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| **Change Request** | | | | | | | |
| **Document** | **ORAN-WG6.AAL-HIGH-PHY** | **ver** | **00.01.01** | **CR** | **NVD-001** | **rev** | 1 |

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| --- | --- | --- | --- |
| ***Title:*** | AAL High-PHY Profiles – review comments | | |
| ***Source to WG:*** | NVIDIA | | |
| ***Target WG :*** | **WG6** | | |
| ***Category:*** | **B** | ***CR Creation Date*** | November 18, 2021 |
|  | *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:*** | Editorial changes, clarifications of some parameters and suggestion for removing implementation restriction related to SRS usage |
| ***Summary of change:*** | New text is proposed and can be reviewed by track change in the text below |
| ***Consequences if not aproved:*** | If not included, AAL HIGH-PHY Spec. will retain editorial errors and undue restrictions |

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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.

# Overview

## Purpose

The AAL General Aspects and Principles is described in ‎[7] including a high level architecture of the AAL and definition of the AAL profiles. This document details the AAL specification consisting of the description of the interface, information models and requirements to implement an AALI, for the AAL\_DOWNLINK\_High-PHY and AAL\_UPLINK\_High-PHY profiles.

This release requires inline accelerators supporting High-PHY profiles in inline acceleration mode to implement both AAL\_DOWNLINK\_High-PHY and AAL\_UPLINK\_High-PHY profiles. Support for partial profiles is for future study.

These profiles are illustrated below in Figure ‎2.1 and Figure ‎2.2.



Figure ‎2.1 AAL\_DOWNLINK\_High-PHY Profile



Figure ‎2.2 AAL\_UPLINK\_High-PHY Profile

## Document Structure

This present document is structured as follows: chapter 2 presents the overview and main purpose of this specification. Chapter 3 will present the high level AALI configuration and management principles for the AAL\_DOWNLINK\_High-PHY and AAL\_UPLINK\_High-PHY Profiles. Chapter 4 presents the Profile Overview for these two profiles, sample capabilities, inputs, and outputs as well as AF parameters for the channels constituting the profiles.

# AALI Configuration and Management

The AALI configuration and management APIs are the APIs that an application (O-DU) executes to configure and manage the AAL-LPU(s) that have been allocated to the application by the O-Cloud. The high-level Configuration and Management Principles are presented in ‎[7].

# AAL Profile Specifications

## Profile Specifications Overview

This section contains information for each AAL profile that is supported. A profile can provide several APIs for specific profile configuration that may be required in addition to the general AAL configuration APIs. Profile specific configuration shall be done on a per AAL-LPU basis. Each profile shall define a list of capabilities that will be used to define the operations supported by the AAL-LPU.

### Naming

Parameters and capabilities based on this stage-2 specification should follow the following naming guidelines:

* Parameter and capability names shall start with a lowercase letter;
* No spaces may be used in the names;
* The names shall consist only of letters and digits;
* The first letter of each non-initial word in a name shall be capitalized.

## O-DU AAL\_DOWNLINK\_HIGH-PHY Profile Specification

This profile provides acceleration functionality for the following channels and signals:

* PDSCH (including Data, DM-RS and PT-RS)
* PDCCH (including Data and DM-RS)
* CSI-RS
* SSB (Including PSS, SSS and PBCH)

This section presents parametrization for each of these channels and signals.

### Profile Operation

The AAL\_DOWNLINK\_High-PHY Profile interface shall work on a slot basis, where the slot, numerology and SFN are signaled for the API.

The input data is specific to each downlink channel composing the profile. The output data is a set of C/U-Plane O-RAN Fronthaul (OFH) packets ‎[8].

The AAL-LPU interfaces directly with the OFH and is responsible for handling its exchange of information with OFH.

### Summary of Capabilities

The AAL\_DOWNLINK\_High-PHY Profile capabilities shall be reported to the application.

Table ‎4‑1 lists a subset of the AAL\_DOWNLINK\_High-PHY profile capabilities that should be reported to the application with respect to the acceleration of the various channel functionality and interaction.

Note: additional capabilities can also be reported by the AALI implementation.

Table ‎4‑1 Sample AAL DOWNLINK HIGH PHY Profile Capabilities

|  |  |  |
| --- | --- | --- |
| **Capability** | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| 3GPP Release | Rel-15, Rel-16, … | <https://www.3gpp.org/specifications/work-plan> |
| PDSCH TB(s) / slot | Number of PDSCH TB(s) per slot | Outside the scope of 3GPP |
| PDSCH TB CRC caching | Supported, or not supported | Outside the scope of 3GPP |
| PDSCH CB CRC caching | Supported, or not supported | Outside the scope of 3GPP |
| Cyclic Prefix | Normal or Extended | 3GPP TS 38.211, sec 4.2 |
| Subcarrier Spacing | 15, 30, 60, 120, 240 kHz; can be channel-specific. | 3GPP TS 38.211, sec 4.2 |
| Bandwidth Support | 5, 10, 15, … MHz | 3GPP TS 38.104, sec 5.3 |
| PDSCH Mapping Type(s) | A or B or both | 3GPP TS 38.211, sec 7.4.1.1.2 |
| PDSCH Allocation Type(s) | 0 or 1 or both | 3GPP TS 38.214, sec 5.1.2.2 |
| PDSCH VRB to PRB Mapping Type | interleaved, or, non-interleaved or both | 3GPP TS 38.211, sec 7.3.1.6 |
| PDSCH DM-RS Configuration Type | 1 or 2 or both | 3GPP TS 38.211, sec 7.4.1.1.2 |
| PDSCH DM-RS additional positions | pos0-pos3 | 3GPP TS 38.211, sec 6.4.1.1.3 |
| PDSCH DM-RS max length | 1 or 2 | 3GPP TS 38.211, sec 7.4.1.1.2 |
| PDSCH CBG ReTx | Supported or not | 3GPP TS 38.212, sec 5.4.2.1, 7.3.1.2.2 |
| PDSCH Max Modulation | QPSK, 16-QAM, etc. | 3GPP TS 38.214, sec 5.14.3 |
| PDSCH PT-RS support | Support for PT-RS | 3GPP TS 38.211, sec 7.4.1.2 |
| PDCCH Coresets / Slot | Number of Coresets per slot | Outside the scope of 3GPP |
| Coreset CCE Mapping Type | Interleaved or not | 3GPP TS 38.211, sec 7.3.2.2 |
| Coreset Precoder Granularity | Wideband (all contiguous RBs) or same as REG bundle | 3GPP TS 38.211, sec 7.3.2.2 |
| Coreset Placement | Any symbol restriction (e.g. first three) | 3GPP TS 38.213, sec 13 |
| PDCCH Precoder support | Short Cyclic Delay Diversity, Precoder Cycling, None, etc. | Outside the scope of 3GPP |
| PDSCH Rate Matching capabilities (around CSI-RS, SSB, etc.) | Support for the rate matching, as well as any support of overlaps between channels:   * PDSCH and SSB * PDSCH and CSI-RS * PDSCH and PDCCH   And overlaps between PDSCH and structures:   * PDSCH and LTE-CRS * PDSCH and PrbSymbPattern (bitmap or Coreset)   Capabilities for this would also list limitations on number and scope of overlaps / patterns. | 3GPP TS 38.214, sec 5.1.4 |
| DL MIMO: SDM & Bandwidth joint support | Support for forming joint precoders across bandwidth, and across baseband antenna ports. Includes the option of “no support” | Outside the scope of 3GPP |
| DL MIMO: Cross Channel MUX | Ability to spatially multiplex same or different channel types (PDSCH, PDCCH, etc.). Includes the option of “no support” | Outside the scope of 3GPP |
| DL MIMO: Maximum number of layers | The maximum number of layers that can be multiplexed (can be channel specific). | Outside the scope of 3GPP |
| DL: MIMO Maximum number of layers per UE | The maximum number of layers that can be allocated to a UE | 3GPP TS 38.211, sec 7.3.1.3 |
| … | … | … |

### PDSCH Channel Model

Per section 5.1.3.2.7 of the O-RAN AAL GAnP document ‎[7] for the PDSCH High PHY Profile, the PDSCH Channel model of the AAL\_DOWNLINK\_High-PHY Profile supports acceleration of PDSCH Data, DM-RS and PT-RS functionalities.

The set of accelerated functions associated with the processing of PDSCH TB(s) is as follows:

* TB CRC attachment
* CB segmentation and CRC attachment
* LDPC encoding
* Rate matching
* CB concatenation
* Scrambling
* Modulation
* Layer mapping
* Precoding [[1]](#footnote-2)
* RE mapping
* Power Offset
* IQ compression1

The set of accelerated functions associated with the processing of PDSCH DM-RS is as follows:

* PDSCH DM-RS sequence generation
* Modulation
* Precoding1
* RE mapping
* Power Offset
* IQ compression1

The set of accelerated functions associated with the processing of PDSCH PT-RS is as follows:

* Sequence Generation
* Layer Mapping
* Modulation
* Precoding1
* RE Mapping
* Power Offset
* IQ compression1

#### PDSCH input for AAL\_DOWNLINK\_HIGH-PHY Profile

The AAL\_DOWNLINK\_High-PHY profile shall signal PDSCH allocation(s) per slot. The input consists of the TB(s), and the associated parameters for the PDSCH allocation.

