**O-RAN White Box Hardware Working Group Outdoor Micro Cell Hardware Architecture and Requirements (FR1)**

**Specification**

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**Specification**

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# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Date | Revision | Author | Description |
| 2021.01.14 | v01.00 | WG7 | Final Version for Publication |

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# Chapter 1 Introductory Material

## 1.1 Scope

1. This Technical Specification has been produced by the O-RAN.org.
2. The contents of the present document are subject to continuing work within O-RAN WG7 and may change
3. following formal O-RAN approval. Should the O-RAN.org modify the contents of the present document, it will
4. be re-released by O-RAN Alliance with an identifying change of release date and an increase in version number
5. as follows:
6. Release x.y.z
7. where:
8. x the first digit is incremented for all changes of substance, i.e. technical enhancements, corrections,
9. updates, etc. (the initial approved document will have x=01).
10. y the second digit is incremented when editorial only changes have been incorporated in the document.
11. z the third digit included only in working versions of the document indicating incremental changes during
12. the editing process. This variable is for internal WG7 use only.
13. The present document specifies system requirements and high-level architecture for the Outdoor Micro Cell
14. deployment scenario case as specified in the Deployment Scenarios and Base Station Classes document [[1].](#_bookmark0)

## 1.2 References

1. The following documents contain provisions which, through reference in this text, constitute provisions of the
2. present document.
3. [1] O-RAN-WG7.DSC.0-V01.00 Technical Specification, ‘Deployment Scenarios and Base Station Classes
4. for White Box Hardware’.
5. [2] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".
6. [3] 3GPP TR 38.104: "NR; Base Station (BS) radio transmission and reception".
7. [4] O-RAN-WG4.CUS.0-v01.00 Technical Specification, ‘O-RAN Fronthaul Working Group Control, User
8. and Synchronization Plane Specification’.
9. [5] CPRI Specification V7.0 (2015-10-09) Interface Specification, ‘Common Public Radio Interface (CPRI).
10. [6] Small Cell Forum, SCF222.10.02 5G FAPI: PHY API Specification,
11. https://scf.io/en/documents/222\_5G\_FAPI\_PHY\_API\_Specification.php
12. [7] 3GPP TS 38.113: “NR: Base Station (BS) Electromagnetic Compatibility (EMC)
13. [8] O-RAN Architecture Description, O-RAN-WG1-O-RAN Architecture Description - v01.00.00

## 1.3 Definitions and Abbreviations

### 1.3.1 Definitions

1. For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [[2]](#_bookmark1) and the
2. following apply. A term defined in the present document takes precedence over the definition of the same term,
3. if any, in [[2].](#_bookmark1) For the base station classes of Pico, Micro and Macro, the definitions are given in 3GPP TR 38.104
4. [[3].](#_bookmark2)
5. **Carrier Frequency:** Center frequency of the cell.
6. **F1 interface:** The standard interface between an O-CU and an O-DUx specified in [8].
7. **Integrated architecture:** An architecture wherein the O-RUx and O-DUx are implemented on one platform.
8. Each O-RUx and RF front end is associated with one O-DUx and is connected to O-CU via F1 interface.
9. **Split architecture:** An architecture wherein O-RUx and O-DUx are physically separated from one another. A
10. switch may aggregate multiple O-RUx (s) to one O-DUx. The O-DUx, switch and O-RUx (s) are connected by
11. the fronthaul interface as defined in [4].
12. **Transmission Reception Point (TRxP**): Antenna array with one or more antenna elements available to the
13. network located at a specific geographical location for a specific area.
14. **Occupied Bandwidth (OBW)**: It refers to the bandwidth occupied by the base station when operated, defined
15. by the sum of the active bandwidths of the band allocation(s) operated. As defined by 3GPP TS 34.121 section
16. 5.8, occupied bandwidth is the bandwidth containing 99% of the total integrated power of the transmitted
17. spectrum, centered on the assigned channel frequency. The bandwidth between the 0.5% power frequency points
18. is the occupied bandwidth.
19. **Instantaneous Bandwidth (IBW)**: It refers to the bandwidth in which all frequency components can be
20. simultaneously analyzed. It is defined by the frequency boundaries of the operating band(s).
21. **Frequency Range**: It refers to bandwidth defined by the frequency range within which the Base Station can be
22. operated, defined by the band-pass filter of the BS; e.g., 3.4 – 3.8 GHz (400 MHz)
23. **Frequency Band:** A designated frequency range for the operation of the base station and the UE radios. [5G](https://en.wikipedia.org/wiki/5G_NR)
24. [NR](https://en.wikipedia.org/wiki/5G_NR) frequency bands are divided into two different frequency ranges: Frequency Range 1 (FR1) that mainly
25. includes sub-6GHz frequency bands, some of which are bands traditionally used by previous standards but has
26. been extended to cover potential new spectrum offerings from 410MHz to 7125MHz; Frequency Range 2
27. (FR2) that includes frequency bands from 24.25 GHz to 52.6 GHz. Bands in this [mmWave](https://en.wikipedia.org/wiki/MmWave) range have shorter
28. range but higher available bandwidth than bands in the FR1.
29. **Fronthaul Gateway (FHGW)**: A fronthaul gateway is a physical entity that is located between a distributed
30. unit and one or more radio units where it distributes, aggregates, and/or converts fronthaul protocols between the
31. distributed unit and multiple radio units.
32. Normative terms used in this specification are defined in following:
33. Shall: indicates a requirement
34. Should: indicated as recommendation
35. May: indicates a permission

