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Technical Specification

O-RAN Working Group 6

Acceleration Abstraction Layer

High-PHY Profiles

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# Revision History

|  |  |  |  |
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| **Date** | **Revision** | **Author** | **Description** |
| 2021.10.28 | 00.00.01 | Qualcomm | Initial draft of specification - Overview, profile specifications. |
| 2021.11.02 | 00.00.02 | Qualcomm | Removed Rel-16 parameters |
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| 2021.11.03 | 00.00.04 | Qualcomm | Edits to beamforming sections to include additional requirement. Additional profile capabilities. |
| 2021.11.03 | 00.00.05 | Qualcomm | Integration of technical and editorial comments from Nokia and Ericsson; fixing typos. |
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| 2021.11.11 | 00.00.07 | Qualcomm | Removed FFS and related Notes, and moved open items to wiki  Added section 4.1.2 on parameter naming convention  Changed “AF” to “AAL DL/UL Hight-PHY profile” in the first paragraph of sections 4.2.7.2 and 4.3.7.2  Typos, editorials |

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# Introductory Material

## Scope

This Technical Specification has been produced by the O-RAN Alliance.

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

Release x.y.z

where:

x the first digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc. (the initial approved document will have x=01).

y the second digit is incremented when editorial only changes have been incorporated in the document.

z the third digit included only in working versions of the document indicating incremental changes during the editing process.

The present document focuses on the Acceleration Abstraction Layer for the AAL\_DOWNLINK\_High-PHY and AAL\_DOWNLINK\_High-PHY Profiles.

## References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document. 3GPP references refer to 3GPP release 16.

1. 3GPP TR 21.905: “Vocabulary for 3GPP Specifications”.
2. Cloud Architecture and Deployment Scenarios for O-RAN Virtualized RAN, 2019.
3. WG6 2020 Use Case for BBU Pooling, 2019.
4. 3GPP TS 38.211: "NR; Physical channels and modulation".
5. 3GPP TS 38.212: "NR; Multiplexing and channel coding".
6. 3GPP TR 38.300: "NR; NR and NG-RAN Overall Description".
7. O-RAN WG6 Acceleration Abstraction Layer General Aspects and Principles
8. O-RAN WG4 Control, User and Synchronization Plane Specification

## Definitions and Abbreviations

### Definitions

For the purposes of the present document, the terms and definitions given in [7] apply.

### Abbreviations

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

AAL Acceleration Abstraction Layer

AALi Acceleration Abstraction Layer interface

AAL-LPU Acceleration Abstraction Layer Logical Processing Unit

CB Code Block

CNF Containerized Network Function

NF Network Function

O-CU O-RAN Centralized Unit

O-DU O-RAN Distributed Unit

O-RU O-RAN Radio Unit

OS Operating System

TB Transport Block

# 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 AF to implement both AAL\_DOWNLINK\_High-PHY and AAL\_UPLINK\_High-PHY profiles. Partial profiles are FFS.

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



Figure 2.1 Downlink Channel Profile



Figure 2.2 Uplink Channel 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 AAL Hardware Acceleration Management specification 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 AALi parameters for the channels constituting the profiles.

# AALi Configuration and Management

The chapter is expected to define configuration and management aspects of the AALi as they relate to the the inline profiles defined in ‎Chapter 4. The AALi configuration and management API’s are the API’s 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 accelerator basis and only for functionality that cannot be changed at run time. Each profile shall define a capabilities list that will be used to define the operations supported by the AAL-LPU.

### Operation Representation

Operations offloaded to the AAL-LPU are represented by a single operation context that shall include all necessary information required for the AAL operation to be processed on a particular AAL-LPU.

The operation context by itself defines the operation type as supported by the AAL Profile. It includes an operation status, a reference to the operation specific data, which can vary in size and content depending on the operation/profile being provisioned. Application software is responsible for specifying all the operation specific fields in the which are then used by the AAL-LPU to process the requested operation.

### 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 HI 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. An operation can be performed one slot at a time, where the slot, numerology and SFN are signaled for the API.