#### PDSCH Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are organized per signal type: Data, DM-RS, PT-RS.

##### **PDSCH Data Parameters**

Table ‎4‑2: PDSCH Data Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| MAC PDU for TB(s) | | | |
| NrOfCodewords | | number of codewords in the PDSCH transmission (CW index q = 0,1)  In case of single-codeword transmission, q = 0. | 3GPP TS 38.214, sec 5.1.3.2 (max #CW) 3GPP TS 38.211, sec 7.3.1.1 (q index) |
| MAC PDU[q] | | Initial transmission/non-CBG-based Re-tx: full TB to transmit CBG-based Re-tx: CBs to re-transmit | 3GPP TS 38.214, sec 5.1.3.2 (non-CBG ReTx/initial Tx) 3GPP TS 38.214, sec 5.1.7 (CBG-based Tx) |
| TBS[q] | | Transport block size. Computed at L2. | 3GPP TS 38.214, sec 5.1.3.2 |
| TB CRC | | | |
| TB CRC caching[q] | | Compute CRC once, reuse in case of re-transmission (CBG case: must be appended if last CB is retransmitted).  Note: support for CRC caching is up to implementation, and may be subject to capabilities. | 38.212, section 7.2.1 |
| CB Segmentation + CRC | | | |
| last CB Re-tx[q] | | In case of CBG-based Re-tx, and last CBG is re-tx (CBGTI in 38.212), TB CRC is appended to the last CRC in the MAC Payload. Separate per CW  CB CRC is computed in L1 accelerator from MAC PDU (no special controls needed for initial tx; see CB Concatenation section for handling options in case of CBG Re-tx)  Note: cached CRC provisioning is up to implementation, and may be subject to capabilities. | 3GPP TS 38.214, sec 5.1.3.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| LDPC Encoding | | | |
| rv\_{id}[q] | | redundancy version, per CW. Determines starting position k\_0 in the circular buffer. In DCI, or from aggregation, or from first TB (in case of mTRP tx with multiple TBs) | 3GPP TS 38.212, Table 5.4.2.1-2,  3GPP TS 38.214, Table 5.1.2.1-2 |
| R[q] or (MCS Table and MCS index[q]). | | R[q]: target code rate (per CW) Explicit, for initial transmission. Implicit from TBSize and allocation, for retransmissions.  MCS Table and MCS index[q]: target code rate can be extracted from the index (first transmission), or as above for retransmissions. | 3GPP TS 38.212, sec 5.4.2.1 3GPP TS 38.214, sec 5.1.3.1 |
| new Data Indication[q] | | Signals whether there is a new transmission, or a retransmission (per CW) | 3GPP TS 38.212, sec 7.3.1.2.1/2 |
| LDPC base graph[q] | | LDPC base graph to use (can be explicit, or derived from TB size and initial target rate) (per CW) | 3GPP TS 38.212, sec 7.2.2 |
| TBS\_{LBRM} or N\_{CB} | | TBS\_{LBRM}: Reference TBS for allocations subject to rateMatching = limitedBufferRM; impacts circular buffer length  N\_{CB} = circular buffer length, after account for any FBRM/LBRM considerations. | 3GPP TS 38.212, sec 5.4.2.1, 7.2.5 |
| Rate Matching references (determining unavailable REs) | | | |
| SS/PBCH Blocks for Rate Matching | | Set of SSBs, where PDSCH mapping is not possible. | 3GPP TS 38.214, sec 5.1.4 |
| PrbSymbol Bitmap Patterns | | Bitmap-based set of RBs and symbols not available for allocation | 3GPP TS 38.214, sec 5.1.4.1 3GPP TS 38.331, sec 6.3.2 |
| Coreset & SearchSpace Patterns | | CORESET-based set of RBs and symbols not available for allocation | 3GPP TS 38.214, sec 5.1.4.1 3GPP TS 38.331, sec 6.3.2 |
| PDCCH indication | | Rate Matching around the PDCCH grant for the allocation (+ special consideration for AL16 candidates).  See the ‘same-index CCE Candidate’ currently part of PDCCH Profile. Alternatively, that field can be signaled as a part of the PDSCH Profile, as it is applicable to PDSCH Rate Matching. | 3GPP TS 38.214, sec 5.1.4.1 |
| CRS Rate Match Patterns | | LTE-CRS REs not available for allocation (+MBSFN awareness, for LTE-CRS RE mapping to symbols)  Note: in 3GPP, this is an RRC parameter | 3GPP TS 38.214, sec 5.1.4.2 3GPP TS 38.331, sec 6.3.2 |
| CSI-RS Rate Match Patterns | | CSI-RS REs not available for allocation | 3GPP TS 38.214, sec 5.1.4.2 3GPP TS 38.331, sec 6.3.2 |
| CB Concatenation | | | |
| Presence of last CB[q] | | CBG-based Re-tx: presence of last CB requires TB CRC to be re-appended. | 3GPP TS 38.214, sec 5.1.3.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| *see section on MAC PDU for TB(s)* | | CB concatenation is handled in L2, in case of CBG-retx. CB CRC attachment in L1 Accelerator.  Alternatively, CB concatenation can be handled exclusively in L1 accelerator, based on CBGTI signaling from L2 | see section on MAC PDU for TB(s) |
| Scrambling | | | |
| n\_{ID} or c\_{init}[q] | | n\_{UD}: data scrambling identity (PCI by default)  c\_{init}[q]: scrambling initialization for codeword q. | 3GPP TS 38.211, sec 7.3.1.1 |
| n\_{RNTI} | | RNTI associated with the PDSCH transmission | 3GPP TS 38.211, sec 7.3.1.1 |
| q | | index of the codeword being scrambled | 3GPP TS 38.211, sec 7.3.1.1 |
| Modulation | | | |
| Q\_m[q] or (MCS Table and MCS index[q]). | | Q\_m[q]: Signaled via MCS in DCI; also impacts bit interleaving  MCS Table and MCS index[q]: modulation can be extracted from the MCS table and index. | 3GPP TS 38.214, sec 5.1.3.1 3GPP TS 38.212, sec 5.4.2.2 |
| Layer Mapping | | | |
| ν | | total number of layers (when > 4, assignment to codewords described in 38.211; assignment for mTRP case is described in 38.214) | 3GPP TS 38.211, sec 7.3.1.3 3GPP TS 38.214, sec 5.1 |
| Precoding | | | |
| *See section ‎4.2.7* | | Conceptually similar to FH signaling when precoding for Cat-B. 3GPP leaves DL precoding to implementation. Per layer (which also implies per CW) |  |
| RE Mapping | | | |
| Frequency Domain | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PDSCH allocation | 3GPP TS 38.211, sec 7.3.1.6 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PDSCH allocation | 3GGP TS 38.211, sec 7.3.1.6 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| number of DMRS CDM groups without data | No PDSCH mapping on DMRS CDM groups marked as having no data. | 3GPP TS 38.214, sec 5.1.3.2  3GPP TS 38.212, sec 7.3.1.2.2 3GPP TS 38.214, Table 4.1-1 |
| resource allocation type | Mapping to VRBs: bitmap-based (type 0) or offset & length (type 1) | 3GPP TS 38.214, sec 5.1.2.2 |
| RB bitmap | type 0: allocation is based on this bitmap. In 3GPP, it is signaled at RB group resolution | 3GPP TS 38.214, sec 5.1.2.2.1 3GPP TS 38.212, sec 7.3.1.2.2 |
| RB\_{start} | type 1: start of allocation derived from DCI RIV | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| L\_{RBs} | type1: number of contiguously allocated VRBs derived from DCI RIV | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| VRB-to-PRB mapping | virtual resource blocks are mapped to physical resource blocks: interleaved or non-interleaved | 3GPP TS 38.211, sec 7.3.1.6 3GPP TS 38.212, sec 7.3.1.2.1/2 |
| Coreset Type | RB bundling for VRB mapping depends on Coreset Type (DCI format not relevant, if BWP is consistent with Coreset Type) | 3GPP TS 38.211, sec 7.3.1.6 |
| Time Domain | S | Start symbol index, for the allocation | 3GPP TS 38.214, Table 5.1.2.1-1 |
| L | Number of symbols, for the allocation | 3GPP TS 38.214, Table 5.1.2.1-1 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation.  Note: applies only to µ=2. | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Rate Matching | *see the rate matching section* | Rate Matching determines which (RE x Symbol) resources are / are not available for RE mapping. | 3GPP TS 38.214, sec 5.1.4 |
| Power Offset | | | |
|  | <acceleration based on hard-coded values> | Derived based on table 3GPP TS 38.214 table 4.1-1, DMRS Config Type and number of DMRS CDM groups without data | 3GPP TS 38.214, sec 4.1, Table 4.1-1 |

##### **PDSCH DM-RS Parameters**

Table ‎4‑3 PDSCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Sequence Generation | | | |
| N\_{ID} or c\_{init}[l] | | N\_{ID}: scrambling identifier for n\_{SCID}  c\_{init}[l]: scrambling initialization for DMRS symb l. | 3GPP TS 38.211, sec 7.4.1.1.1 |
| n\_{SCID} | | sequence index (from DCI; defaults to 0) | 3GPP TS 38.211, sec 7.4.1.1.1 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PDSCH DM-RS uses QPSK modulation | 3GPP TS 38.211, sec 7.4.1.1.1 |
| Precoding | | | |
| [see PDSCH data precoding] | | DMRS follows PDSCH-data precoding |  |
| RE Mapping | | | |
| Frequency Domain | N\_{BWP}^{start} | see PDSCH data tab | 3GPP TS 38.211, section 7.3.1.6 |
| N\_{BWP}^{size} | see PDSCH data tab | 3GGP TS 38.211, section 7.3.1.6 |
| µ, µ\_{0} | see PDSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| resource allocation type | see PDSCH data tab | 3GPP TS 38.214, sec 5.1.2.2 |
| RB bitmap | see PDSCH data tab | 3GPP TS 38.214, sec 5.1.2.2.1 3GPP TS 38.212, sec 7.3.1.2.2 |
| RB\_{start} | see PDSCH data tab | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| L\_{RBs} | see PDSCH data tab | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| VRB-to-PRB mapping | see PDSCH data tab | 3GPP TS 38.211, sec 7.3.1.6 3GPP TS 38.212, sec 7.3.1.2.1/2 |
| DMRS location referenced from CRB0 | Notes:   * reference point for RE mapping depends on Coreset Type for grant. * This parameter can also be derived from the Coreset Type | 3GPP TS 38.211, sec 7.4.1.1.2 |
| DMRS ports (per layer) | OC weights applied to DM-RS REs, based on DM-RS CDM group and identifier for each DM-RS port. | 3GPP TS 38.211, sec 7.4.1.1.2 |
| configuration type | DMRS configuration type controls port to CDM group correspondence and frequency density (type 1: 8 ports, type 2:12 ports) | 3GPP TS 38.211, sec 7.4.1.1.2 |
| Time Domain | symbol Positions | location of DMRS in slot sufficiently captures the impact of upper layer parameters, e.g., mapping type, additional pos | 3GPP TS 38.211, sec 7.4.1.1.2 and Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 |
|  |  |  |
| DMRS ports (per layer) | OC weights applied to DM-RS REs, based on DM-RS CDM group and identifier for each DM-RS port. | 3GPP TS 38.211, sec 7.4.1.1.2 |
| Cyclic Prefix | see PDSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
| [Power offset w.r.t. SSS] | | power offset with respect to SSS | 3GPP TS 38.214, sec 5.2.2.3.1 3GPP TS 38.214, sec 4.1 3GPP TS 38.213, sec 4.1 |

##### **PDSCH PT-RS Parameters**

Table ‎4‑4 PDSCH PR-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (mostly from 3GPP)** | **3GPP Spec Reference** |
| Sequence Generation | | | |
| dmrs Port(s) | | DMRS port associated with the PT-RS port according to clause  5.1.6.3 in [6, TS 38.214]. Can be two ports, for mTRP | 3GPP TS 38.211, sec 7.4.1.2.1 |
| Layer Mapping | | | |
| dmrs Port(s) | | DMRS port associated with the PT-RS port according to clause  5.1.6.3 in [6, TS 38.214]. Can be two ports, for mTRP | 3GPP TS 38.211, sec 7.4.1.2.2 3GPP TS 38.214, sec 5.1.6.3 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PDSCH PTRS uses QPSK modulation, like PDSCH DMRS | 3GPP TS 38.211, sec 7.4.1.1.1 |
| Precoding | | | |
| same as the associated dmrs Port(s) | |  |  |
| RE Mapping | | | |
| Frequency Domain | N\_{BWP}^{start} | see PDSCH data tab | 3GPP TS 38.211, section 7.3.1.6 |
| N\_{BWP}^{size} | see PDSCH data tab | 3GGP TS 38.211, section 7.3.1.6 |
| µ, µ\_{0} | see PDSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| K\_{PT-RS} | frequency density (includes the case where there is no PT-RS) | 3GPP TS 38.214, sec 5.1.6.3, Table 5.1.6.3-2 |
| k\_{ref}^{RE} | re offset (can depend on DMRS association and RRC signaling of resourceElementOffset) | 3GPP TS 38.211, sec 7.4.1.2.2 , table 7.4.1.2.2-1 3GPP TS 38.331, sec 6.3.1 |
| n\_{RNTI} | RNTI associated with the PDSCH transmission | 3GPP TS 38.211, sec 7.4.1.2.2 |
|  |  |  |
|  |  |  |
| Time Domain | L\_{PT-RS} | time density (includes the case where there is no PT-RS) | 3GPP TS 38.214, sec 5.1.6.3Table 5.1.6.3-1 |
| symbol Positions | see PDSCH DMRS tab symbols used for DMRS (PT-RS skips over these) | 3GPP TS 38.211, sec 7.4.1.1.2 and Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 |
| Cyclic Prefix | see PDSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
| epre-Ratio | | Derived based on table 3GPP TS 38.214 table 4.1-2, epre-Ratio and number of associated DMRS ports (mTRP dependency) | 3GPP TS 38.214, sec 4.1, Table 4.1-2 |

### PDCCH Channel Model

Per section 5.1.3.2.7 of the O-RAN AAL GAnP document ‎[7] for the PDCCH High PHY Profile, the PDCCH Channel model of the AAL\_DOWNLINK\_High-PHY Profile supports acceleration of PDCCH Data and DM-RS functionality.