### 1.3.2 Abbreviations

1. For the purposes of the present document, the abbreviations given in [[2]](#_bookmark1) and the following apply. An
2. abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if
3. any, as in [[2].](#_bookmark1)
4. 7-2 Fronthaul interface split option as defined by O-RAN WG4, also referred to as 7-2x
5. 3GPP Third Generation Partnership Project
6. 5G Fifth-Generation Mobile Communications
7. 5GC 5G Core
8. ACS Adjacent Channel Selectivity
9. ADC Analog to Digital Converter
10. ASIC Application Specific Integrated Circuit
11. ATA Advanced Technology Attachment
12. BPSK Binary Phase Shift Keying
13. BS Base Station
14. CDR Clock/Data Recovery
15. CFR Crest Factor Reduction
16. CU Centralized Unit as defined by 3GPP
17. DAC Digital to Analog Converter
18. DDC Digital Down Conversion
19. DDR Double Data Rate
20. DL Downlink
21. DPD Digital Pre-Distortion
22. DSP Digital Signal Processor
23. DU Distributed Unit as defined by 3GPP
24. DUC Digital Up Conversion
25. EMC ElectroMagnetic Compatibility
26. EVM Error Vector Magnitude
27. FFT Fast Fourier Transform
28. FH Fronthaul
29. FHGW Fronthaul Gateway
30. FHGWx Fronthaul gateway with no FH protocol translation, supporting an O-DUx with split option x
31. and an O-RUx with split option x, with currently available options 66, 7-27-2 and 88

|  |  |  |
| --- | --- | --- |
| 1 | FHGWxy | Fronthaul Gateway that can translate FH protocol from an O-DUx with split option x to an O- |
| 2 |  | RUy with split option y, with currently available option 7-28. |
| 3 | FPGA | Field Programmable Gate Array |
| 4 | GbE | Gigabit Ethernet |
| 5 | GNSS | Global Navigation Satellite System |
| 6 | GPP | General Purpose Processor |
| 7 | IEEE | Institute of Electrical and Electronics Engineers |
| 8 | IMD | InterModulation Distortion |
| 9 | I/O | Input/Output |
| 10 | JTAG | Joint Test Action Group |
| 11 | L1 | Layer 1, also referred to as PHY or Physical Layer in OSI model |
| 12 | L2 | Layer 2, also referred to as Data Link layer in OSI model |
| 13 | L3 | Layer 3, also referred to as Network Layer in OSI model |
| 14 | LED | Light Emitting Diode |
| 15 | LTE | Long Term Evolution |
| 16 | MAC | Media Access Control |
| 17 | MCP | Multi-Chip Package |
| 18 | MIMO | Multiple Input Multiple Output |
| 19 | MTBF | Mean Time Between Failures |
| 20 | MU-MIMO | Multiple User MIMO |
| 21 | NG | Next Generation |
| 22 | NR | New Radio |
| 23 | OAM | Operations, Administrations and Maintenance |
| 24 | OBW | Occupied Bandwidth |
| 25 | O-CU | O-RAN Centralized Unit as defined by O-RAN |
| 26 | O-DUx | A specific O-RAN Distributed Unit having fronthaul split option x where x may be 6, 7-2 (as |
| 27 |  | defined by WG4) or 8 |
| 28 | O-RUx | A specific O-RAN Radio Unit having fronthaul split option x, where x is 6, 7-2 (as defined |
| 29 |  | by WG4) or 8, and which is used in a configuration where the fronthaul interface is the same |
| 30 |  | at the O-DUx |
| 31 | PCIe | Peripheral Component Interface Express |
| 32 | PDCP | Packet Data Convergence Protocol |
| 33 | PHY | Physical Layer, also referred as L1 |
| 34 | PLL | Phase Locked Loop |
| 35 | POE | Power over Ethernet |
| 36 | QAM | Quadrature Amplitude Modulation |
| 37 | QPSK | Quadrature Phase Shift Keying |
| 38 | RAN | Radio Access Network |
| 39 | RF | Radio Frequency |

|  |  |  |
| --- | --- | --- |
| 1 | RLC | Radio Link Controller |
| 2 | RRC | Radio Resource Controller |
| 3 | RU | Radio Unit as defined by 3GPP |
| 4 | RX | Receiver |
| 5 | SDU | Service Data Unit |
| 6 | SFP | Small Form-factor Pluggable |
| 7 | SFP+ | Small Form-factor Pluggable Transceiver |
| 8 | SoC | System on Chip |
| 9 | SPI | Serial Peripheral Interface |
| 10 | TR | Technical Report |
| 11 | TRP | Total Radiated Power |
| 12 | TS | Technical Specification |
| 13 | TX | Transmitter |
| 14 | UL | Uplink |
| 15 | USB | Universal Serial Bus |
| 16 | WG | Working Group |

# Chapter 2 Deployment Scenarios and White Box Base

1. Station Architecture
2. This chapter consists of two parts: the deployment scenario and the white box architecture. The deployment
3. scenarios outline more specific functional requirements of the base station. All the reference designs shall meet
4. these requirements in order to comply with O-RAN white box standard. In the white box hardware architecture
5. section, it describes the overall gNB hardware architecture and function partition that meet the design
6. requirements. The details on each of these topics are described in the following sections.

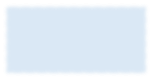
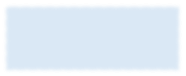
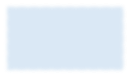
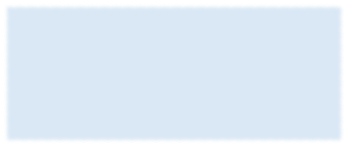
## 2.1 Deployment Scenarios

1. The specification here addresses a specific deployment scenario defined by the white box Deployment Scenarios
2. and Base Station Classes document [[1].](#_bookmark0) Its requirements are also defined in [[1].](#_bookmark0) Some of the key requirements
3. described in that document are highlighted below:
4.  Cell type: Outdoor Micro Cell
5.  Mounting Options: Rooftop, side of building/wall, pole
6.  Inter site distance: 1.5 kilometers
7.  Possible Carrier Frequency Bands: n2, n4, n5, n13, n41, n48, n66, n77, n78, n79
8.  [Instantaneous] Bandwidth: Up to 280 MHz
9.  Antennas Configuration: Up to 16T16R
10.  Coverage: Sectorized
11.  Conducted Power: up to 10W per port
12.  Number of Layers: Up to 16 layers
13.  Fronthaul Type: O-RAN FH (WG4) split option 7.2x.
14.  Architecture: Split architecture

