4 in [TS38.211] for details.

**RE mapping**: Refer to Subclause 7.3.2.5 in [TS38.211] for details.

The downlink physical layer processing of broadcast channel (PBCH) carrying maximum one transport block consists of the following steps:

**PBCH payload generation**: Refer to Subclause 7.1.1 in [TS38.212] for details.

**Scrambling**: Refer to Subclause 7.1.2 in [TS38.212] for details.

**TB CRC attachment**: Refer to Subclause 7.1.3 in [TS38.212] for details.

**Polar encoding**: Refer to Subclauses 7.1.4 and 5.3.1 in [TS38.212] for details.

**Rate matching**: Refer to Subclauses 7.1.5 and 5.4.1 in [TS38.212] for details.

**Data scrambling**: Refer to Subclause 7.3.3.1 in [TS38.211] for details.

**Modulation**: Refer to Subclause 7.3.3.2 in [TS38.211] for details.

**RE mapping**: Refer to Subclause 7.3.3.3 in [TS38.211] for details.

The downlink physical signals (DM-RS, PSS, SSS, CSI-RS/TRS, PT-RS) correspond to a set of resource elements used by the physical layer but does not carry information originated from higher layers (i.e. layer 2 and above).

Reference Signals (DM-RS, CSI-RS/TRS, PT-RS) and Synchronization signals (PSS/SSS) are generated using the following steps:

**Sequence Generation and Modulation**: Refer to Subclauses 7.4.1.1.1 (PDSCH DM-RS), 7.4.1.3.1 (PDCCH DM-RS), 7.4.1.4.1 (PBCH DM-RS), 7.4.1.5.2 (CSI-RS/TRS), 7.4.1.2.1 (PT-RS), 7.4.2.2.1 (PSS) and 7.4.2.3.1 (SSS) in [TS38.211] for details

**RE mapping**: Refer to Subclauses 7.4.1.1.2 (PDSCH DM-RS), 7.4.1.3.2 (PDCCH DM-RS), 7.4.1.4.2 (PBCH DM-RS), 7.4.1.5.3 (CSI-RS/TRS), 7.4.1.2.2 (PT-RS), 7.4.2.2.2 (PSS) and 7.4.2.3.2 (SSS) in [TS38.211] for details.

An O-DU AAL profile for 5G NR downlink shall specify a set of accelerated functions corresponding to one or more than one physical downlink channel(s) and/or physical downlink signal(s).

In addition to the processing blocks mentioned above, each of these downlink physical channels/signals may include some additional functional blocks (e.g. precoding, IQ compression) which are implementation specific and may also depend on system configurations/capabilities (for example, whether a O-DU is connected to a CAT-A/CAT-B O-RU). Each of these physical channels/signals can be implemented with/without these optional functional blocks.

Figure 4.2 illustrates the building blocks for processing various O-DU PHY layer Uplink (UL) channels and signals (with 7.2-x functional split between O-DU and O-RU) defined by 3GPP [ref. 38.211] as part of 5G NR specification.



**Figure 4.2 O-DU PHY processing blocks for 5G NR (UL)**

The O-DU PHY layer in uplink consists of the following physical channels and reference signals:

* Physical Uplink Shared Channel (PUSCH).
* Physical Uplink Control Channels (PUCCH) with formats 0/1/2/3/4.
* Physical Random Access Channel (PRACH).
* Sounding Reference Signal (SRS).
* Phase Tracking Reference Signal (PT-RS) for UL.

The uplink physical channels (PUSCH, PUCCH, PRACH) carry information originating from higher layers (i.e. layer 2 and above).

The uplink physical layer processing of shared channel (PUSCH) carrying uplink data with or without Uplink Control Information (UCI) consists of the following steps at the receiver (O-DU):

**RE demapping**: Refer to Subclauses 6.3.1.6, 6.3.1.7 and 6.4.1.1.3 of [TS 38.211] for details on RE mapping at the transmitter.

**Channel estimation and equalization**: up to O-DU implementation.

**Transform precoding** **(IDFT)**: optional, for DFT-s-OFDM waveform. Refer to Subclause 6.3.1.4 of [TS38.211] for details on transform precoding (if applicable) applied at the transmitter.

**Demodulation**: Refer to Subclause 6.3.1.2 in [TS38.211] for details on modulation applied at the transmitter.

**Descrambling**: Refer to Subclause 6.3.1.1 in [TS 38.211] for details on scrambling applied at the transmitter.

**Rate dematching**: Refer to Subclause 6.2.5 in [TS38.212] for details on rate matching applied at the transmitter.

**LDPC decoding**: Refer to Subclause 6.2.4 in [TS38.212] for details on LDPC encoding applied at the transmitter.

**CRC check**: Refer to Subclauses 6.2.1 and 6.2.3 in [TS38.212] for details on TB and CB level CRC attachments applied at the transmitter.