The set of accelerated functions associated with the processing of PDCCH DCIs is as follows:

* CRC attachment
* Polar encoding
* Rate matching
* Scrambling
* Modulation (QPSK)
* Precoding1
* RE mapping
* IQ compression1
* Power Offset

The set of accelerated functions associated with the processing of PDCCH DM-RS is as follows:

* Sequence generation
* Modulation
* Precoding1
* RE mapping
* IQ compression1

#### PDCCH input for AAL\_DOWNLINK\_HIGH-PHY Profile

The AAL\_DOWNLINK\_High-PHY profile shall signal PDCCH Coreset allocation(s) per slot. The input data consists of the DCI payloads and the associated parameters for the PDCCH Coreset and DCI mapping.

#### PDCCH Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are organized per signal type: Data, DM-RS.

##### **PDCCH Data Parameters**

Table ‎4‑5 PDCCH Data Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| MAC PDU(s) – DCI payloads | | | |
| NrOfDCIs | | number of DCIs in the CORESET | 3GPP TS 38.213, section 10.1 |
| per- DCI | DCI Payload | DCI payload generated by L2 | 3GPP TS 38.212, sec 7.3, 7.3.1 |
| DCI Payload Size | Transport block size. Computed at L2. | 3GPP TS 38.212, sec 7.3, 7.3.1 |
| PDU CRC | | | |
| per-DCI | n\_RNTI | CRC computation detailed in 38.212 # payload size A from MAC # parity size L hardcoded to 24 bits # generator polynomial hard-coded to g\_{CRC24C}(D) # CRC scrambled with RNTI | 3GPP TS 38.212, sec 7.3.2 |
| Polar Encoding | | | |
| Aggregation Level (AL) | | Encoding detailed in 38.212: # input sequence (payload with CRC) has K=A + 24 bits # n\_{max} is hardcoded to 9 # I\_{IL} is hardcoded to 1 # n\_{PC} is hardcoded to 0 # n\_{PC}^{wm} is hardcoded to 0  =========  N: encoded bit length is a direct function of K (A+24) and E (#no-DMRS PDCCH symbols based on *AL* \* 2) and a set of hardcoded parameters.  Interleaving: function of I\_IL (hardcoded for PDCCH) and a set of additional hardcoded table and parameters, operates on the payload  Encoding: function of n\_{PC} (hardcoded for PDCCH), n\_{PC}^{wm} (hardcoded for PDCCH), + additional spec hard-coded tables and parameters, operates on the interleaved payload | 3GPP TS 38.212, sec 7.3.3 |
| Rate Matching | | | |
| Aggregation Level (AL) | | Rate matching detailed in 38.212 # out size E = 2\*#non-DMRS REs (function of Aggregation Level)  # rate match algorithm uses this E, the size of the original sequence + CRC (K), n\_{PC} (hardcoded to 0) and n\_{BIL} (hardcoded to 0) to operate on the polar-coded payload | 3GPP TS 38.214, sec 7.3.4 |
| Scrambling | | | |
| per-DCI | n\_{ID} or c\_{init} | n\_{ID}: data scrambling identity (PCI by default, can be UE-specific)  c\_{init}: scrambling initialization | 3GPP TS 38.211, sec 7.3.2.3 |
| n\_{RNTI} | RNTI-based scrambling associated with the DCI transmission (0 for CSS) | 3GPP TS 38.211, sec 7.3.2.3 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PDCCH uses QPSK modulation | 3GPP TS 38.211, sec 7.3.2.4 3GPP TS 38.211, sec 5.1.3 |
| Precoding | | | |
| per-DCI | *See section ‎4.2.7* | Conceptually similar to FH signaling when precoding for Cat-B. 3GPP leaves DL precoding to implementation. |  |
| RE Mapping | | | |
| Frequency Domain | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: RBs indexing for the frequency domain allocation is relative to the Bandwidth part for the PDCCH allocation | 3GPP TS 38.211, sec 7.3.2.2 3GPP TS 38.331, sec 6.3.2 |
| N\_{BWP}^{size} | Size of bandwidth part: RBs indexing for the frequency domain allocation is relative to the Bandwidth part for the PDCCH allocation | 3GGP TS 38.211, section 7.3.1.6 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| L | Number of REGs in an REG Bundle | 3GPP TS 38.211, sec 7.3.2.2 3GPP TS 38.331, sec 6.3.2 |
| R | Interleaver size | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| cce-REG-MappingType | Mapping of Control Channel Elements (CCE) to Resource Element Groups (REG) | 3GPP TS 38.211, sec 7.3.2.2 3GPP TS 38.211, sec 7.4.1.3.2 3GPP TS 38.331, sec 6.3.2 |
| Frequency Domain Resources | Frequency domain resources for the CORESET. Each bit corresponds a group of 6 RBs, with grouping starting from the first RB g group in the BWP. Validity and bit mapping per the homonymous RRC parameter in 38.331  This parameter applies to both regular CORESETs, as well as CORESET0. For the interpretation regarding CORESET0, see sec 13 of 38.213. | 3GPP TS 38.211, sec. 7.3.2.2 3GPP TS 38.331, sec 6.3.2 3GPP TS 38.213, sec 13 |
| n\_{shift} | offset used in the computation of the interleaver function for CCE-to-REG mapping | 3GPP TS 38.211, sec 7.3.2.2 |
| [precoder Granularity] | Precoder granularity in frequency domain (for data, this is strictly not needed, as it will be accounted for in the precoding) | 3GPP TS 38.211, sec 7.3.2.2 3GPP TS 38.211, sec 7.4.1.3.2 |
| Freq Domain  per DCI | cce Index | cce Index for sending the DCI | 3GPP TS 38.213, sec 10.1 |
| same-index CCE Candidate | indicates presence of an AL-16 candidate existing at the same CCE Index, for PDSCH rate matching purposes  Note: this information is relevant to PDSCH rate matching, and could be signaled in PDSCH for rate matching purposes, instead. See the Rate Matching section of the PDSCH Profile | 3GPP TS 38.214, sec 5.1.4.1 |
| aggregation level | aggregation level for the DCI | 3GPP TS 38.211, sec 7.3.2.1 3GPP TS 38.213, sec 10.1 |
| Time  Domain | first OFDM symbol | Start symbol index, for the allocation | 3GPP TS 38.211, sec. 7.3.2.2 |
| N\_{symb}^{CORESET} | Number of symbols, for the allocation | 3GPP TS 38.211, sec. 7.3.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
| [Power offset w.r.t. SSS] can be hardcoded, for MVP. | | see PDCCH DMRS tab. Can be set to the same value. | 3GPP TS 38.214, sec 5.2.2.3.1 3GPP TS 38.214, sec 4.1 3GPP TS 38.213, sec 4.1 |

##### **PDCCH DM-RS Parameters**

Table ‎4‑6 PDCCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
|  | | | |
| per DCI | N\_{ID} or c\_{init}[l] | N\_{ID}: scrambling identifier  c\_{init}[l]: scrambling initialization for DMRS symb l. | 3GPP TS 38.211, sec 7.4.1.3.1 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PDCCH DM-RS uses QPSK modulation | 3GPP TS 38.211, sec 7.4.1.3.1 |
| Precoding | | | |
| per DCI | [see PDCCH data precoding] | DMRS follows PDCCH-data precoding |  |
| RE Mapping | | | |
| Frequency Domain | N\_{BWP}^ {start} | see PDCCH data tab | 3GPP TS 38.211, section 7.3.2.2 |
| N\_{BWP}^ {size} | see PDCCH data tab | 3GGP TS 38.211, section 7.3.2.2 |
| µ, µ\_{0} | see PDCCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| DMRS Reference Point | reference point for RE mapping physical resources of DMRS depends on Coreset type (#0 or not) | 3GPP TS 38.211, sec 7.4.1.3.2 |
| Precoder Granularity | Precoder granularity in frequency domain (impacts whether DMRS should be generated for all RBs or only allocated RBs) | 3GPP TS 38.211, sec 7.3.2.2 3GPP TS 38.211, sec 7.4.1.3.2 |
| Freq Domain  per DCI | cce Index | see PDCCH data tab | 3GPP TS 38.213, sec 10.1 |
| aggregation level | see PDCCH data tab | 3GPP TS 38.211, sec 7.3.2.1 3GPP TS 38.213, sec 10.1 |
| Time Domain | first OFDM symbol | see PDCCH data tab | 3GPP TS 38.211, sec. 7.3.2.2 |
| N\_{symb}^ {CORESET} | see PDCCH data tab | 3GPP TS 38.211, sec. 7.3.2.2 |
| Cyclic Prefix | see PDCCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
| Power offset w.r.t. SSS | | power offset with respect to SSS | 3GPP TS 38.214, sec 5.2.2.3.1 3GPP TS 38.214, sec 4.1 3GPP TS 38.213, sec 4.1 |

### CSI-RS Channel Model

Per section 5.1.3.2.7 of the O-RAN AAL GAnP document ‎[7] for the CSI-RS High PHY Profile, the CSI-RS Channel model of the AAL\_DOWNLINK\_High-PHY Profile supports acceleration of CSI-RS functionality.

The set of accelerated functions associated with the processing of CSI-RS is as follows:

* CSI-RS sequence generation
* Modulation
* Precoding1
* RE mapping
* IQ compression1
* Power Offset

#### CSI-RS input for AAL\_DOWNLINK\_HIGH-PHY Profile

The AAL\_DOWNLINK\_High-PHY profile shall signal CSI-RS Resource(s) per slot. The input consists of the CSI-RS resource parameters.

#### CSI-RS Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters.

##### **CSI-RS Parameters**

Table ‎4‑7 CSI-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF Parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| Sequence Generation | | | |
| n\_{ID} or c\_{init}[l] | | n\_{ID}: scrambling id  c\_{init}[l]: scrambling initialization for symb [l] | 3GPP TS 38.211, sec 7.4.1.5.2 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | CSI-RS uses QPSK modulation | 3GPP TS 38.211, sec 7.4.1.5.2 |
| Precoding | | | |
| *See section ‎4.2.7* | | Conceptually similar to FH signaling when precoding for Cat-B. 3GPP leaves DL precoding to implementation. |  |
| RE Mapping | | | |
| Frequency Domain | µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| startingRB | PRB where this CSI resource starts in relation to CRB#0 | 3GPP TS 38.331, sec 6.3.2 |
| nrofRBs | Number of PRBs across which this CSI resource spans. | 3GPP TS 38.331, sec 6.3.2 |
| Frequency Domain Allocation | Bitmap defining the frequencyDomainAllocation, with interpretation subject to the Row selection for table 7.4.1.5.3-1 | 3GPP TS 38.331, sec 6.3.2 3GPP TS 38.211, sec 7.4.1.5.3 |
| CSI-RS locations Row | row indicating the CSI-RS location in table 7.4.1.5.3-1. Can be used to derive;   * density ρ (see also Frequency Density) * cdmType * ports * \bar{k} in the (\bar{k}, \bar{l})-tuple | 3GPP TS 38.331, sec 6.3.2  3GPP TS 38.211, sec 7.4.1.5.3 |
|  | Density Dot5 Prb Location | Indicates whether even or odd PRBs are occupied by CSI-RS.  Applicable when density = dot5 (0.5) | 3GPP TS 38.331, sec 6.3.2  3GPP TS 38.211, sec 7.4.1.5.3 |
| Time Domain | CSI-RS locations Row | row indicating the CSI-RS location in table 7.4.1.5.3-1. Can be used to derive;   * \bar{l} in the (\bar{k}, \bar{l})-tuple | 3GPP TS 38.331, sec 6.3.2  3GPP TS 38.211, sec 7.4.1.5.3 |
| l\_0 | value of l\_0 for the interpretation of table 7.4.1.5.3-1. Signaled by RRC parameter firstOFDMSymbolInTimeDomain | 3GPP TS 38.331, sec 6.3.2 3GPP TS 38.211, sec 7.4.1.5.3 |
| l\_1 | value of l\_1 for the interpretation of table 7.4.1.5.3-1. Signaled by RRC parameter firstOFDMSymbolInTimeDomain2 | 3GPP TS 38.331, sec 6.3.2 3GPP TS 38.211, sec 7.4.1.5.3 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
| [Power offset w.r.t. SSS] | | power offset with respect to SSS | 3GPP TS 38.214, sec 5.2.2.3.1 |

### SSB Model

Per section 5.1.3.2.7 of the O-RAN AAL GAnP document ‎[7] for the PBCH High-PHY Profile, the SSB Channel model of the AAL\_DOWNLINK\_High-PHY Profile supports acceleration of PSS+SSS and PBCH Data and PBCH DM-RS functionality.