## 2.2 White Box Base Station Architecture

1. In general, the base station hardware architecture can be classified by using different criteria. The physical partition
2. method is adopted by O-RAN; hence, the base station architecture is divided into two categories namely split and
3. integrated. In split architecture, the fronthaul interface determines the gNB functions location. Here we refer to
4. the two partitions as O-DUx and O-RUx; where the “x” is split option number. In case the O-RAN WG4 defined
5. fronthaul interface is used, these two partitions are called O-DU7-2 and O-RU7-2. For a more complete description
6. of the terminology used, refer to the Deployment Scenarios and Base Station Classes Document [[1].](#_bookmark0)
7. The split architecture is shown in [Figure 2-1.](#_bookmark7) A Fronthaul Gateway (FHGW) is an optional device between the
8. O-DUx and O-RUx to aggregate multiple radio units together as shown in [Figure 2-5.](#_bookmark11) Within this specification, a
9. Back End fronthaul interface is defined as the connection between the FHGWx and the O-DUx, while the Front
10. End fronthaul interface is defined as the connection between the FHGWx and the O-RUx. With split architectures,
11. one may choose to have O-CU and O-DUx as either co-located or shared configuration with respect to hardware.

3



Front Haul

Interface

O-CU & O-DU may be integrated into one Whitebox

O-DUx

O-CU

O-RUx

1. **Figure 2-1: Split Architecture**
2. For integrated base station architecture, the O-DU is integrated with the O-RU into one box. [Figure 2-2](#_bookmark8) shows
3. the integrated architecture.

7



F1

Interface

O-DU&O-RU

O-DU&O-RU

Switch/ Router

O-CU

F1

Interface

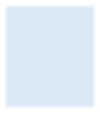
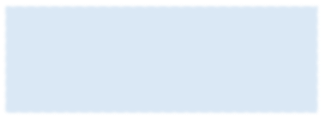
O-DU&O-RU

1. **Figure 2-2: Integrated Architecture**

### 2.2.1 Split RAN Architecture

1. For medium and large coverage deployment scenarios, the base station with split RAN architecture is more cost
2. effective. This type of architecture is widely deployed in 4G networks. The main idea of this architecture is
3. “shared cell”. By using the fronthaul gateway, many radio units can then share the same radio spectrum resource
4. in one cell. This configuration is very useful in both low and high capacity scenarios. Therefore, when an O-
5. DUx and FHGWx are capable of handling cell splits, multiple O-RUx(s) can be grouped together to share the
6. radio resources. Accordingly, the choice of fronthaul split option changes the architecture of the base station.
7. WG7 has recognized the following four split option architectures per service providers’ deployment needs which
8. are shown in [Figure 2-3](#_bookmark9) through [Figure 2-6.](#_bookmark12)
9. 1) Option 6 to option 6 split architecture
10. In split option 6, all L1 functions are within O-RU6 while the O-DU6 contains functions of MAC and
11. above. [Figure 2-3](#_bookmark9) shows the block diagram of base station having an option 6 split architecture. 21

1



FH

Option6

FH

Option6

O-CU & O-DU may/may not be integrated into one Whitebox

O-RU6

O-RU6

Switch/ Router or

Fronthaul Gateway

O-DU6

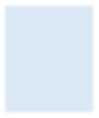
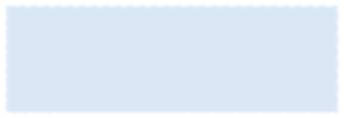
O-CU

O-RU6

* 1. **Figure 2-3: Option 6 to Option 6 Split Architecture**
  2. 2) Option 7-2 to option 7-2 split architecture:
  3. In split option 7-2, low PHY functions reside in the O-RU7-2, while the high PHY functions reside in
  4. the O-DU7-2. O-RAN WG4 CUS-plane spec [[4]](#_bookmark3) outlines the details of this split option under different
  5. usage scenarios.

7

8



FH

Option7-2

FH

Option7-2

O-CU & O-DU may/may not be integrated into one Whitebox

O-RU

O-RU

Switch/ Router or

Fronthaul Gateway

O-DU

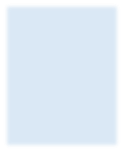
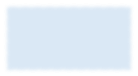
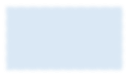
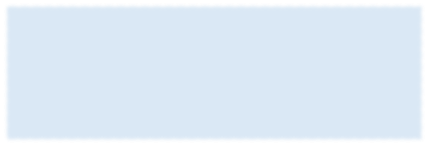
O-CU

O-RU

9 **Figure 2-4: Option 7-2 to Option 7-2 Split Architecture**

1. 3) Option 7-2 to option 8 split:
2. This configuration is selected when a deployment scenario requires a radio unit which only supports
3. split option 8 architecture. Since this is currently not part of overall O-RAN architecture, CPRI based
4. option 8 fronthaul and FHGW7-28 will be included in the reference design specification. [Figure 2-5](#_bookmark11)
5. depicts the option 7-2 to option 8 based split architecture. There is no change for the definition of O-
6. DU7-2, However, O-RU8 supports option 8 fronthaul interface while the FHGW7-28 translates the
7. fronthaul protocol between option 7-2 and CPRI.

17



FH

Option7-2

O-CU & O-DU may/may not be integrated into one Whitebox

O-RU8

O-RU8

FH

Option8

O-DU7-2

O-CU

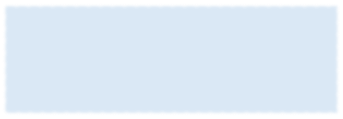
Fronthaul Gateway with Option Translator

O-RU8

18 **Figure 2-5: Option 7-2 to Option 8 Split Architecture**

1. 4) Option 8 to option 8 split architecture:
2. Currently, Option 8 is a non-O-RAN defined split option where the CPRI fronthaul interface is
3. needed in order to make the interoperability work with O-DU8 and O-RU8 from different vendors.
4. The option 8 fronthaul interface definition and the requirements shall be part of the white box
5. reference design, if adopted. In this case, the O-DU8 consists of L1 and L2 processing functions.
6. [Figure 2-6](#_bookmark12) shows an option 8 based split architecture. Note that O-CU and O-DU8 hardware may be
7. integrated into one Whitebox this is also shown in [Figure 2-6.](#_bookmark12)

8



FH

Option8

FH

Option8

O-CU & O-DU may/may not be integrated into one Whitebox

O-RU8

O-RU8

Fronthaul Gateway

O-DU8

O-CU

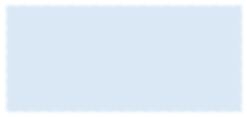
O-RU8

9 **Figure 2-6: Option 8 to Option 8 Split Architecture**

### 2.2.2 Integrated gNB-DU Architecture

1. For integrated gNB-DU, the complete L1/L2 and radio functions are integrated into a single box which includes
2. all logical functions of O-DU and O-RU. [Figure 2-7](#_bookmark13) shows the block diagram of integrated gNB-DU. The gNB-
3. DU connects with the O-CU through an F1 interface as defined by [[8]](#_bookmark6). This specification does not support an
4. integrated option [per requirements in Section 2.1].