The input data is specific to each downlink channel composing the profile. The Application ensures that the input data buffer is sized appropriately to accommodate the required input data. The output data is a set of C/U-Plane OFH packets.

The AF interfaces directly with the OFH and is responsible for handling its own output buffers.

### 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 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 HI 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 TBs / slot | Number of PDSCH TBs per slot | Outside 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 Types | A or B | 3GPP TS 38.211, sec 7.4.1.1.2 |
| PDSCH Allocation Types | 0 or 1 | 3GPP TS 38.214, sec 5.1.2.2 |
| PDSCH VRB to PRB Mapping Type | interleaved, non-interleaved | 3GPP TS 38.211, sec 7.3.1.6 |
| PDSCH DM-RS Configuration Type | 1 or 2 | 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 | QPK, 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 scope of 3GPP |
| Coreset CCE Mapping Type | Interleaved or not (more description FFS) | 3GPP TS 38.211, sec 7.3.2.2 |
| Coreset Precoder Granularity | Wideband or allocation (more description FFS) | 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 | C-SDD, Precoder cycling, etc. | Outside 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 ovelaps / 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. | Outside scope of 3GPP |
| DL MIMO: Cross Channel MUX | Ability to spaptially multiplex same of different channel types (PDSCH, PDCCH, etc) | Outside scope of 3GPP |
| DL MIMO: Maximum number of layers | The maxmum number of layers that can be multiplexed (can be channel specific) | Outside scope of 3GPP |
| … | … | … |

### PDSCH Channel Model

Similarly to the O-RAN AAL GAnP document [7] for the PDSCH HI PHY Profile, the PDSCH Channel model of the AAL DOWNLINK HI PHY Profile supports acceleration of PDSCH Data, DM-RS and PT-RS functionality.



Figure 4.1 PDSCH Channel Model

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\_HI PHY Profile

The PDSCH interface for the AAL DOWNLINK HI PHY profile shall work on a PDSCH allocation basis. The input data consists of the TB(s) input to the encoder, 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.

User plane parameters (transport block/s) may be supplied separately from other allocation-defining parameters.

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

Table ‎4‑2: PDSCH Data Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF parameters** | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| MAC PDU for TB(s) / User Plane | | | |
| 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 capabilties. | 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 Concatentation section for handling options in case of CBG Re-tx)  Note: cached CRC provisioning is up to implementation, and may be subject to capabilties. | 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 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 based 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 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 Concatentation | | | |
| 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 concatentation is handled in L2, in case of CBG-retx. CB CRC attachment in L1 Accelerator.  Alternatively, CB concatentation 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 continuously allocated VRBs derived froM DCI RIV | 3GPP TS 38.214, sec 5.1.2.2.2 3GPP TS 38.212, sec 7.3.1.2.2 |
| 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 Corese 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 locations 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 assocaited DMRS ports (mTRP dependency) | 3GPP TS 38.214, sec 4.1, Table 4.1-2 |

### PDCCH Channel Model

Similarly to the O-RAN AAL GAnP document [7] for the PDCCH HI PHY Profile, the PDCCH Channel model of the AAL DOWNLINK HI PHY Profile supports acceleration of PDCCH Data and DM-RS functionality.



Figure 4.2 PDCCH Channel Model

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\_HI PHY Profile

The PDCCH interface for the AAL DOWNLINK HI PHY profile shall work on a PDCCH Coreset allocation basis. The input data consists of the DCI payloads input to the encoder, 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 ‎4‑6 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 bt length is a direct function of K (A+24) and E (#no-DMRS PDCCH symbols based on *AL* \* 2) and a set of hard-coded parameters.  Interleaving: functon 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 paramerrs, 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 roup 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 interpetation 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 accounded 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 exists 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 | Cyclick 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 ‎4‑7 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

Similarly to the O-RAN AAL GAnP document [7] for the CSI-RS HI PHY Profile, the CSI-RS Channel model of the AAL DOWNLINK HI PHY Profile supports acceleration of CSI-RS functionality.