The set of accelerated functions associated with the processing of PSS+SSS is as follows:

* Sequence generation
* Modulation
* Precoding1
* RE mapping
* IQ compression1
* Power Offset

The set of accelerated functions associated with the processing of PBCH Data is as follows:

* PBCH payload generation
* Scrambling
* TB CRC attachment
* Polar encoding
* Rate matching
* Data scrambling
* Modulation (QPSK)
* Precoding1
* RE mapping
* IQ compression1

The set of accelerated functions associated with the processing of PBCH DM-RS is as follows:

* Sequence generation
* Modulation
* Precoding1
* RE mapping
* IQ compression1
* Power Offset

#### SSB input for AAL\_DOWNLINK\_High-PHY Profile

The AAL\_DOWNLINK\_High-PHY profile shall signal SSB allocation(s), per slot (up to two per slot and SSB configuration, at the SSB slot numerology). The input consists of the PBCH payload and the associated SSB resource allocation parameters.

#### SSB Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are organized per signal type: PBCH Data, PBCH DM-RS, PSS&SSS.

##### **PBCH Data Parameters**

Table ‎4‑8 PBCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF Parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| MAC PDU(s) | | | |
| Payload | | PBCH payload (generated by L2, or in AF) - 32 bits | 3GPP TS 38.212, sec 7.1, 7.1.1 |
| Payload Scrambling | | | |
| N\_{ID}^{cell} or c\_{init} | | N\_{ID}^{cell}: Physical layer cell ID, as defined in as defined in 3GPP TS 38.211, section 7.4.2.1  c\_ | 3GPP TS 38.211, sec 7.4.1.4.1, 7.1.2 |
| L\_{max} | | maximum number of candidate SS/PBCH blocks in a half frame | 3GPP TS 38.211, sec 7.3.3.1, 7.1.2 |
| CRC | | | |
| <acceleration based on hard-coded values> | | CRC computation detailed in 38.212: # (scrambled) payload size A from MAC: 24+8=32 bits (Rel-15,16) # parity size L hardcoded to 24 bits # generator polynomial hard-coded to g\_{CRC24C}(D) | 3GPP TS 38.212, sec 7.1.3 |
| Polar Coding | | | |
| <acceleration based on hard-coded values> | | Encoding detailed in 38.212: # input sequence (scrambled payload with CRC) has K = B = 32 + 24 = 56 bits (result of adding up two hardcoded numbers) # n\_{max} is hardcoded to 9 # I\_{IL} is hardcoded to 1 # n\_{PC} is hardcoded to 0 # n\_{PC}^{wm} is hardcoded to 0  =========  N: encoded bit length is a direct function of K (56) and E (rate match output 864, spelled out in spec) and a set of hard-coded parameters = 512  Interleaving: function of I\_IL (hardcoded for PBCH) and a set of additional hardcoded table and parameters, operates on the payload  Encoding: function of n\_{PC} (hardcoded for PBCH), n\_{PC}^{wm} (hardcoded for PBCH), + additional spec hard-coded tables and parameters, operates on the interleaved payload | 3GPP TS 38.212, sec 7.1.4 |
| Rate Matching | | | |
| <acceleration based on hard-coded values> | | Rate matching detailed in 38.212 # out size E = 864, explicit in the spec, but can be derived as (#non-DMRS REs \* 2) # rate match algorithm uses this E, the size of the original sequence + CRC (K = 56), n\_{PC} (hardcoded to 0) and n\_{BIL} (hardcoded to 0) to operate on the polar-coded payload | 3GPP TS 38.212, sec 7.1.5 |
| Scrambling | | | |
| L\_{max} | | maximum number of candidate SS/PBCH blocks in a half frame | 3GPP TS 38.211, sec 7.3.3.1 |
| \nu | | candidate SS/PBCH block index | 3GPP TS 38.211, sec 7.3.3.1 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PBCH data uses QPSK modulation | 3GPP TS 38.211, sec 7.3.3.2  3GPP TS 38.211, sec 5.1.3 |
| Precoding | | | |
| *See section ‎4.2.7* | | Conceptually similar to FH signaling when precoding for Cat-B. 3GPP leaves DL precoding to implementation. |  |
| RE Mapping | | | |
| Frequency Domain | offsetToPointA | Frequency offset between point A and the lowest subcarrier of the lowest resource block, which has the subcarrier spacing provided by the higher-layer parameter subCarrierSpacingCommon and overlaps with the SS/PBCH block" | 3GPP TS 38.211, sec 4.4.4.2 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| k\_{SSB} | subcarrier offset | 3GPP TS 38.211, sec 7.4.3.1 |
| Time Domain | Case | Case determines first symbol mapping | 3GPP TS 38.213, sec 4.1 |
| ssb index in slot | Index of SSB in slot | 3GPP TS 38.213, sec 4.1 |
| Power Offset | | | |
| <acceleration based on hard-coded values> | | The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE | 3GPP TS 38.213, sec 4.1 |

##### **PBCH DM-RS Parameters**

Table ‎4‑9 PBCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF Parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| Sequence Generation | | | |
| N\_{ID}^{cell} | | Physical cell ID | 3GPP TS 38.211, sec 7.4.1.4.1, 7.4.2.1 |
| L\_{max} | | maximum number of candidate SS/PBCH blocks in a half frame | 3GPP TS 38.211, sec 7.4.1.4.1 |
| i\_{SSB} | | candidate SSB SS/PBCH block index | 3GPP TS 38.211, sec 7.4.1.4.1 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PBCH DM-RS uses QPSK modulation | 3GPP TS 38.211, sec 7.4.1.4.1 |
| Precoding | | | |
| [see PBCH data precoding] | | DMRS follows PDCCH-data precoding |  |
| RE Mapping | | | |
| Frequency Domain | offsetToPointA | see PBCH data | 3GPP TS 38.211, sec 4.4.4.2 |
| µ, µ\_{0} | see PBCH data | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| k\_{SSB} | see PBCH data | 3GPP TS 38.211, sec 7.4.3.1 |
| Time Domain | Case | see PBCH data | 3GPP TS 38.213, sec 4.1 |
| ssb index in slot | see PBCH data | 3GPP TS 38.213, sec 4.1 |
| Power Offset | | | |
| <acceleration based on hard-coded values> | | The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE | 3GPP TS 38.213, sec 4.1 |

##### **PSS & SSS Parameters**

Table ‎4‑10 PSS & SSS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF Parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| Sequence Generation | | | |
| N\_{ID}^{cell} | | Physical cell ID - used to derive N\_ID(1) for SSS and N\_ID(2) for PSS | 3GPP TS 38.211 , sec 7.4.2.1, 7.4.2.2.1, 7.4.2.3.1 |
| Modulation | | | |
| <acceleration based on hard-coded values> | | PSS and SSS use BPSK modulation | 3GPP TS 38.211, sec 7.4.2.2.1, 7.4.2.3.1 |
| Precoding | | | |
| *See section ‎4.2.7* | | Conceptually similar to FH signaling when precoding for Cat-B. 3GPP leaves DL precoding to implementation. |  |
| RE Mapping | | | |
| Freq Domain | offsetToPointA | see PBCH data tab | 3GPP TS 38.211, sec 4.4.4.2 |
| µ, µ\_{0} | see PBCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| k\_{SSB} | see PBCH data tab | 3GPP TS 38.211, sec 7.4.3.1 |
| Time Domain | Case | see PBCH data tab | 3GPP TS 38.213, sec 4.1 |
| ssb index in slot | see PBCH data tab | 3GPP TS 38.213, sec 4.1 |
| Power Offset | | | |
| \beta\_{PSS} | | PSS EPRE to SSS EPRE in an SSB | 3GPP TS 38.213, sec 4.1 |

### Beamforming

In this release, the AAL\_DOWNLINK\_High-PHY profile supports the following beamforming methods available for OFH signaling:

* Predefined-Beam Beamforming, as defined in section 10.4.2.1 of ‎[8];
* Weight-based Dynamic Beamforming, as defined in section 10.4.2.2 of ‎[8];
* Attribute-Based Dynamic Beamforming, as defined in section 10.4.3 of ‎[8];
* Channel-Information-Based Beamforming, as defined in section 10.4.4 of ‎[8].

#### Predefined-Beam Beamforming

AALI shall support Application signaling of the following parameters, as needed for AF-signaling of beamId in C-Plane Section Types 1, 3 [8]:

* frequency-domain beam indices
* time-domain-domain beam indices
* a mixture of the two (“hybrid beamforming”).

#### Weight-based Dynamic Beamforming

AALI shall support Application signaling of the following parameters, as needed for AF-signaling of beamforming weight vectors of (bfwI, bfwQ) in C-Plane Extensions 1, 11, 19 [8]:

Table ‎4‑11 Weight-based Dynamic Beamforming Parameters for Downlink

|  |  |  |
| --- | --- | --- |
| **AF Parameters** | **Summary** | **AF Role** |
| AF 🡪 Application | | |
| Channel Estimation Abstraction | A representation of SRS-based channel observations, as documented in the SRS report in section ‎4.3.5.2 | Signals an abstraction of the Channel Estimation to the Application |
| Application 🡪 AF | | |
| UEs | Selected UEs for scheduling (for an illustration refer to the L users referenced in Appendix J.4 of [8] | Compute precoding weights for the selected UEs and layers, e.g. based on the reported Channel Estimation and its Abstraction.  Signal to O-RU beamforming vectors of weights (bfwI, bfwQ) over C-Plane for the Application-selected UEs and layers.  Alternatively, the beamforming weights may be consumed in AF itself, e.g. Cat-A, when precoding is applied in the O-DU. |
| Layers, per UE | Selected Layers for scheduling (for an illustration refer to the K layers referenced in Appendix J.4 of [8] |

The High-PHY AAL API shall be extensible to allow, in future releases, the optional ability for the beamforming weights to be generated outside the AF that consumes them for generating the appropriate C- and U-plane signaling by the accelerator, e.g. to generate the corresponding U-Plane eAxC I/Q sample streams and C-plane ueId field(s).

#### Attribute-Based Dynamic Beamforming

AALI shall support Application signaling of the following parameters, as needed for AF-signaling of beamforming attributes (bfAzPt, bfZePt, bfAz3dd, bfZe3dd, bfAzSl, bfZeSl) in C-Plane Extensions 2 [8]:

* Zenith main and 3dB angles
* Azimuth main and 3dB angles
* Sidelobe Angles

#### Channel-Information-Based Beamforming

AALI shall support Application signaling of the following parameters, as needed for AAL\_DOWNLINK\_High-PHYprofile signaling of channel estimate vectors of (ciIsample, ciQsample) in C-Plane Section 6 [8]:

Table ‎4‑12 Channel-Information-Based Beamforming Parameters for Downlink

|  |  |  |
| --- | --- | --- |
| **AF Parameters** | **Summary** | **AF Role** |
| AF à Application | | |
| Channel Estimation Abstraction | A representation of SRS-based channel observations, as documented in the SRS report in section ‎4.3.5.2 | Signals an abstraction of the Channel Estimation to the Application |
| Application à AF | | |
| UEs | Selected UEs for scheduling (for an illustration refer to the L users referenced in Appendix J.4 of [8] | Signal to O-RU the Channel Estimates for the Application-selected UEs and layers |
| Layers, per UE | Selected Layers for scheduling (for an illustration refer to the K layers referenced in Appendix J.4 of [8] |

## O-DU AAL UPLINK High-PHY Profile Specification

This profile provides acceleration functionality for the following channels and signals:

* PUSCH (including Data, DM-RS and PT-RS)
* PUCCH (including Data ~~and DM-RS~~) – Format 0
* PUCCH (including Data and DM-RS) – Format 1
* PUCCH (including Data and DM-RS) – Formats 2, 3, 4
* SRS
* PRACH

This section presents parametrization for each of these channels and signals.