15



gNB-DU

F1

O-CU

O-RU

O-DU

16 **Figure 2-7: Integrated gNB-DU Architecture**

17

# Chapter 3 White Box Hardware Architecture

1. Based on the gNB physical implementation architectures discussed earlier, this chapter provides the architecture,
2. major building blocks and all external/internal interfaces for each Whitebox.

## 3.1 O-CU Hardware Architecture

1. In a 3GPP system architecture, the gNB Central Unit (CU) communicates to the Distribution Unit (DU) via an
2. F1 interface. This interface has been adopted by O-RAN Alliance as well. F1 is an IP based protocol interface,
3. which offers more flexibility in the O-CU platform design.

### 3.1.1 O-CU Architecture Diagram

1. The O-CU can be implemented with any General-Purpose Processor (GPP) based platform having an optional
2. hardware accelerator block. The O-CU functions can be implemented either on separated hardware platforms or
3. on the same hardware platforms integrated with O-DUx functions. In either case, the O-CU hosts L2/L3
4. functions, whereas O-DU hosts L2/L1 functions which require different CPU, Storage, Acceleration and
5. Networking capabilities. [Figure 3-1](#_bookmark14) shows the hardware blocks and interfaces within the O-CU white box.

14

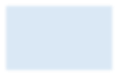
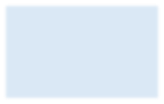
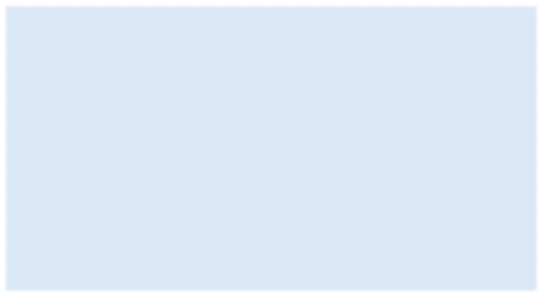
15

Digital Processing Unit

Ethernet Interface

Hardware Accelerator

Backhaul (Ethernet or Wireless)



16

17

O-CU

Ethernet Interface

F1

Interface (Ethernet)

1. **Figure 3-1: O-CU White Box Hardware Block Diagram**

### 3.1.2 O-CU Functional Module Description

1. The O-CU functional architecture comprises Digital Signal Processing, optional HW Acceleration, and
2. Connectivity (GbE) units as well as memory and storage units as shown in Figure 3-1.

### 3.1.3 O-CU Interfaces

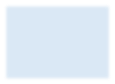
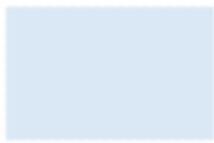
1. The O-CU interfaces through backhaul with the vEPC or 5GC core network and via F1 interface with the O-
2. DU7-2. The backhaul and the F1 interfaces are typically implemented with GbE transport/connections.

## 3.2 O-DU7-2 Hardware Architecture

1. For a split RAN architecture, the functional blocks of the RAN physical layer are divided into two parts – high
2. PHY and low PHY. The O-RAN lower layer split is defined in O-RAN WG4 fronthaul interface specification
3. [[4].](#_bookmark3) It also provides the details of the interface protocol as well as function partitions.

### 3.2.1 O-DU7-2 Architecture Diagram

1. Depending on the 3GPP standards and category of the radio unit, the split function blocks within O-DU7-2 and
2. O-RU7-2 may vary accordingly. The O-RAN fronthaul C/U/S-plane specification [[4]](#_bookmark3) provides comprehensive
3. information on this topic. The hardware functional partition architecture is shown in [Figure 3-2.](#_bookmark15) The High-PHY
4. functions in O-DU are run on Digital Processing Unit, Hardware Accelerator, or both.



1 PPS (IN or OUT)

F

Inter

O-RAN FH

Interface

O-RU7-

O-DU7-2

1

face

Timing and

Synchronization (IEEE 1588)

Ethernet Interface

Digital Processing Unit

Low PHY

Ethernet Interface

Hardware Accelerator

13

1. **Figure 3-2: O-DU7-2 with Split Physical Layer Function**

### 3.2.2 O-DU7-2 Functional Module Description

1. The choice of O-DU7-2 hardware components depends on the product design requirements and is outside the
2. scope of this specification. [Figure 3-3](#_bookmark16) shows the main components of O-DU7-2. Their descriptions and
3. requirements are as follows:

#### Digital Processing Unit

1. The processing unit can be any GPP, FPGA or digital signal processor (DSP), with I/O chipset. It may also be in
2. the form of System-On-Chip (SOC), or Multi-Chip Package (MCP).

#### Memory

1. DDR memory devices are used to store the runtime data and software for the processing unit.

#### Flash Memory

1. On board non-volatile storage device is used to store the firmware and non-volatile data, such as log data.

#### Board Management Controller

1. The controller is used to manage/control the power and monitors the operational status of the board.

#### Storage Device

1. The storage device such as hard drive is used to store OS, driver and applications software.

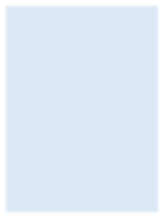
#### Ethernet Controller

1. The Ethernet ports transport the fronthaul or backhaul traffic according to the gNB hardware node requirements.
2. The Ethernet device shall support IEEE1588 based timing synchronization.