The uplink physical layer processing for control channel (PUCCH) carrying UCI depends on PUCCH formats.

PUCCH format 0 processing consists of the following steps at the receiver (O-DU):

**RE demapping**:Refer to subclause 6.3.2.3.2 of [TS 38.211] for details on RE mapping applied at the transmitter.

**Sequence detection**: The transmitted sequence (refer to Subclause 6.3.2.3 in [TS38.211] for details) is detected at O-DU using a non-coherent detector, since PUCCH format 0 does not carry any DM-RS. The detailed design is up to O-DU implementation.

PUCCH format 1 processing consists of the following steps at the receiver (O-DU):

**RE demapping**: Refer to Subclauses 6.3.2.4.2 and 6.4.1.3.1.2 of [TS38.211] for details on RE mapping applied at the transmitter.

**Channel estimation and equalization**: up to O-DU implementation.

**Demodulation**: Refer to Subclause 6.3.2.4.1 in [TS38.211] for details on modulation applied at the transmitter.

PUCCH formats 2/3/4 processing consists of the following steps at the receiver (O-DU):

**RE demapping**: Refer to Subclauses 6.3.2.5.3 and 6.4.1.3.2.2 (format 2); 6.3.2.6.5 and 6.4.1.3.3.2 (formats 3/4) of [TS38.211] for details on RE mapping applied at the transmitter.

**Channel estimation and equalization**: up to O-DU implementation.

**Transform precoding** **(IDFT)**: optional, for DFT-s-OFDM waveform. Refer to Subclause 6.3.2.6.4 of [TS38.211] for details on transform precoding (applicable for formats 3/4) applied at the transmitter.

**Demodulation**: Refer to Subclause 6.3.2.5.2 (format 2) and 6.3.2.6.2 (formats 3/4) in [TS38.211] for details on modulation applied at the transmitter.

**Descrambling**: Refer to Subclause 6.3.2.5.1 (format 2) and 6.3.2.6.1 (formats 3/4) in [TS 38.211] for details on scrambling applied at the transmitter.

**Rate dematching**: Refer to Subclause 6.3.1.4 in [TS38.212] for details on rate matching applied at the transmitter.

**Polar/Block decoding**: Refer to Subclause 6.3.1.3 in [TS38.212] for details on Polar/Block encoding applied at the transmitter.

**CRC check**: Refer to Subclause 6.3.1.2 in [TS38.212] for details on CRC attachment applied at the transmitter.

The uplink physical layer processing for random access channel (PRACH) carrying preamble consists of the following steps at the receiver (O-DU):

**RE demapping**:Refer to Subclause 6.3.3.2 in [TS38.211] for details on RE mapping applied at the transmitter.

**Root sequence correlation**: Perform correlation operation between root sequence and received signals. Refer to Subclause 6.3.3.1 in [TS38.211] for details on root sequence generation.

**IFFT**: perform the inverse Fast Fourier Transform (iFFT) operation on the received signal(s).

**Noise estimation**: perform the noise estimation operation.

**Peak search**: detect the peak for different root sequences.

**Preamble detection and Timing Advance (TA) or delay estimation**: determine the preamble sequence(s) received and the corresponding timing advance estimate(s).

The uplink physical signals (SRS, PT-RS) do not carry any information from the higher layers (i.e. layer 2 and above).

The Sounding Reference Signal (SRS) in uplink is received at O-DU using the following steps:

**RE demapping**: Refer to Subclauses 6.4.1.4.3 and 6.4.1.4.4 in [TS38.211] for details on RE mapping applied at the transmitter.

**Sequence detection and Channel estimation**: Up to O-DU implementation. Refer to 6.4.1.4.2 in [TS38.211] for details on SRS sequence generation at the transmitter. Channel condition in uplink is estimated at the O-DU based on the processing of received SRS.

The Phase-Tracking Reference Signal (PT-RS) in uplink is received at the O-DU using the following steps:

**RE demapping**: Refer to Subclause 6.4.1.2.2 in [TS38.211] for details on RE mapping applied at the transmitter.

**Sequence detection**: Up to O-DU implementation. Refer to Subclause 6.4.1.2.1 of [TS38.211] for details on sequence generation at the transmitter.

An O-DU AAL profile for 5G NR uplink shall specify a set of accelerated functions corresponding to one or more than one physical uplink channel(s) and/or physical uplink signal(s).

In addition to the processing blocks mentioned above, each of these uplink physical channels/signals may include an additional functional block, viz. IQ decompression, which is implementation specific and may depend on system configuration/capability. Each of these physical channels/signals can be implemented with/without this optional functional block.