### Profile Operation

The AAL\_UPLINK\_High-PHY Profile interface shall work on a slot basis. An operation can be performed one slot at a time, where the slot, numerology and SFN are signaled for the API.

The output data is specific to each uplink channel composing the profile.

The input data consists of:

* a set of Application-supplied parameters for each of the modelled uplink channels
* a set of U-Plane OFH packets.

For the OFH packets, the AAL-LPU interfaces directly with the OFH and is responsible for handling its exchange of information with OFH.

### Summary of Capabilities

The AAL\_UPLINK\_High-PHY Profile capabilities shall be reported to the application.

Table ‎4‑1 lists a subset of the AAL\_UPLINK\_High-PHY profile capabilities that should be reported to the application with respect the acceleration of the various channel functionalities and interaction.

Note: additional capabilities can also be reported by the AALI implementation.

Table ‎4‑13 Sample AAL\_UPLINK\_High-PHY Profile Capabilities

|  |  |  |
| --- | --- | --- |
| **Capability** | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| 3GPP Release | Rel-15, Rel-16, … | https://www.3gpp.org/specifications/work-plan |
| PUSCH TBs / slot | Number of PUSCH TBs per slot | Outside the scope of 3GPP |
| Cyclic Prefix | Normal or Extended | 3GPP TS 38.211, sec 4.2 |
| Subcarrier Spacing | 15, 30, 60, 120, 240 kHz; can be channel-specific. | 3GPP TS 38.211, sec 4.2 |
| Bandwidth Support | 5, 10, 15, … MHz | 3GPP TS 38.104, sec 5.3 |
| PUSCH UCI Multiplexing | Supported or not | 3GPP TS 38.212, sec 6.3.2 |
| PUSCH Frequency Hopping | Supported or not | 3GPP TS 38.214, sec 6.3 |
| PUSCH DM-RS Configuration Type | 1 or 2 or both | 3GPP TS 38.211, sec 6.4.1.1.3 |
| PUSCH DM-RS Max Length | 1 or 2 | 3GPP TS 38.211, sec 6.4.1.1.3 |
| PUSCH Mapping Type | A or B or both | 3GPP TS 38.211, sec 6.4.1.1.3 |
| PUSCH Waveform | CP-OFDM or DFT-S-OFDM | 3GPP TS 38.211, sec 6.3.1.4 |
| PUSCH CBG ReTx | Supported or not | 3GPP TS 38.212, sec 5.4.2.1, 7.3.1.1.2 |
| PUSCH PT-RS support | Support for PT-RS | 3GPP TS 38.211, sec 6.4.1.2 |
| PUSCH Aggregation Factor | 1-8 or not supported | 3GPP TS 38.214, sec 6.1.2.1 |
| PUSCH LBRM Support | Supported or not | 3GPP TS 38.212, sec 5.4.2.1 |
| PUCCH Formats | 0, 1, 2, 3 or 4 | 3GPP TS 38.211, sec 6.3.2 |
| PUCCH Group and Sequence Hopping | Group, sequence or neither | 3GPP TS 38.211, sec 6.3.2.2 |
| PUCCHs per Slot | Max number of PUCCH Resources per slot | Outside the scope of 3GPP |
| PUCCH Aggregation Factor | Supported or not (formats 1, 3, 4) |  |
| SRS usage support | beamManagement, codebook, nonCodebook, antennaSwitching | 3GPP TS 38.214, sec 6.2.1 |
| SRS Report RB subsampling | RB resolution for SRS reports | Outside the scope of 3GPP |
| SRS Reports per Slot | Maximum number of SRS reports per slot | Outside the scope of 3GPP |
| SRS: Max number ports per UE | Maximum number of ports to sample per UE | Partly outside the scope of 3GPP  3GPP TS 38.211, sec 6.4.1.4.1 |
| SRS Configurations | Capabilities regarding SRS configurations:   * Support for consecutive SRS symbols * SRS frequency hopping * Comb Size * Cyclic shifts * Symbols per slot | 3GPP TS 38.211, sec 6.4.1.4 |
| SRS distribution | Capabilities regarding SRS occurrence in time:   * Periodicity * Duty Cycle * Bitmap of symbols per slot * Symbols per slot | 3GPP TS 38.211, sec 6.4.1.4  Partly outside 3GPP Scope |
| PRACH Formats | 0-3, A1-3, B1-4, C0-1 | 3GPP TS 38.211, sec 6.3.3 |
| PRACH Restricted Sets | Type A, B, none | 3GPP TS 38.211, sec 6.3.3 |
| PRACH FD Occasions Per Slot | Per configuration | 3GPP TS 38.211, sec 6.3.3.2 |
| PRACH Configurations | Max number of PRACH configurations | 3GPP TS 38.331, 6.3.2 |
| PRACH ROs per slot | Max number of Time and Frequency domain ROs per slot, across all configurations | Outside the scope of 3GPP |
| PRACH Root Processing Rate | Number of roots that can be processed per unit of time. Can be per preamble format | Outside the scope of 3GPP |
| PRACH ROs Queue Size | The maximum queue size for processing Rach Occasions | Outside the scope of 3GPP |
| UCI Part1 🡪 Part2 Maps | Limitations regarding to the storage of UCI Part1🡪Part2 maps | Outside the scope of 3GPP |
| UL MIMO: SDM & Bandwidth joint support | Support for forming joint precoders across bandwidth, and across baseband antenna ports. Includes the option of “no support” | Outside the scope of 3GPP |
| UL MIMO: Maximum number of layers | The maximum number of layers that can be multiplexed (can be channel specific) | Outside the scope of 3GPP |
| UL: MIMO Maximum number of layers per UE | The maximum number of layers that can be allocated to a UE | 3GPP TS 38.211, sec 6.3.1.3 |
| … | … | … |

### PUSCH Channel Model

Per section 5.1.3.3.7 of the O-RAN AAL GAnP document ‎[7] for the PUSCH High-PHY Profile, the PUSCH Channel model of the AAL\_UPLINK\_High-PHY Profile supports acceleration of PUSCH Data, DM-RS and PT-RS functionality.

The set of accelerated functions associated with the processing of PUSCH TB(s) is as follows:

* IQ decompression1
* RE de-mapping
* Combining
* Channel estimation (see DM-RS and PT-RS)
* Channel equalization (see DM-RS and PT-RS)
* Transform precoding (optional- only required for DFT-s-OFDM waveform)
* Demodulation
* Descrambling
* Rate de-matching
* LDPC decoding
* CRC check
* UCI Decoding

The set of accelerated functions associated with the processing of PUSCH DM-RS is as follows:

* IQ decompression1
* RE de-mapping
* Combining
* Demodulation
* Sequence detection

The set of accelerated functions associated with the processing of PUSCH PT-RS is as follows:

* IQ decompression1
* RE de-mapping
* Combining
* Demodulation
* Layer demapping
* Sequence detection

#### PUSCH input and output for AAL\_UPLINK\_High-PHY Profile

The AAL\_UPLINK\_High-PHY profile shall signal PUSCH allocation(s) per slot.

From Application, the PUSCH interface receives the associated parameters for the PUSCH allocation.

The output data consists of:

* the CRC status for the PUSCH codeword, as well as optionally for individual CBs.
* in cases of successful CRC verification: the TB(s) output of the decoder.
* in case of UCI inclusion: the included UCI payload(s)

#### PUSCH Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are organized per signal type: Data, DM-RS, PT-RS.

##### **PUSCH Data Parameters**

Table ‎4‑14: PUSCH Data Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| MAC TB | | | |
| TBS | | Transport block size. Computed at L2. | 3GPP TS 38.214, sec 6.1.4.2 |
| 🡨 TB (if TB CRC passes) | | This is an output: the TB corresponding to the PUSCH codeword |  |
| UCI detection (if relevant) | | | |
| UCI part 1 size | | Size of UCI part 1 (or single UCI) | 3GPP TS 38.212, sec 6.3.2.4 |
| alphaScaling | | Needed to comput number of coded symbols per layer | 3GPP TS 38.212, sec 6.3.2.4 |
| harqAckBitLength | | Number of HARQ-ACK bits | 3GPP TS 38.212, sec 6.3.2.4 |
| betaOffsetHarq or Q’\_{ACK} | | betaOffsetHarq: Beta Offset for HARQ-ACK bits.  Q’\_{ACK}: the number of coded modulation symbols per layer for HARQ-ACK transmission | 3GPP TS 38.212, sec 6.3.2.4 |
| betaOffsetCsiPart1 or Q’\_{CSI-1} | | betaOffsetCsiPart1: Beta Offset for CSI part 1 bits.  Q’\_{CSI-1}: number of coded modulation symbols per layer for CSI part 1 transmission | 3GPP TS 38.212, sec 6.3.2.4 |
| betaOffsetCsiPart2 | | Beta Offset for CSI part 2 bits. | 3GPP TS 38.212, sec 6.3.2.4 |
| mappings from Csi Part1 to length and priorities of CSI part 2 reports | | Needed to compute in L1 the actual size of CSI part 2 | 3GPP TS 38.213, sec 9.3 |
| 🡨 UCI part 1 | | This is an output: Uninterpreted UCI part 1 |  |
| 🡨 UCI part 2 | | This is an output: Uninterpreted UCI part 2 |  |
| CRC Check | | | |
| 🡨 CRC status | | This is an output: CRC Status for CW + other metrics (e.g. SINR) | 38.212, section 6.2.1 |
| CB CRC and CB Desegmentation | | | |
| C | | number of expected code blocks | 3GPP TS 38.214, sec 5.2.2 |
| CB presence[\*] | | Presence indicator (e.g. bitmap), for each CB | 3GPP TS 38.214, sec 6.2.3 |
| 🡨 report: per-CB CRC status | | This is an output: CRC Status per CB + other metrics (e.g. SINR) | 3GPP TS 38.214, sec 6.2.3 |
| LDPC Decoding | | | |
| rv\_{id} | | redundancy version, per CW. Determines starting position k\_0 in the circular buffer. In DCI, or from aggregation, or from first TB (in case of mTRP tx with multiple TBs) | 3GPP TS 38.214, sec 6.1.4, sec 6.1.2.1 |
| R or (MCS Table and MCS index) | | R: target code rate Explicit, for initial transmission. Implicit from TBSize and allocation, for retransmissions.  MCS Table and MCS index: target code rate can be extracted from the index (first transmission), or as above for retransmissions. | 3GPP TS 38.214, sec 6.1.4.1 |
| new Data Indication | | Signals whether there is a new transmission, or a retransmission (per CW) | 3GPP TS 38.212, sec 7.3.1.1 3GPP TS 38.214, sec 5.1.7.2 |
| HARQ process number | | harq process number for the UL buffer | 3GPP TS 38.212, sec 7.3.1.1 |
| LDPC base graph | | LDPC base graph to use (can be explicit, or derived from TB size and initial target rate) (per CW) | 3GPP TS 38.212, sec 7.2.2 |
| Rate Dematching | | | |
| TBS\_{LBRM} or N\_{CB} | | TBS\_{LBRM}: Reference TBS for allocations subject to rateMatching = limitedBufferRM; impacts circular buffer length  N\_{CB} = circular buffer length, after account for any FBRM/LBRM considerations. | 3GPP TS 38.212, sec 5.4.2.1, 6.2.5 |
| C | | number of expected code blocks. Also uses the rate match size E\_r, which is a computed field | 3GPP TS 38.212, sec 6.2.6 |
| N[\*] | | number of bits in each CB | 3GPP TS 38.212, sec 6.2.6 |
| CB Deconcatentation | | | |
| C | | number of expected code blocks. Also uses the rate match size E\_r, which is a computed field | 3GPP TS 38.212, sec 6.2.6 |
| N[\*] | | number of bits in each CB | 3GPP TS 38.212, sec 6.2.6 |
| Descrambling | | | |
| n\_{ID} or c\_{init} | | n\_{ID}: data scrambling identity (PCI by default)  c\_{init}: scrambling initialization | 3GPP TS 38.211, sec 6.3.1.1 |
| n\_{RNTI} | | RNTI associated with the PDSCH transmission | 3GPP TS 38.211, sec 6.3.1.1 |
| Demodulation | | | |
| Q\_m or (MCS Table and MCS index) | | Q\_m: Signaled via MCS in DCI  MCS Table and MCS index: modulation can be extracted from the MCS table and index. | 3GPP TS 38.214, sec 6.1.4.1 |
| IDFT for DFT-s-OFDM | | | |
| transformPrecoder | | Signaled in DCI | 3GPP TS 38.214, sec 6.3.1.4 |
| Channel Estimation & Equalization | | | |
| <see PUSCH DMRS> | |  |  |
| <see PUSCH PTRS> | |  |  |
| Combining | | | |
| *See section ‎4.2.7‎4.3.7* | | Combiner matrix is per PUSCH allocation |  |
| RE Demapping | | | |
| **Frequency**  **Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| number of DMRS CDM groups without data | No PUSCH mapping on DMRS CDM groups marked as having no data. | 3GPP TS 38.212, sec 7.3.1.1 |
| resource allocation type | Bitmap-based (type 0) or offset & length (type 1) | 3GPP TS 38.214, sec 6.1.2.2 |
| RB bitmap | type 0: allocation is based on this bitmap. In 3GPP, it is signaled at RB group resolution | 3GPP TS 38.214, sec 6.1.2.2.1 3GPP TS 38.212, sec 7.3.1.1.2 |
| RB\_{start} | type 1: start of allocation derived from DCI RIV | 3GPP TS 38.214, sec 6.1.2.2.2 3GPP TS 38.212, sec 7.3.1.1.2 |
| L\_{RBs} | type1: number of continuously allocated VRBs derived from DCI RIV | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.1.2 |
| (intra-slot) frequency hopping | indicates whether PUSCH allocation is based on intra-slot frequency hopping | 3GPP TS 38.212, sec 7.3.1.1 3GPP TS 38.214, sec 6.3 |
| RB\_{start} | location of the second frequency hop | 3GPP TS 38.214, sec 6.3 |
| txDirect Current Location | indicates the subcarrier index within the carrier corresponding to the numerology of the corresponding uplink BWP | 3GPP TS 38.331, sec 6.3.2 |
| shift7dot5kHz | Indicates whether there is 7.5 kHz shift or not. | 3GPP TS 38.331, sec 6.3.2 |
| **Time Domain** | S | Start symbol index, for the allocation | 3GPP TS 38.214, Table 6.1.2.1-1 |
| L | Number of symbols, for the allocation | 3GPP TS 38.214, Table 6.1.2.1-1 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUSCH DM-RS Parameters**