#### Hardware Accelerator

1. The hardware accelerator is an optional device. For performance improvement, the hardware accelerator can be
2. used to process computationally-intensive functions (e.g., Forward Error Correction (FEC)) and to offload the
3. processor.

1



PCIe

USB

Memory

Channel

VGA

SPI

PCIe

Digital Processing Unit

SMbus

RS232

SATA

Timing Signal

Ethernet

Ethernet Ports

Timing

Storage Drives

Serial Ports

SMBus Port

PCIe Slots

Flash Memory

Video Port

DDR RAM

USB Ports

Accelerator

* 1. **Figure 3-3: O-DU7-2 Functional Block and Interface Diagram.**

### 3.2.3 O-DU7-2 Interfaces

* 1. The O-DU7-2 supported interfaces described below are also shown in [Figure 3-3.](#_bookmark16)

#### Memory Channel Interface

* 1. Support DDR4 and later memory interface.

#### PCIe Interface

* 1. Support for PCIe Gen3 x16 and later interface versions; the bandwidth depends on the use cases, and it can be
  2. used to connect an accelerator device or network card.

#### Ethernet Interfaces

* 1. Supports any one or combination of GbE/10GbE/25GbE/40GbE links.

#### Serial ATA Interface

* 1. SATA3 shall be supported in case of software storage, such as hard drive.

#### SPI Interface

* 1. The SPI interface connects the processor with flash type of device for firmware.

#### Video Interface

* 1. Video interface is optional

#### USB Interface

1. Used to connect with local device for debug or on-board firmware update.

#### Miscellaneous Interface

1. Other interfaces that may be needed such as serial port, JTAG, etc.

## 3.3 O-DU6 Hardware Architecture

1. This section intentionally left blank.

## 3.4 O-DU8 Hardware Architecture

1. This section intentionally left blank.

## 3.5 FHGW7-2 - Option 7-2 to Option 7-2 Hardware Architecture

1. This section intentionally left blank.

## 3.6 FHGW6 - Option 6 to Option 6 Hardware Architecture

1. This section intentionally left blank.

## 3.7 FHGW7-2->8 - Option 7-2 to Option 8 Hardware Architecture

1. This section intentionally left blank.

## 3.8 FHGW8 - Option 8 to Option 8 Hardware Architecture

1. This section intentionally left blank.

## 3.9 O-RU7-2 Hardware Architecture

1. O-RU7-2 consists of four modules, namely optical interface, digital processing unit, RF processing unit and
2. antenna unit, as well as a timing unit as shown in [Figure 3-4.](#_bookmark17) The Ethernet interface complies with O-RAN
3. WG4 open fronthaul interface. The O-RU7-2 can directly connect with an O-DU7-2 or connect through a FHGW7-
4. 2. While the O-RU7-2 hardware supports NR by default, LTE support is not precluded.

### 3.9.1 O-RU7-2 Architecture Diagram

1. The O-RU7-2 hardware architecture consists of the digital processing unit which handles all digital signal and
2. interface processing and an RF processing unit handling all analog. There is a data conversion block for each
3. transceiver path after the digital processing block which converts between digital signals and analog signals. A
4. frequency conversion or mixer unit may be used to convert the IF or baseband frequencies to RF frequencies and
5. vice versa. In some cases, a direct RF sampling transceiver is used, where no external mixer is required. The
6. PA/LNA amplifies the RF signal, and the antenna module is used to transmit and receive signal over the air.
7. There is at least one Ethernet port available which is used as the O-RAN fronthaul interface.

9

To/From O-DU7-2



O-RU7-2

O-RAN

FH

eCPRI

Digital

Processing Unit

Local timing

from CDR

GNSS

(optional)

Local timing from GNSS or equivalent

Timing Unit

Power Unit

RF

Processing Unit

10

11

1. **Figure 3-4: O-RU7-2 Architecture Diagram**

### 3.9.2 O-RU7-2 Functional Module Description

1. In Figure 3-5, we illustrate O-RU7-2 functional blocks that support O-RAN FH with split option 7-2x. There is at
2. least one interface port which supports all fronthaul interface and PoE functionalities. The digital processing unit
3. block of O-RU7-2 is responsible for low-PHY functions such as FFT/IFFT, CP addition/removal, and PRACH
   1. filtering. Digital Down Converter (DDC), Digital Up Converter (DUC), Crest Factor Reduction (CFR) and
   2. Digital Pre-Distortion (DPD) functions are also performed in digital processing unit. For bandwidth reduction,
   3. O-RU7-2 architecture also supports the optional compression and decompression functions of FH interface. The
   4. ADC and DAC are mixed signal devices responsible for conversion of data between the digital and analog
   5. domains. As such, this block can be included as part of the either the digital processing unit or the radio
   6. processing unit. The RF Processing Unit consists of an optional frequency converter (mixer), Power Amplifier
   7. (PA)/ Low Noise Amplifier (LNA) and TX/RX filters. An antenna module follows that comprises physical
   8. antennae, RF feed distribution/aggregation network, and calibration network. The timing unit includes any
   9. clock and frequency synthesis required as well as other timing and synchronization circuits. In any given
   10. implementation, the physical boundaries between blocks may be slightly different, but the logical interfaces
   11. between will generally follow those shown in Figure 3-5.

Optical Interface

**Timing/LO**



**(De-)**

**Compression Low-PHY**

**DDC/**

**DUC**

**CFR/**

**DPD**

**ADC/**

**DAC**

**Mixer**

To/Fro m

O-DU7-2x

**O-RU7-2x**

**Antenna Module**

**PA/LN A/ and TX/RX Filters**

**O-RAN FH/ IEEE 1588v2**

**eCP RI**

**RF Processing and Antenna Module s**

**Digital Signal Processing Module**

12

1. **Figure 3-5: O-RU7-2 Generic Functional Module Diagram**

## 3.10 O-RU6 Hardware Architecture

1. This section intentionally left blank.

## 3.11 O-RU8 Hardware Architecture

1. This section intentionally left blank.

## 3.12 Integrated gNB-DU Hardware Architecture

1. This section intentionally left blank.

# Chapter 4 White Box Hardware Requirements

* 1. This chapter provides the requirements for various white boxes used within the Outdoor Microcell base station.
  2. These white boxes are O-CU, O-DUx, O-RUx and FHGWx. The O-CU and O-DUx can be implemented in an
  3. integrated fashion into one white box hardware or they can be separated. The reference design based on
  4. specification shall meet all these requirements based on their priority as specified by operators.