Figure 4.3 CSI-RS and TRS Channel Model

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\_HI PHY Profile

The CSI-RS interface for the AAL DOWNLINK HI PHY profile shall work on a CSI-RS Resource basis basis. The input data consists 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 ‎4‑8 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

Similarly to 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.



Figure 4.4 PBCH Channel Model

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 SSB interface for the AAL DOWNLINK High-PHY profile shall work on a SSB allocation basis basis (up to two per slot, at the SSB slot numerology). The input data consists 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.

User plane parameters (PBCH payload) may be supplied separately from other allocation-defining parameters.

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

Table ‎4‑8 PBCH DM-RS Parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **AF Parameters** | | **Summary (3GPP-based)** | **3GPP Spec Reference** |
| MAC PDU(s)/User Plane | | | |
| 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 bt 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: functon 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 paramerrs, 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 ‎4‑9 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 ‎4‑9 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 for usage: antennaSwitching in section ‎4.3.5.2 | Computes Channel Estimates and Channel Estimation Abstraction, and signals the abstraction 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 atributes (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 ‎4‑9 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 for usage: antennaSwitching in section ‎4.3.5.2 | Computes Channel Estimates and Channel Estimation Abstraction, and signals the abstraction 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 Application ensures that the output data buffer is sized appropriately to accommodate the expected output.

The input data consits 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 AF interfaces directly with the OFH and is responsible for handling its own input buffers.

### 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 functionality and interaction.

Note additional capabilities can also be reported by the AALi implementation.

Table ‎4‑1 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 |
| PDSCH TBs / slot | Number of PDSCH TBs per slot | Outside 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 | 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 | 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 Slort | Max number of PUCCH Resources per slot | Outside 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 scope of 3GPP |
| SRS Reports per Slot | Maximum number of SRS reports per slot | Outside scope of 3GPP |
| SRS: Max number ports per UE | Maximum number of ports to sample per UE | Partily outside the scope of 3GPP  3GPP TS 38.211, sec 6.4.1.4.1 |
| SRS Configurations | Capabilities regarding SRS configurations:   * Support fo consecutive SRS symbols * SRS hopping * Comb Size * Cyclic shifts * Symbols per slot | 3GPP TS 38.211, sec 6.4.1.4 |
| SRS distribution | Capabiliuties regarding SRS occurrence in time:   * Periodicity * Duty Cycle * Bitmap of symbopls 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 | Pper 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 scope of 3GPP |
| PRACH Root Processing Rate | Number of roots that can be processed per unit of time. Can be per preamble foramt | Outside scope of 3GPP |
| PRACH ROs Queue Size | The maxmum queue size for processing Rach Occasions | Outside scope of 3GPP |
| UCI Part1 🡪 Part2 Maps | Limitations regarding to the storage of UCI Part1🡪Part2 maps | Outside scope of 3GPP |
| UL MIMO: SDM & Bandwidth joint support | Support for forming joint precoders across bandwidth, and across baseband antenna ports. | Outside scope of 3GPP |
| UL MIMO: Maximum number of layers | The maxmum number of layers that can be multiplexed (can be channel specific) | Outside scope of 3GPP |
| … | … | … |

### PUSCH Channel Model

Similarly to 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; per 3GPP, it also supports acceleration of the PUSCH 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 PUSCH interface for the AAL UPLINK High-PHY profile shall work on a PUSCH allocation basis.

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 ‎4‑12: 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 computer 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 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 based 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 ‎‎4.3.7* | | 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 PDSCH 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 PDSCH 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 offet & 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 ‎4‑13: 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 |  |
| TMPI | | [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 locations in 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 time 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 ‎4‑14: 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 assciation 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

Similarly to 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 and Formats 2,3,4.

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 is as follows:

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

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

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

The PUCCH interface for the AAL UPLINK High-PHY profile shall work on a PUCCH resource basis.