Table ‎4‑15: PUSCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| DMRS Sequence | | | |
| N\_{ID} or c\_{init}[l] | | N\_ID: scrambling identifier for n\_{SCID}  c\_{init}[l]: scrambling initialization for DMRS symb l (CP-OFDM) or for entire DMRS (Rel-15 DFT-S-OFDM) | 3GPP TS 38.211, sec 6.4.1.1.1.1/2 |
| n\_{SCID} | | sequence index (from DCI; defaults to 0) | 3GPP TS 38.211, sec 6.4.1.1.1.1/2 |
|  | |  |  |
| N\_{ID}^{RS} | | same as N\_ID^PUSCH, or PCI (DFT-S-OFDM) | 3GPP TS 38.211, sec 6.4.1.1.1.2 |
| seqOrGroup Hopping | | indicates whether sequence or group hopping is enabled | 3GPP TS 38.211, sec 6.4.1.1.1.2 |
| U | | low PAPR group number [DFT-s-OFDM] | 3GPP TS 38.211, sec 5.2.2 |
| V | | low PAPR sequence number [DFT-s-OFDM] | 3GPP TS 38.211, sec 5.2.2 |
| Demodulation | | | |
| Transform Precoder | | CP-OFDM: PUSCH DM-RS uses QPSK modulation DFT-s-OFDM: PUSCH DMRS uses ZC/CAG sequences | 3GPP TS 38.211, sec 6.4.1.1.1.1/2 |
| Combining | | | |
| [see PUSCH data combining] | | DMRS follows PUSCH-data combining |  |
| TPMI | | [optional] PMI of the UE, can help with combiner formation | 3GPP TS 38.211, sec 6.3.1.5 |
| RE Demapping | | | |
| Frequency Domain | N\_{BWP}^{start} | see PUSCH data tab | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | see PUSCH data tab | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | see PUSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| DMRS ports (per layer) | OC weights applied to DM-RS REs, based on DM-RS CDM group and identifier for each DM-RS port. | 3GPP TS 38.211, sec 6.4.1.1.3 |
| Time Domain | symbol Positions | location of DMRS in a slot sufficiently captures the impact of upper layer parameters, e.g. mapping type, additional pos | 3GPP TS 38.211, sec 6.4.1.1.3 |
| configuration type | DMRS configuration type controls port to CDM group correspondence | 3GPP TS 38.211, sec 6.4.1.1.3 |
| DMRS ports (per layer) | OC weights applied to DM-RS REs, based on DM-RS CDM group and identifier for each DM-RS port. | 3GPP TS 38.211, sec 6.4.1.1.3 |
| Cyclic Prefix | see PUSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUSCH PT-RS Parameters**

Table ‎4‑16: PUSCH PT-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Sequence Detection | | | |
| NrofPorts | | number of PT-RS ports (Rel-15: only one) | 3GPP TS 38.212, sec 7.3.1.1.2 |
| associated DM-RS ports[\*] | | DM-RS ports associated with each of the PT\_RS ports | 3GPP TS 38.214, sec 6.2.3.1 3GPP TS 38.212, sec 7.3.1.1.2 |
| N\_{group}^{PT-RS} | | Number of PT-RS groups | 3GPP TS 38.211, sec 6.4.1.2.1.2 3GPP TS 38.214, sec 6.2.3.2 |
| N\_{samp}^ {group} | | Number of samples per PT-RS group | 3GPP TS 38.211, sec 6.4.1.2.1.2 3GPP TS 38.214, sec 6.2.3.2 |
| N\_{ID} | | Identity for associated PUSCH | 3GPP TS 38.211, sec 6.2.3.2 |
| Layer Demapping | | | |
| NrofPorts | | number of PT-RS ports | 3GPP TS 38.212, sec 7.3.1.1.2 |
| dmrs Port(s) | | DM-RS ports associated with each of the PT-RS ports | 3GPP TS 38.214, sec 6.2.3.1 3GPP TS 38.212, sec 7.3.1.1.2 |
| Combining | | | |
| same as the associated dmrs Port(s) | |  |  |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | see PUSCH data tab | 3GPP TS 38.211, section 7.3.1.6 |
| N\_{BWP}^{size} | see PUSCH data tab | 3GGP TS 38.211, section 7.3.1.6 |
| µ, µ\_{0} | see PUSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| K\_{PT-RS} | frequency density (includes the case where there is no PT-RS) | 3GPP TS 38.214, sec 6.2.3.1, table 6.2.3.1-2 |
| k\_{ref}^{RE} | re offset (can depend on DMRS association and RRC signaling of resourceElementOffset) | 3GPP TS 38.211, sec 6.4.1.2.2, table 6.4.1.2.2.1-1 3GPP TS 38.331, sec 6.3.1 |
| n\_{RNTI} | RNTI associated with the PUSCH transmission | 3GPP TS 38.211, sec 7.4.1.2.2 |
| **Time Domain** | L\_{PT-RS} | time density (includes the case where there is no PT-RS) [CP-OFDM] | 3GPP TS 38.214, sec 6.2.3.1, table 6.2.3.1-1 |
| symbol Positions | see PUSCH DMRS tab symbols used for DMRS (PT-RS skips over these) | 3GPP TS 38.211, sec 7.4.1.1.2 and Tables 7.4.1.1.2-3 and 7.4.1.1.2-4 |
| Cyclic Prefix | see PUSCH data tab | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |
| Power Offset | | | |
|  | alpha\_ {PTRS}^{PUSCH} | PUSCH to PT-RS power ratio per layer per RE | 3GPP TS 38.214, sec 6.2.3.1, Table 6.2.3.1-3 |

### PUCCH Channel Model

Per section 5.1.3.3.7 of the O-RAN AAL GAnP document ‎[7] for the PUCCH High-PHY Profile, the PUCCH Channel model of the AAL\_UPLINK\_High-PHY Profile supports acceleration of PUCCH Format 0, Format 1 UCI and DM-RS and Formats 2,3,4 UCI and DM-RS.

The set of accelerated functions associated with the processing of PUCCH Format 0 is as follows:

* IQ decompression1
* RE de-mapping
* Sequence detection

The set of accelerated functions associated with the processing of PUCCH Format 1 UCI is as follows:

* IQ decompression1
* RE de-mapping
* Channel estimation
* Channel equalization
* Demodulation

The set of accelerated functions associated with the processing of PUCCH Format 1 DM-RS is as follows:

* IQ decompression1
* RE de-mapping
* Combining
* Demodulation
* Sequence detection

The set of accelerated functions associated with the processing of PUCCH Formats 2, 3, 4 is as follows:

* IQ decompression1
* RE de-mapping
* Channel estimation
* Channel equalization
* Transform precoding (optional- only required for DFT-s-OFDM waveform)
* Demodulation
* Descrambling
* Rate de-matching
* Polar/Block decoding
* CRC check

The set of accelerated functions associated with the processing of PUCCH Formats 2, 3, 4 DM-RS is as follows:

* IQ decompression1
* RE de-mapping
* Combining
* Demodulation
* Sequence detection

#### PUCCH input and output for AAL\_UPLINK\_High-PHY Profile

The AAL\_UPLINK\_High-PHY profile shall signal PUCCH resource(s) per slot.

From Application, the PUCCH interface receives the associated parameters for the configuration of the PUCCH resource.

The output data consists of:

* the CRC or detection status of the PUCCH UCI payload (HARQ, SR or CSI), as well as related metrics (e.g. SINR)
* The UCI Payload: HARQ, SR (Formats 0/1) or transparent UCI payload(s) (Formats 2/3/4).