## 4.1 O-CU Requirements

* 1. O-CU requirements are described in the following sections, which include the performance, interface,
  2. environmental. EMC, mechanical, thermal and power requirements.

### 4.1.1 O-CU Performance

* 1. The performance requirements of the O-CU are listed in [Table 4-1.](#_bookmark19)
  2. **Table 4-1 :O-CU Performance Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Synchronization | Support 1588v2 Synchronization | Timing synchronization method | High |
| Support GNSS Synchronization | High |
| Support BeiDou Synchronization | Low |
| Support Galileo Synchronization | Low |
| Support GLONASS Synchronization | Low |
| Support  switching between 1588v2 and GNSS | High |
| Support SyncE | Low |
| Number of O- DUx supported | For O-CU/O-DUx integrated architecture: N/A | Number of O- DUx(s) connected to a single O-CU | None |
| For O-CU/O-DUx non-integrated architecture: Determined by operator deployment requirements | High |
| Supported Cell Number | For O-CU/O-DUx integrated architecture: N/A | Cells supported by an O-CU | None |
| For O-CU/O-DUx non-integrated architecture: Determined by operator deployment requirements | High |

|  |  |  |  |
| --- | --- | --- | --- |
| Supported RRC link number | For O-CU/O-DUx integrated architecture: N/A | RLC links supported by O-CU | None |
| For O-CU/O-DUx non-integrated architecture: Determined by operator deployment requirements | High |
| Throughput between O-DUx | For O-CU/O-DUx integrated architecture: N/A | Throughput between O-CU and O-DUx link | None |
| For O-CU/O-DUx non-integrated architecture: Determined by operator deployment requirements | High |
| Peak Data Rate | TBD | Highest theoretical data rate in error free conditions. | None |
| Latency | Control Plane< 10ms (def: Msg1 to Msg5)  User Plane DL < 4ms UL< 4ms (def: PDCP SDU-  > PDCP SDU) | O-CU latency | High |

### 4.1.2 O-CU Interfaces

* + 1. The interface requirements of the O-CU are listed in [Table 4-2: O-CU Interface Requirements.](#_bookmark20)
    2. **Table 4-2: O-CU Interface Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Transport Interface | 10 GbE F1 Interface to connect with O-DUx or  25 GbE F1 Interface to connect with O-DUx | O-CU transport links to O-DUx and 5GC | High |
| 10 GbE NG interface to connect with 5G core(b) or  25 GbE NG interface to connect with 5G core | High |

4

### 4.1.3 O-CU Environmental and EMC

1. The EMC requirements of the O-CU are listed in [Table 4-3.](#_bookmark21)
2. **Table 4-3: O-CU EMC Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| EMC | Shall comply with the requirements of 3GPP TS 38.113 (2017-12 Rel-15) [[7]](#_bookmark5) for equipment used in telecommunication room | Electromagnetic Compatibility requirement | High |

1. Note: For O-CU and O-DUx integrated solution, this requirement for O-CU portion is captured in the following O-DUx
2. section.

### 4.1.4 O-CU Mechanical, Thermal and Power

1. The mechanical, thermal and power requirements of the O-CU are listed in the following tables.
2. **Table 4-4: O-CU Mechanical Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Dimensions | Built in any 19" standard rack, or stand alone, with overall height of no more than 5U(a) and depth (including the connector) less than 750mm. | Measurement in three dimensions | Low |
| Status Indicator LED | Shall include as a minimum the following status indicators:  ---1 indicating on/off status of the power supply  ---1 indicating on/off status of the transmission link | Indicator light | High |

1. Note:
2. (a) Note that this dimension is application dependent and its value may change accordingly.

8

1. **Table 4-5: O-CU Thermal Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Temperature and Humidity | Operate steadily and reliably over a long period of time under the following environmental conditions for data center:  Operating Temperature: - 0 ℃ ~ + 50 ℃ Relative humidity: 15% ~ 85% | Environmental requirements for reliability | High |
| The solution should support extended temperature range (- 40℃ to +65 ℃) and humidity (5%-95%) if implemented outdoors. | Environmental requirements for reliability | Low |

1. Note: For O-CU and O-DUx integrated solution, this requirement for O-CU portion is captured in the following O-DUx
2. section.
3. **Table 4-6: O-CU Power Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |

|  |  |  |  |
| --- | --- | --- | --- |
| Power Supply | DC -48 VDC (-40v ~ -57v) (can be connected to AC/DC converter) or AC 220V power supply, voltage range of 140V~ 300v, frequency range of 45Hz ~ 65Hz. | Power supply for O-CU | High |
| Power Dissipation | < TBD W full load operation | O-CU Power Requirement | High |

* 1. Note: For O-CU and O-DUx integrated solution, this requirement for O-CU portion is captured in the following O-DUx
  2. section.

## 4.2 O-DUx Common Requirements

* 1. The O-DUx here takes the function of high PHY or whole PHY, OAM function and layer 2. Usually the
  2. hardware is placed in the machine room, which can be collocated in the coverage building or in the central
  3. machine room far away from the coverage building.