From Application, the PUSCH interface receives the associated parameters for the configuration of the PUSCH 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, PUCC Formats 2/3/4. Only one of these sets of parameters is applicable to any one PUCCH resource:

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

Table ‎4‑15: 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 wheter 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 PDSCH 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 PDSCH 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-hop freqency 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 Parameters**

Table ‎4‑16: PUCCH Format 1 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 wheter 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 | | | |
| **<tbd why no parameters>** | |  |  |
| 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 PDSCH 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 PDSCH 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 freqency 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 2/3/4 Parameters**

Table ‎4‑17: 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) | 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 correspoding 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 Foramts 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 | | | |
| additionalDMRS | | Indicates 2 additional DMRS symbol per hop of a PUCCH Format 3 or 4 (depending on length) | 3GPP TS 38.213, sec 9.2.2 |
| 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 |
| 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 PDSCH 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 PDSCH 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-hop freqency 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 |

### SRS Channel Model

Similarly to 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 PUCCH Format 0 is as follows:

* IQ decompression1
* RE de-mapping
* Channel estimation

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

The SRS interface for the AAL UPLINK High-PHY profile shall work on a SRS Resource basis.

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

The output data consists of the channel estimationmetrics

#### 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 ‎4‑18: SRS Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **AF parameters** | | | **Short summary (from 3GPP)** | **3GPP Spec Reference** |
| Channel Estimation | | | | |
|  | 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 ‎‎4.3.7* |
| 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 SVR 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 ‎‎4.3.7* |
| 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 reports type for various usages can be added, based on WG6/vendor interest** |  | |  |  |
|  |  | |  |  |
| 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 PDSCH 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 PDSCH 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

Similarly to 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 PUCCH Format 0 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 PRACH interface for the AAL UPLINK High-PHY profile shall work on a PRACH Resource Occasion basis.

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 ‎4‑19: 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 lenth> | | The formula for generating the PRACH waveform is provided n 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 ‎4‑9 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 for usage: codebook or usage: noncodebook in section ‎4.3.5.2 | Computes Channel Estimates and Channel Estimation Abstraction, and signals the abstraction 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 ‎‎4.2.7.3

#### 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 ‎4‑9 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 for usage: antennaSwitching in section ‎4.3.5.2 | Computes Channel Estimates and Channel Estimation Abstraction, and signals the abstraction 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] | 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) |

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1.6 “Defensive Suspension” means for the purposes of any license grant pursuant to Section 3, Member, Contributor, Academic Contributor, Adopter, or any of their Affiliates, may have the discretion to include in their license a term allowing the licensor to suspend the license against a licensee who brings a patent infringement suit against the licensing Member, Contributor, Academic Contributor, Adopter, or any of their Affiliates.

## Section 2: COPYRIGHT LICENSE

2.1 Subject to the terms and conditions of this Agreement, O-RAN Alliance hereby grants to Adopter a nonexclusive, nontransferable, irrevocable, non-sublicensable, worldwide copyright license to obtain, use and modify O-RAN Specifications, but not to further distribute such O-RAN Specification in any modified or unmodified way, solely in furtherance of implementations of an ORAN

Specification.

2.2 Adopter shall not use O-RAN Specifications except as expressly set forth in this Agreement or in a separate written agreement with O-RAN Alliance.

## Section 3: FRAND LICENSE

3.1 Members, Contributors and Academic Contributors and their Affiliates are prepared to grant based on a separate Patent License Agreement to each Adopter under Fair Reasonable And Non- Discriminatory (FRAND) terms and conditions with or without compensation (royalties) a nonexclusive, non-transferable, irrevocable (but subject to Defensive Suspension), non-sublicensable, worldwide patent license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Implementations; provided, however, that such license shall not extend: (a) to any part or function of a product in which a Compliant Implementation is incorporated that is not itself part of the Compliant Implementation; or (b) to any Adopter if that Adopter is not making a reciprocal grant to Members, Contributors and Academic Contributors, as set forth in Section 3.3. For the avoidance of doubt, the foregoing licensing commitment includes the distribution by the Adopter’s distributors and the use by the Adopter’s customers of such licensed Compliant Implementations.