#### PUCCH Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are grouped as follows, in alignment with the O-RAN AAL GAnP document ‎[7]: PUCCH Format 0, PUCCH Format 1 (UCI and DMRS), PUCCH Formats 2/3/4 (UCI and DMRS). Only one of these sets of parameters is applicable to any one PUCCH resource:

##### **PUCCH Format 0 Parameters**

Table ‎4‑17: PUCCH Format 0 Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| UCI | | | |
| SR presence | | indicates whether SR can be indicated | 3GPP TS 38.213, sec 9.2 |
| HARQ bits | | indicates number of HARQ bits | 3GPP TS 38.213, sec 9.2 |
| 🡨 SR and HARQ | | This is an output: SR and HARQ observations, or outcome of detection; Also: metrics like SINR, RSRP, etc. | 3GPP TS 38.213, sec 9.2 |
| Sequence Detection | | | |
| pucch-GroupHopping | | indicates whether group, sequence or no hopping is applied | 3GPP TS 38.211, sec 6.3.2.2.1 |
| n\_{ID} hopping | | hopping identifier | 3GPP TS 38.211, sec 6.3.2.2.1 |
| M0 | | initial cyclic shift | 3GPP TS 38.211, sec 6.3.2.2.2 |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| RB\_{BWP}^{offset} | PRB offset, prior to any hopping | 3GPP TS 38.213, sec 9.2.1 |
| [intra-slot] frequency hopping | indicates whether the allocation hops in frequency or not | 3GPP TS 38.211, sec 6.3.2.2.1 |
| second Hop RB offset | RB offset of the second hop, in case of intra-slot frequency hopping | 3GPP TS 38.213, sec 9.2.1 |
| **Time Domain** | symbol start | first symbol for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| number of symbols | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUCCH Format 1 UCI Parameters**

Table ‎4‑18: PUCCH Format 1 UCI Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| UCI | | | |
| SR presence | | indicates whether SR can be indicated | 3GPP TS 38,213, sec 9.2.4 |
| HARQ/SR bits | | indicates number of HARQ bits | 3GPP TS 38,213, sec 9.2.2 |
| 🡨 SR and HARQ | | This is an output: SR and HARQ observations, if any (or outcome of detection + metrics like SINR, RSRP) |  |
| Demodulation | | | |
| pucch-GroupHopping | | indicates whether group, sequence or no hopping is applied | 3GPP TS 38.211, sec 6.3.2.2.1 |
| n\_{ID} hopping | | hopping identifier | 3GPP TS 38.211, sec 6.3.2.2.1 |
| m0 | | initial cyclic shift | 3GPP TS 38.211, sec 6.3.2.2.2 |
| timeDomainOCC | | index of orthogonal sequence w | 3GPP TS 38.211, sec 6.3.2.4.1 3GPP TS 38.213, section 9.2.1 |
| HARQ/SR bits | | Number of bits determines modulation: BPSK or QPSK | 3GPP TS 38.211, sec 6.3.2.4.1 |
| Channel Estimation and Equalization | | | |
| see PUCCH Format 1 DM-RS | |  |  |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| RB\_{BWP}^{offset} | PRB offset, prior to any hopping | 3GPP TS 38.213, sec 9.2.1 |
| RB Size | Actual number of RBs used by the UE for this allocation | 3GPP TS 38.213, sec 9.2.1 |
| [intra-slot] frequency hopping | indicates whether the allocation hops in frequency or not | 3GPP TS 38.211, sec 6.3.2.2.1 |
| second Hop RB offset | RB offset of the second hop, in case of intra-hop frequency hopping | 3GPP TS 38.213, sec 9.2.1 |
| **Time Domain** | symbol start | first symbol for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| number of symbols | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUCCH Format 1 DM-RS Parameters**

Table ‎4‑19: PUCCH Format 1 DM-RS Parameters[[2]](#footnote-3)

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Descrambling | | | |
| pucch-GroupHopping | | indicates whether group, sequence or no hopping is applied | 3GPP TS 38.211, sec 6.3.2.2.1, 6.4.1.3.1.1 |
| n\_{ID} hopping | | hopping identifier | 3GPP TS 38.211, sec 6.3.2.2.1, 6.4.1.3.1.1 |
| m0 | | initial cyclic shift | 3GPP TS 38.211, sec 6.3.2.2.2, 6.4.1.3.1.1 |
| timeDomainOCC | | index of orthogonal sequence w | 3GPP TS 38.211, sec 6.3.2.4.1, 6.4.1.3.1.1  3GPP TS 38.213, sec 9.2.1 |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7, 6.4.1.3.1.2 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7, 6.4.1.3.1.2 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1, 6.4.1.3.1.2 |
| RB\_{BWP}^{offset} | PRB offset, prior to any hopping | 3GPP TS 38.213, sec 9.2.1  3GPP TS 38.211, sec 6.4.1.3.1.2 |
| RB Size | Actual number of RBs used by the UE for this allocation | 3GPP TS 38.213, sec 9.2.1  3GPP TS 38.211, sec 6.4.1.3.1.2 |
| [intra-slot] frequency hopping | indicates whether the allocation hops in frequency or not | 3GPP TS 38.211, sec 6.3.2.2.1, 6.4.1.3.1.2 |
| second Hop RB offset | RB offset of the second hop, in case of intra-slot frequency hopping | 3GPP TS 38.213, sec 9.2.1  3GPP TS 38.211, sec 6.4.1.3.1.2 |
| **Time Domain** | symbol start | first symbol for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2  3GPP TS 38.211, sec 6.4.1.3.1.2 |
| number of symbols | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2  3GPP TS 38.211, sec 6.4.1.3.1.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1, 6.4.1.3.1.2  3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUCCH Format 2/3/4 UCI Parameters**

Table ‎4‑20: PUCCH Formats 2/3/4 Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| UCI | | | |
| O^{SR} | | indicates the number of SR bits | 3GPP TS 38.213, sec 9.2 3GPP TS 38.212, Table 6.3.1.4-1 |
| O^{ACK} | | indicates number of HARQ bits | 3GPP TS 38.213, sec 9.2 3GPP TS 38.212, Table 6.3.1.4-1 |
| O^{CSI-part1} | | indicates the number of CSI part 1 bits | 3GPP TS 38.213, sec 9.2 3GPP TS 38.212, Table 6.3.1.4-1 |
| mappings from CSI Part1 to length and priorities of CSI part 2 reports | | Needed to compute in L1 the actual size of CSI part 1 (Formats 3,4) | 3GPP TS 38.213, sec 9.2.5 |
| <-- UCI part1 & part2 (if present) | | This is an output: UCI reports (or outcome of decoding + metrics like SINR, RSRP etc.) | 3GPP TS 38.213, sec 9.2 |
| PUCCH Format Type | | 2, 3 or 4 | 3GPP TS 38.213, sec 9.2.2 |
| CRC check | | | |
| <acceleration based on hardcoded parameters> | | CRC size and generator depend on the payload size A, and fixed parameters | 3GPP TS 38.212, sec 6.3.1.2 |
| Polar/Block decoding | | | |
| <acceleration based on hardcoded parameters> | | Encoding depends on the payload size A, and corresponding number of code blocks, and fixed parameters | 3GPP TS 38.212, sec 6.3.1.3 |
| Rate de-matching | | | |
| N\_{symb,UCI}^{PUCCH,\*} | | number of symbols carrying UCI for PUCCH formats 2/3/4 respectively | 3GPP TS 38.212, Table 6.3.1.4-1 |
| N\_{SF}^{PUCCH,\*} | | spreading factor for PUCCH formats 4 | 3GPP TS 38.213, Table 6.3.1.4 |
| N\_{PRBI}^{PUCCH,\*} | | Actual number of RBs used by the UE for this allocation, for each format, respectively | 3GPP TS 38.213, sec 9.2.1 |
| \pi/2-BPSK | | indicates that Formats 3-4 use \pi/2-BPSK, rather than QPSK modulation Note: QPSK for Format 2 | 3GPP TS 38.211, sec 6.3.2.6.2, sec 6.3.2.5.2 |
| R\_{UCI}^{max} | | Max coding rate to determine how to feedback UCI | 3GPP TS 38.212, Table 6.3.1.4-1 |
| Descrambling | | | |
| n\_{RNTI} | | RNTI associated with the PUCCH transmission | 3GPP TS 38.211, sec 6.3.2.5.1 and 6.3.2.6.1 |
| n\_{ID} or c\_{init} | | n\_{ID}: scrambling id (PCI by default)  c\_{init}: scrambling initialization | 3GPP TS 38.211, sec 6.3.2.5.1 and 6.3.2.6.1 |
| Demodulation | | | |
| \pi/2-BPSK | | indicates that Formats 3-4 use \pi/2-BPSK, rather than QPSK modulation Note: QPSK for Format 2 | 3GPP TS 38.211, sec 6.3.2.6.2, sec 6.3.2.5.2 |
| Block-wise Despreading | | | |
| occ-Index | | index of orthogonal sequence for Format 4. | 3GPP TS 38.213, section 9.2.1 |
| occ-Length | | length of orthogonal sequence for Format 4. | 3GPP TS 38.213, section 9.2.1 |
| IDFT for DFT-s-OFDM | | | |
| RB Size | | Actual number of RBs used by the UE for this allocation (Format 3) | 3GPP TS 38.213, sec 9.2.1 |
| number of symbols | | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| Channel Estimation and Equalization | | | |
| see PUCCH Format 2/3/4 DM-RS | |  |  |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| RB\_{BWP}^ {offset} | PRB offset, prior to any hopping | 3GPP TS 38.213, sec 9.2.1 |
| N\_{PRBI}^ {PUCCH,\*} | Actual number of RBs used by the UE for this allocation, for each format, respectively | 3GPP TS 38.213, sec 9.2.1 |
| [intra-slot] frequency hopping | indicates whether the allocation hops in frequency or not | 3GPP TS 38.211, sec 6.3.2.2.1 3GPP TS 38.212, sec 6.3.1.4 |
| second Hop RB offset | RB offset of the second hop, in case of intra-slot frequency hopping | 3GPP TS 38.213, sec 9.2.1 |
| **Time Domain** | symbol start | first symbol for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| N\_{symb,UCI}^ {PUCCH,\*} | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

##### **PUCCH Format 2/3/4 DM-RS Parameters**

Table ‎4‑21: PUCCH Formats 2/3/4 DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Descrambling | | | |
| N\_{ID}^0 or c\_{init}[l] | | N\_{ID}^0: scrambling ID 0 for Format 2  c\_{init}[l]: scrambling initialization, per DMRS symb l. | 3GPP TS 38.211, sec 6.4.1.3.2.1 |
| pucch-GroupHopping | | indicates whether group, sequence or no hopping is applied (Formats 3/4) | 3GPP TS 38.211, sec 6.3.2.2.1 |
| n\_{ID} hopping | | hopping identifier (Formats 3/4) | 3GPP TS 38.211, sec 6.3.2.2.1 |
| m0 | | initial cyclic shift (Formats 3/4) | 3GPP TS 38.211, sec 6.3.2.2.2 |
| occ-Index | | index of orthogonal sequence for Format 4. | 3GPP TS 38.213, section 9.2.1 |
| occ-Length | | length of orthogonal sequence for Format 4. | 3GPP TS 38.213, section 9.2.1 |
| RE Demapping | | | |
| **Frequency Domain** | N\_{BWP}^{start} | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| RB\_{BWP}^ {offset} | PRB offset, prior to any hopping | 3GPP TS 38.213, sec 9.2.1 |
| N\_{PRBI}^ {PUCCH,\*} | Actual number of RBs used by the UE for this allocation, for each format, respectively | 3GPP TS 38.213, sec 9.2.1 |
| [intra-slot] frequency hopping | indicates whether the allocation hops in frequency or not | 3GPP TS 38.211, sec 6.3.2.2.1 3GPP TS 38.212, sec 6.3.1.4 |
| second Hop RB offset | RB offset of the second hop, in case of intra-slot frequency hopping | 3GPP TS 38.213, sec 9.2.1 |
| **Time Domain** | symbol start | first symbol for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| N\_{symb,UCI}^ {PUCCH,\*} | number of symbols for the PUCCH allocation | 3GPP TS 38.213, sec 9.2.2 |
| additionalDMRS | Indicates 2 additional DMRS symbols per hop of a PUCCH Format 3 or 4 (depending on length) | 3GPP TS 38.213, sec 9.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

### SRS Channel Model

Per section 5.1.3.3.7 of the O-RAN AAL GAnP document ‎[7] for the SRS High-PHY Profile, the SRS Channel model of the AAL\_UPLINK\_High-PHY Profile supports acceleration of SRS.