### 4.2.1 O-DUx Performance

* 1. The performance requirements of the O-DUx are listed in [Table 4-7.](#_bookmark25)
  2. **Table 4-7: O-DUx Performance Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Channel Bandwidth | ≤200 MHz OBW | RF Bandwidth | High |
| Antenna Configuration (Number of Transceivers) | 4T4R | Tx/Rx antenna number | High |
| up to 16T16R | Low |
| Transmission distance | Measured in delay. TBD | Distance between DU and FHGWx /RU | High |
| Connect Topology | NA | Fronthaul Gateway connection topology | None |
| Synchronization | Support 1588v2 Synchronization | Timing synchronization method | High |
| Support GNSS Synchronization;  Sync. between BS <= 150 ns; Carrier freq. error within one subframe <±0.1 PPM | High |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Support BeiDou Synchronization |  | Low |
| Support Galileo Synchronization | Low |
| Support GLONASS Synchronization | Low |
| Support  switching between 1588v2 and GNSS | High |
| Support SyncE | Low |
| Capacity/MIMO | 4T4R: 4 layers and 200 MHz OBW | MIMO related capability | High |
| up to 16T16R and TBD | Low |
| Peak Rate | TBD | Peak data rate | High |
| Modulation | DL: QPSK,16QAM,64QAM,256QAM  UL: π/2-bpsk, QPSK, 16QAM, 64QAM | Modulation schemes | High |
| UL: 256QAM | Medium |
| Latency | Control Plane< 10ms (def: Msg1 to Msg5) User Plane DL < 4ms UL< 4ms (def: PDCP SDU-> PDCP SDU) | Control/user plane Latency | High |

### 4.2.2 O-DUx Interfaces

1. The interface requirements of the O-DUx are listed in [Table 4-8.](#_bookmark26)
2. **Table 4-8: O-DUx Interface Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Transport Interface | Fronthaul Gateway: N/A | O-DUx  transport links | None |
| At least one 10 GbE F1 interface to connect with O-CU(b) | High |

1. Notes:
2. (a) For O-CU and O-DUx that are co-located
3. (b) For O-CU and O-Dux that are separated physically

### 4.2.3 O-DUx Environmental and EMC

1. The EMC requirements of the O-DUx are listed in [Table 4-9.](#_bookmark27)
2. **Table 4-9: O-DUx EMC Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| EMC | Complying with the requirements of 3GPP TS 38.113 (2017- 12R15) [[7]](#_bookmark5) for equipment used in telecommunication room | Electromagnetic Compatibility requirement | High |

2

### 4.2.4 O-DUx Mechanical, Thermal and Power

1. The mechanical requirements of the O-DUx are listed in [Table 4-10.](#_bookmark28)
2. **Table 4-10: O-DUx Mechanical Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Dimension | Built in any 19" standard rack, or stand alone, and the height does not exceed 5U(a), the depth (including the connector) must be less than 750mm. | Measurement in three dimensions | Low |
| Status Indicator LED | Shall include as a minimum the following status indicators:  ---1 indicating the on/off status of optical fiber interface  ---1 indicating off status of the power supply  ---1 indicating on/off status of the transmission link | Indicator lights | High |

1. Note:
2. (a) Note that this dimension is application dependent and its value may change accordingly.

8

9 The thermal requirements of the O-DUx are listed in [Table 4-11](#_bookmark29).

10 **Table 4-11: O-DUx Thermal Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Temperature and Humidity | The O-DUx shall operate steadily and reliably over a long period of time under the following environmental conditions for data center:  Operating Temperature: - 0 ℃ ~ + 50 ℃ Relative humidity: 15% ~ 85% | Environmental requirements for reliability | High |
| The solution should support extended temperature range (-40℃ to +65 ℃) and humidity (5%-95%) if implemented outdoors. | Environmental requirements for reliability | Low |

1

1. The power requirements of the O-DUx are listed in [Table 4-12.](#_bookmark30)
2. **Table 4-12: O-DUx Power Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Power Supply | DC -48 VDC (-40v ~ -57v) (can be connected to AC/DC converter) or AC 220V power supply, voltage range of 140V~ 300v, frequency range of 45Hz ~ 65Hz. | Power supply for O-DUx | High |
| Power Dissipation | < TBD W, with 4 cells full load operation | O-DUx Power Requirement | High |
| < TBD W, with 8 cells full load operation | Medium |

4

## 4.3 O-DUx Split Option Specific Requirements

1. In addition to the common O-DUx requirements, there may be some specific requirements that apply to O-DUx
2. due to the split option. These requirements are listed in the following sections.

### 4.3.1 O-DU7-2 Specific Requirements

1. The specific requirements of O-DU7-2 are listed in [Table 4-13.](#_bookmark31)

1 **Table 4-13: O-DU7-2 Specific Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Transport Interface | At least 4 Ethernet interfaces connected with Fronthaul Gateway | O-DU7-2  fronthaul transport links | High |

2

### 4.3.2 O-DU6 Specific Requirements

1. This section intentionally left blank.

### 4.3.3 O-DU8 Specific Requirements

1. This section intentionally left blank.

## 4.4 O-RUx Common Requirements

1. The O-RUx common requirements apply to all the radio units regardless of the split option. In the indoor
2. environment, O-RUx hardware is placed on the cell or wall of the coverage building; it converts the base band
3. signal into RF signal or vice versa to supply the coverage.

### 4.4.1 O-RUx Performance

1. The O-RUx performance requirements cover all the aspects of radio unit including frequency bands, antenna
2. configurations, power efficiency, etc. [Table 4-14](#_bookmark32) lists the performance parameters related to O-RUx.
3. **Table 4-14: O-RUx Performance Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Operating band | n77 | Radio frequency band | High |
| n2, n4, n13, n41, n48, n66, n78, n79 | Low |
| [Occupied] Bandwidth | ≤200 MHz | Frequency bandwidth | High |
| Antenna Configuration (Number of Transceivers) | 4T4R | Tx/Rx Antenna numbers | High |
| up to 16T16R | Low |