3.2 Notwithstanding the above, if any Member, Contributor or Academic Contributor, Adopter or their Affiliates has reserved the right to charge a FRAND royalty or other fee for its license of Necessary Claims to Adopter, then Adopter is entitled to charge a FRAND royalty or other fee to such Member, Contributor or Academic Contributor, Adopter and its Affiliates for its license of Necessary Claims to its licensees.

3.3 Adopter, on behalf of itself and its Affiliates, shall be prepared to grant based on a separate Patent License Agreement to each Members, Contributors, Academic Contributors, Adopters and their Affiliates under Fair Reasonable And Non-Discriminatory (FRAND) terms and conditions with or without compensation (royalties) a nonexclusive, non-transferable, irrevocable (but subject to Defensive Suspension), non-sublicensable, worldwide patent license under their Necessary Claims to make, have made, use, import, offer to sell, lease, sell and otherwise distribute Compliant Implementations; provided, however, that such license will not extend: (a) to any part or function of a product in which a Compliant Implementation is incorporated that is not itself part of the Compliant Implementation; or (b) to any Members, Contributors, Academic Contributors, Adopters and their Affiliates that is not making a reciprocal grant to Adopter, as set forth in Section 3.1. For the avoidance of doubt, the foregoing licensing commitment includes the distribution by the Members’, Contributors’, Academic Contributors’, Adopters’ and their Affiliates’ distributors and the use by the Members’, Contributors’, Academic Contributors’, Adopters’ and their Affiliates’ customers of such licensed Compliant Implementations.

## Section 4: TERM AND TERMINATION

4.1 This Agreement shall remain in force, unless early terminated according to this Section 4.

4.2 O-RAN Alliance on behalf of its Members, Contributors and Academic Contributors may terminate this Agreement if Adopter materially breaches this Agreement and does not cure or is not capable of curing such breach within thirty (30) days after being given notice specifying the breach.

4.3 Sections 1, 3, 5 - 11 of this Agreement shall survive any termination of this Agreement. Under surviving Section 3, after termination of this Agreement, Adopter will continue to grant licenses (a) to entities who become Adopters after the date of termination; and (b) for future versions of ORAN Specifications that are backwards compatible with the version that was current as of the date of termination.

## Section 5: CONFIDENTIALITY

Adopter will use the same care and discretion to avoid disclosure, publication, and dissemination of O-RAN Specifications to third parties, as Adopter employs with its own confidential information, but no less than reasonable care. Any disclosure by Adopter to its Affiliates, contractors and consultants should be subject to an obligation of confidentiality at least as restrictive as those contained in this Section. The foregoing obligation shall not apply to any information which is: (1) rightfully known by Adopter without any limitation on use or disclosure prior to disclosure; (2) publicly available through no fault of Adopter; (3) rightfully received without a duty of confidentiality; (4) disclosed by O-RAN Alliance or a Member, Contributor or Academic Contributor to a third party without a duty of confidentiality on such third party; (5) independently developed by Adopter; (6) disclosed pursuant to the order of a court or other authorized governmental body, or as required by law, provided that Adopter provides reasonable prior written notice to O-RAN Alliance, and cooperates with O-RAN Alliance and/or the applicable Member, Contributor or Academic Contributor to have the opportunity to oppose any such order; or (7) disclosed by Adopter with O-RAN Alliance’s prior written approval.

## Section 6: INDEMNIFICATION

Adopter shall indemnify, defend, and hold harmless the O-RAN Alliance, its Members, Contributors or Academic Contributors, and their employees, and agents and their respective successors, heirs and assigns (the “Indemnitees”), against any liability, damage, loss, or expense (including reasonable attorneys’ fees and expenses) incurred by or imposed upon any of the Indemnitees in connection with any claims, suits, investigations, actions, demands or judgments arising out of Adopter’s use of the licensed O-RAN Specifications or Adopter’s commercialization of products that comply with O-RAN Specifications.