The set of accelerated functions associated with the processing of SRS is as follows:

* IQ decompression1
* RE de-mapping
* Channel estimation

#### SRS input and output for AAL\_UPLINK\_High-PHY Profile

The AAL\_UPLINK\_High-PHY profile shall signal SRS Resource(s) per slot.

From Application, the SRS interface receives the associated parameters for the configuration of the SRS Resource.

The output data consists of the channel estimation metrics

#### SRS Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are grouped as follows, in alignment with the O-RAN AAL GAnP document ‎[7]:

##### **SRS Parameters**

Table ‎4‑22: SRS Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **AF parameters** | | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Channel Estimation (report types are per implementation and may be optional) | | | | |
|  | usage | | usage of the SRS resource | 3GPP TS 38.331, sec 6.3.2 |
|  | requested report type | | depends on usage |  |
| **usage: antennaSwitching w/ SRS report** | format of U, V entries | | Size e.g. 16-bit, 32-bit and formats e.g. BFP, etc used for encoding channel eigenvector matrices | *See section ‎4.2.7‎4.3.7* |
| format of eigenvalues | | Size e.g. 8-bit, 16-bit and formats e.g. BFP, etc used for encoding channel singular values |
| frequency resolution of SVD report | | e.g. RB, PRG, etc |
| <-- SVD reports | | at the required resolution |
| **usage: codebook or noncodebook w/ H report** | format of H entries | | Size e.g. 16-bit, 32-bit and formats e.g. BFP, etc used for encoding channel matrices | *See section ‎4.2.7‎4.3.7* |
| frequency resolution of H report | | e.g. RB, PRG, etc |
| <-- H reports | | at the required resolution |
| **usage: beamManagement** | frequency resolution of H report | | e.g. RB, PRG, etc |  |
| <-- SINR reports | | at the required resolution (per symbol) |  |
| **Additional report types can be added** |  | |  |  |
| RE demapping | | | | |
| N\_{ap}^{SRS} | | | number of SRS Ports | 3GPP TS 38.211 , sec 6.4.1.4.1 |
| n\_{SRS}^{CS} | | | cyclic shift | 3GPP TS 38.211 , sec 6.4.1.4.2 |
| n\_{ID}^{SRS} | | | SRS sequence identity | 3GPP TS 38.211 , sec 6.4.1.4.2 |
| SRS Group and Sequence Hopping | | | Group, sequence or neither | 3GPP TS 38.211, sec 6.4.1.4.2 |
| Frequency domain | N\_{BWP}^{start} | | Start, w.r.t. CRB, of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| N\_{BWP}^{size} | | Size of bandwidth part: VRBs indexing is relative to the Bandwidth part for the PUSCH allocation | 3GPP TS 38.211, sec 6.3.1.7 |
| µ, µ\_{0} | | subcarrier spacing impacts waveform generation, including centering | 3GPP TS 38.211, sec 4.2, 5.3.1 |
| K\_{TC} | | transmission comb number | 3GPP TS 38.211 , sec 6.4.1.4.2 |
| \bar{k}\_{TC} | | transmission comb offset | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| n\_{shift} | | frequency domain shift value | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| n\_{RRC} | | frequency domain position | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| Frequency Hopping Signaling Alt-1: RRC parameters | C\_{SRS} | SRS bandwidth index | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| B\_{SRS} | SRS bandwidth config index | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| b\_{hop} | frequency hopping | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| Frequency Hopping Signaling Alt-2: L2 computed fields | m\_{SRS,b} | SRS bandwidth size | 3GPP TS 38.211, sec 6.4.1.4.3 |
| srs Bandwidth Start | PRB index (w.r.t. CRB0) for the start of SRS signal transmission | 3GPP TS 38.211 [2], section 6.4.1.4.2 |
| Time domain | N\_{symb}^{SRS} | | number of consecutive OFDM symbols for SRS | 3GPP TS 38.211 , sec 6.4.1.4.1 |
| l\_0 | | the starting position in the time domain given | 3GPP TS 38.211 , sec 6.4.1.4.1 |
| T\_{SRS} | | periodicity for SRS | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| T\_{offset} | | slot offset | 3GPP TS 38.211 , sec 6.4.1.4.3 |
| R | | Repetition factor | 3GPP TS 38.211 , sec 6.4.1.4.3 |

### PRACH Channel Model

Per section 5.1.3.3.7 of the O-RAN AAL GAnP document ‎[7] for the PRACH High-PHY Profile, the PRACH Channel model of the AAL\_UPLINK\_High-PHY Profile supports acceleration of PRACH.

The set of accelerated functions associated with the processing of PRACH is as follows:

* IQ decompression1
* RE de-mapping
* Root sequence generation and correlation
* IFFT
* Noise estimation
* Peak search for power delay profile
* Preamble detection and delay/timing advance estimation

#### PRACH input and output for AAL\_UPLINK\_High-PHY Profile

The AAL\_UPLINK\_High-PHY profile shall signal PRACH Resource Occasion(s) per slot.

From Application, the PRACH interface receives the associated parameters for the configuration of the PRACH Occasion.

The output data consists of the PRACH detection outcome and metrics

#### PRACH Parameters

The following parameters are required to be supported by the AALI implementation when offloading operations. Application shall supply all relevant parameters; for ease of reading, the parameters are grouped as follows, in alignment with the O-RAN AAL GAnP document ‎[7]:

##### **PRACH Parameters**

Table ‎4‑23: PRACH Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Preamble Detection + Delay Estimation | | | |
| <-- report detected preambles | | list of detected preambles, per RO |  |
| <-- timing advance | | per detected preamble & RO: timing advance | 3GPP TS 38.213, sec 4.2 |
| <-- detection metrics | | per detected preamble & RO: SINR, Rx Power, etc. |  |
| Peak Search | | | |
| <see Root Sequence Correlation> | | Correlation is over the root sequences with valid preambles in each RACH occasion. The mechanism for detecting peaks is per implementation. |  |
| Noise Estimation | | | |
| <per implementation> | | One possibility is to perform noise estimation on an unused root sequence, in which case the identity of the unused root sequence can be signaled.  Note: Noise estimation is implementation-specific, and this channel profile does not currently assume any one implementation. |  |
| iFFT | | | |
| <based on RE mapping parameters and sequence length> | | The formula for generating the PRACH waveform is provided in the reference to the right. | 3GPP TS 38.211, sec 5.3.2 |
| Root Sequence Correlation | | | |
| restrictedSetConfig | | Configuration of an unrestricted set or one of two types of restricted sets, type A and type B | 3GPP TS 38.211, sec 6.3.3.1 |
| N\_{preamble}^{total} | | number of preambles, per PRACH occasions | 3GPP TS 38.213, section 8.1 |
| preamble index start | | preamble index start for each PRACH occasion in this PRACH configuration | 3GPP TS 38.213, section 8.1 |
| N\_{cs} | | cyclic shift interval | 3GPP TS 38.211, sec 6.3.3.1 |
| RE Demapping | | | |
| **Frequency Domain** | M | number of FDM occasions per PRACH slot | 3GPP TS 38.211, sec 6.3.3.2 |
| k1[\*] | offset in units of BWP PRBs (per RO) | 3GPP TS 38.211, sec 5.3.2 |
| µ\_{PUSCH} | subcarrier spacing of UL BWP and of maximal SCS BWP | 3GPP TS 38.211, sec 5.3.2 |
| µ\_{PRACH} | subcarrier spacing of PRACH preamble | 3GPP TS 38.211, sec 5.3.2 |
| \bar{k} | guard offset from k1 (can be derived from the SCS for PRACH and PUSCH and PRACH format) | 3GPP TS 38.211, sec 6.3.3 |
| **Time Domain** | starting symbol | prachStartSymbol | 3GPP TS 38.211, sec 6.3.3.2, Tables 6.3.3.2-2 to 6.3.3.2-4 |
| prachFormat | formats of the PRACH slot (0, 1, 2, 3, A1, … A3/B3) | 3GPP TS 38.213, sec 9.2.2 |
| N\_t^{RA,slot} | number of Time domain PRACH occasions within a PRACH slot | 3GPP TS 38.213, sec 9.2.2 |
| Cyclic Prefix | Cyclic prefix type. Impacts time-domain allocation, including waveform generation | 3GPP TS 38.211, sec 4.2, 5.3.1 3GPP TS 38.214, Table 5.1.2.1-1 |

### Beamforming

In this release, the AAL\_UPLINK\_High-PHY profile supports the following beamforming methods available for OFH signaling:

* Predefined-Beam Beamforming, as defined in section 10.4.2.1 of ‎[8];
* Weight-based Dynamic Beamforming, as defined in section 10.4.2.2 of ‎[8];
* Attribute-Based Dynamic Beamforming, as defined in section 10.4.3 of ‎[8];
* Channel-Information-Based Beamforming, as defined in section 10.4.4 of ‎[8].

#### Predefined-Beam Beamforming

AALI shall support Application signaling as described in section ‎4.2.7.1

#### Weight-based Dynamic Beamforming

AALI shall support Application signaling of the following parameters, as needed for AAL\_UPLINK\_High-PHY profile signaling of beamforming weight vectors of (bfwI, bfwQ) in C-Plane Extensions 1, 11, 19 [8]:

Table ‎4‑24 Weight-based Dynamic Beamforming Parameters for Uplink

|  |  |  |
| --- | --- | --- |
| **AF Parameters** | **Summary** | **AF Role** |
| AF 🡪 Application | | |
| Channel Estimation Abstraction | A representation of SRS-based channel observations, as documented in the SRS report in section ‎4.3.5.2 | Signals an abstraction of the Channel Estimates to the Application |
| Application 🡪 AF | | |
| UEs | Selected UEs for scheduling (for an illustration refer to the L users referenced in Appendix J.4 of [8] | Compute combining weights for the selected UEs and Precoders, e.g. based on the reported Channel Estimation and its Abstraction.  Signal to O-RU beamforming vectors of weights (bfwI, bfwQ) over C-Plane for the Application-selected UEs and Precoders |
| UE-based Precoder | Selected precoding matrix for scheduling the UEs (see section 6.3.1.5 in of 3GPP TS 38.211) |

The High-PHY AAL API shall be extensible to allow, in future releases, the optional ability for the beamforming weights to be generated outside the AF that consumes them for generating the appropriate C- and U-plane signaling by the accelerator, e.g. to generate the corresponding U-Plane eAxC I/Q sample streams and C-plane ueId field(s).

#### Attribute-Based Dynamic Beamforming

AALI shall support Application signaling as described in section ‎4.2.7.1‎4.2.7.3

#### Channel-Information-Based Beamforming

AALI shall support Application signaling of the following parameters, as needed for AF-signaling of channel estimate vectors of (ciIsample, ciQsample) in C-Plane Section 6 [8]:

Table ‎4‑25 Channel-Information-Based Beamforming Parameters for Downlink

|  |  |  |
| --- | --- | --- |
| **AF Parameters** | **Summary** | **AF Role** |
| AF 🡪 Application | | |
| Channel Estimation Abstraction | A representation of SRS-based channel observations, as documented in the SRS report in section ‎4.3.5.2 | Signals an abstraction of the Channel Estimation the Application |
| Application 🡪 AF | | |
| UEs | Selected UEs for scheduling (for an illustration refer to the L users referenced in Appendix J.4 of [8] | Signal to O-RU the Channel Estimates for the Application-selected UEs and Precoders |
| Layers, per UE | Selected precoding matrix for scheduling the UEs (see section 6.3.1.5 in of 3GPP TS 38.211) |

1. Configurable functional block, depends on implementation and/or system configuration [↑](#footnote-ref-2)
2. All the parameters in this PUCCH Format 1 DM-RS table are also present in the PUCCH Format 1 UCI table [↑](#footnote-ref-3)