|  |  |  |  |
| --- | --- | --- | --- |
| Output Power Accuracy | Under normal condition: ±2dB | Power accuracy | High |
| Tx off Power Level | less than -85dBm/MHz; See section 6.4.1 in 3GPP TS 38.104 [3]. | Tx power level during an off period | High |
| EVM at maximum output power | 64QAM: EVM smaller than 8%  256QAM: EVM smaller than 3.5% | Max output power | High |
| Operating band unwanted emissions | The Operating band unwanted emissions shall satisfy the Category B limit defined by the section 6.6.4.2.4 in 3GPP TS 38.104 [[3]](#_bookmark2). | RF operation band unwanted emissions requirement | High |
| Transmitter spurious emissions | The Operating band unwanted emissions shall satisfy the Category B limit defined by the section 6.6.4.2.4 in [[3].](#_bookmark2) | Deliberately generated RF signal by transmitter | High |
| Receiver Sensitivity | The throughput shall be ≥ 95% of the maximum throughput of the reference measurement channel of G-FR1-A1-5; the reference sensitivity levels shall be better than  -95.6dBm. | The weakest signal the receiver can identify and process | High |
| Blocking | In Channel selection, ACS, In-band blocking, out-band blocking, IMD and other receiver specification shall follow the 3GPP guidelines in [[3]](#_bookmark2)[[5],](#_bookmark4) the reference sensitivity is allowed to degrade at most 6dB under all kinds of interference signal and corresponding level. | Channel selection related requirement | High |
| Other specifications | Except for all the RF specifications listed above, other RF specifications shall follow the requirement in [[3].](#_bookmark2) | Additional standard to comply | High |
| Downlink modulation Mode | QPSK、16-QAM、64-QAM、256-QAM | DL Modulation schemes | High |
| Uplink modulation mode | π/2-BPSK、QPSK、16-QAM、64-QAM | UL Modulation schemes | High |
| 256QAM | medium |
| Conducted Power | 4T4R: up to 10W per port | RF power | High |
| 16T16R: TBD | Low |

### 4.4.2 O-RUx Interfaces

* 1. The interface related requirements of the O-RUx are listed in [Table 4-15.](#_bookmark33)

1 **Table 4-15: O-RUx Interface Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Interface Number | The O-RUx shall have at least one fronthaul interface based on the split option supported | Number of fronthaul links | High |

2

### 4.4.3 O-RUx Environmental and EMC

* 1. The environmental and EMC requirements of the O-RUx are listed in [Table 4-16.](#_bookmark34)
  2. **Table 4-16: O-RUx Environmental and EMC Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Mounting method | Rooftop, side of building/wall or pole | Mounting requirement | High |
| Grounding | The O-RUx shall support Joint Grounding Method and shall work normally when the grounding resistor is less than 10Ω. | Grounding requirement | High |
| EMC | The O-RUx shall comply with the requirements of 3GPP TS 38.113 [[7]](#_bookmark5) | Electromagnetic Compatibility requirement | High |

6

### 4.4.4 O-RUx Mechanical, Thermal and Power

1. The mechanical, thermal and power requirements of the O-RUx are listed in [Table 4-17.](#_bookmark35)

1 **Table 4-17: O-RUx Mechanical, Thermal and Power Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Requirement** | **Description** | **Priority** |
| Weight | 4T4R: The gross weight of the O-RUx shall be  <13Kg (best estimate) | Weight requirement | High |
| 16T16R: TBD | Low |
| Dimension/Volume | 4T4R: The dimension of the O-RUx shall be smaller than 345x250x130 (mm) and the volume of the O-RUx shall be <12L | Dimensional Measurements | High |
| 16T16R: TBD | Low |
| Stability | The MTBF shall be >200000 hours | Mean Time Between Failures | High |
| Power Consumption | 4T4R: At full load, the power consumption shall not exceed 218W | Power requirement | High |
| 16T16R: At full load, the power consumption shall not exceed TBD | Low |
| Power supply | DC -48 VDC (-40v ~ -57v) (can be connected to AC/DC converter) or AC 220V power supply, voltage range of 140V~ 300v, frequency range of 45Hz ~ 65Hz. | Power Support Requirement | High |
| Level of protection | The protection level of the O-RUx shall be equivalent to the IP65 standard. | Protection level | High |
| Temperature and Humidity | The O-RUx shall operate at the temperature range of -40℃ to ＋55℃ with both cold start and hot start options. Humidity：5%~95% | Ambient temperature and moisture requirement | High |
| Atmospheric pressure | The O-RUx shall operate normally under atmospheric pressure between 70 to 106Kpa. | Operational atmospheric pressure requirement | High |
| Cooling mode | Passive cooling | System cooling requirement | High |

2

## 4.5 O-RUx Split Option Specific Requirements

1. Besides the common requirements which shall apply to all the radio unit types. The following sections list all the
2. specific requirements that only apply to the designated split option.

### 4.5.1 O-RU7-2 Specific Requirements

1. The O-RU7-2 must have one RJ45 or SFP 10G Ethernet interface used as fronthaul interface. The O-RU7-2 must
2. support the lower physical layer functions and comply with [[4].](#_bookmark3)

### 4.5.2 O-RU6 Specific Requirements

1. This section intentionally left blank.

### 4.5.3 O-RU8 Specific Requirements

1. This section intentionally left blank.

## 4.6 FHGWx – Common Requirements

1. This section intentionally left blank.

## 4.7 FHGWx – Split Option Specific Requirements

1. This section intentionally left blank.

## 4.8 Integrated gNB-DU Requirements

1. This section intentionally left blank.

# Annex ZZZ: O-RAN Adopter License Agreement

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3. This O-RAN Adopter License Agreement (the “Agreement”) is made by and between the O-RAN
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6. This is a license agreement for entities who wish to adopt any O-RAN Specification.

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27. Affiliates that is not making a reciprocal grant to Adopter, as set forth in Section 3.1. For the avoidance
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## Section 4: TERM AND TERMINATION

1. 4.1 This Agreement shall remain in force, unless early terminated according to this Section 4.
2. 4.2 O-RAN ALLIANCE on behalf of its Members, Contributors and Academic Contributors may
3. terminate this Agreement if Adopter materially breaches this Agreement and does not cure or is not
4. capable of curing such breach within thirty (30) days after being given notice specifying the breach.
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    3. applicable to Adopter hereunder and are also entitled to the benefits of the rights of Adopter hereunder.

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* + 1. This Agreement is governed by the laws of Germany without regard to its conflict or choice of law
    2. provisions.
    3. This Agreement constitutes the entire agreement between the parties as to its express subject matter and
    4. expressly supersedes and replaces any prior or contemporaneous agreements between the parties,
    5. whether written or oral, relating to the subject matter of this Agreement.
    6. Adopter, on behalf of itself and its Affiliates, agrees to comply at all times with all applicable laws,
    7. rules and regulations with respect to its and its Affiliates’ performance under this Agreement, including
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    9. Adopter acknowledges that this Agreement prohibits any communication that would violate the
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    11. By execution hereof, no form of any partnership, joint venture or other special relationship is created
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