## Section 7: LIMITATIONS ON LIABILITY; NO WARRANTY

EXCEPT FOR BREACH OF CONFIDENTIALITY, ADOPTER’S BREACH OF SECTION 3, AND ADOPTER’S INDEMNIFICATION OBLIGATIONS, IN NO EVENT SHALL ANY PARTY BE LIABLE TO ANY OTHER PARTY OR THIRD PARTY FOR ANY INDIRECT, SPECIAL, INCIDENTAL, PUNITIVE OR CONSEQUENTIAL DAMAGES RESULTING FROM ITS PERFORMANCE OR NON-PERFORMANCE UNDER THIS AGREEMENT, IN EACH CASE WHETHER UNDER CONTRACT, TORT, WARRANTY, OR OTHERWISE, AND WHETHER OR NOT SUCH PARTY HAD ADVANCE NOTICE OF THE POSSIBILITY OF SUCH DAMAGES. O-RAN SPECIFICATIONS ARE PROVIDED “AS IS” WITH NO WARRANTIES OR CONDITIONS WHATSOEVER, WHETHER EXPRESS, IMPLIED, STATUTORY, OR OTHERWISE. THE O-RAN ALLIANCE AND THE MEMBERS, CONTRIBUTORS OR ACADEMIC CONTRIBUTORS EXPRESSLY DISCLAIM ANY WARRANTY OR CONDITION OF MERCHANTABILITY, SECURITY, SATISFACTORY QUALITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, ERROR-FREE OPERATION, OR ANY WARRANTY OR CONDITION FOR O-RAN SPECIFICATIONS.

## Section 8: ASSIGNMENT

Adopter may not assign the Agreement or any of its rights or obligations under this Agreement or make any grants or other sublicenses to this Agreement, except as expressly authorized hereunder, without having first received the prior, written consent of the O-RAN Alliance, which consent may be withheld in O-RAN Alliance’s sole discretion. O-RAN Alliance may freely assign this Agreement.

## Section 9: THIRD-PARTY BENEFICIARY RIGHTS

Adopter acknowledges and agrees that Members, Contributors and Academic Contributors (including future Members, Contributors and Academic Contributors) are entitled to rights as a third-party beneficiary under this Agreement, including as licensees under Section 3.

## Section 10: BINDING ON AFFILIATES

Execution of this Agreement by Adopter in its capacity as a legal entity or association constitutes that legal entity’s or association’s agreement that its Affiliates are likewise bound to the obligations that are applicable to Adopter hereunder and are also entitled to the benefits of the rights of Adopter hereunder.

## Section 11: GENERAL

This Agreement is governed by the laws of Germany without regard to its conflict or choice of law provisions.

This Agreement constitutes the entire agreement between the parties as to its express subject matter and expressly supersedes and replaces any prior or contemporaneous agreements between the parties, whether written or oral, relating to the subject matter of this Agreement.

Adopter, on behalf of itself and its Affiliates, agrees to comply at all times with all applicable laws, rules and regulations with respect to its and its Affiliates’ performance under this Agreement, including without limitation, export control and antitrust laws. Without limiting the generality of the foregoing, Adopter acknowledges that this Agreement prohibits any communication that would violate the antitrust laws.

By execution hereof, no form of any partnership, joint venture or other special relationship is created between Adopter, or O-RAN Alliance or its Members, Contributors or Academic Contributors. Except as expressly set forth in this Agreement, no party is authorized to make any commitment on behalf of Adopter, or O-RAN Alliance or its Members, Contributors or Academic Contributors.

In the event that any provision of this Agreement conflicts with governing law or if any provision is held to be null, void or otherwise ineffective or invalid by a court of competent jurisdiction, (i) such provisions will be deemed stricken from the contract, and (ii) the remaining terms, provisions, covenants and restrictions of this Agreement will remain in full force and effect.

Any failure by a party or third party beneficiary to insist upon or enforce performance by another party of any of the provisions of this Agreement or to exercise any rights or remedies under this Agreement or otherwise by law shall not be construed as a waiver or relinquishment to any extent of the other parties’ or third party beneficiary’s right to assert or rely upon any such provision, right or remedy in that or any other instance; rather the same shall be and remain in full force and effect.

1. Configurable functional block, depends on implementation and/or system configuration [↑](#footnote-ref-2)