ORAN-WG7.DSC.0-v01.00

O-RAN Specification

Deployment Scenarios and Base Station Classes For White Box Hardware

Revision History

Date	Revision	Author	Description
2019.10.08	V01.00	O-RAN-WG7	First published version
2019.10.26	V01.00.01	Nokia, ATT	Updates to terminologies for O-DU, O-RU, FHGW and ANNEX zzz.
2019.10.29	01.00.01	Nokia, ATT	Final Version approved by TSC

Contents

Chapter 1 Introductory Material

1.1 Scope

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

The contents of the present document are subject to continuing work within O-RAN WG7 and may change following formal O-RAN approval. Should the O-RAN.org modify the contents of the present document, it will be re-released by O-RAN Alliance 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. This variable is for internal WG7 use only.

The present document specifies operator requirements for scenarios, use cases and base station classes for O-RAN white box hardware, and identifies typical deployment scenarios associated with carrier frequency, inter-site distance, and other key parameters and attributes.

1.2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document.

[1] 3GPP TR 21.905, “Vocabulary for 3GPP Specifications”
[2] 3GPP TR 38.104, “NR; Base Station (BS) radio transmission and reception”
[3] 3GPP TR 38.874, “Study on Integrated Access and Backhaul”
[4] 3GPP TR 38.340, “NR; Backhaul Adaptation Protocol”
[5] 3GPP TR 38.913, “Study on Scenarios and Requirements for Next Generation Access Technologies”
[6] 3GPP TR 38.401, “NG-RAN Architecture Description”
[7] 3GPP TR 38.473, “NG-RAN F1 Application Protocol (F1AP)”
[8] O-RAN.WG7.CUS.0-v02.00, O-RAN WG4 Control, User and Synchronization Specification

1.3 Definitions and Abbreviations

1.3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1]. For the base station classes of Pico, Micro and Macro, the definitions are given in [2].

Carrier Frequency: Central frequency of the cell.

F1 interface: The open interface between O-CU and O-DU, the definition is given in O-RAN WG5. Refer to [7].

IAB-donor: RAN node which provides UE’s interface to core network and wireless backhauling functionality to IAB nodes. Refer to [6].

IAB-node: AN node that supports wireless access to UEs and wirelessly backhauls the access traffic. Refer to [6].

Integrated architecture: In the integrated architecture, the O-RU and O-DU are implemented on one platform. Each O-RU and RF frontend is associated with one LLS-DU. They are then aggregated to O-CU, connected by F1 interface.

Layout: Network framework.

Mobile-Termination (MT): MT is the UE function in each IAB node that allows it to communicate with parent node. Refer to [6].

Split architecture: The O-RU and O-DU are physically separated from one another in this architecture. A fronthaul gateway may aggregate multiple O-RUs to one O-DU. O-DU, fronthaul gateway and O-RUs are connected by fronthaul interfaces.

System bandwidth: The bandwidth in which a Base Station transmits and receives multiple carriers and/or RATs simultaneously.

Transmission Reception Point (TRxP): Antenna array with one or more antenna elements available to the network located at a specific geographical location for a specific area.

Layer: This term refers to deployment layers. A single layer has no overlay cell. Two layers refers to a layout where the second layer maybe deployed as underlaying cell w.r.t the primary cell.

1.3.2 Abbreviations

For the purposes of the present document, the abbreviations given in [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in [1].

7-2	Fronthaul interface split option as defined by O-RAN WG4, also referred to as 7-2x
3GPP	Third Generation Partnership Project
5G	Fifth-Generation Mobile Communications
AC	Alternating Current
BS	Base Station
CU	Centralized Unit as defined by 3GPP
DC	Direct Current
DL	Downlink
DRX	Discontinuous Reception
DU	Distributed Unit as defined by 3GPP
EDGE	Enhanced Data rates for GSM Evolution
EIRP	Equivalent Isotropic Radiated Power
eMBB	Enhanced Mobile Broadband
FDD	Frequency Division Duplex
FH	Fronthaul
$FHGW_{x \rightarrow y}$	Fronthaul gateway that can translate FH protocol from an O-DU with split option x to an O-RU with split option y, with currently available option 7-2→8.
$FHGW_x$	Fronthaul gateway with no FH protocol translation, supporting an O-DU with split option x and an O-RU with split option x, with currently available options 6→6, 7-2→7-2 and 8→8.
GSM	Global System for Mobile communications
IAB	Integrated Access and Backhaul
IEEE	Institute of Electrical and Electronics Engineers
ISD	Inter-Site Distance
KPI	Key Performance Indicator
MAC	Medium Access Control
MEC	Mobile/Multi-access Edge Computing
MIMO	Multiple Input Multiple Output
MT	Mobile-Termination
MU-MIMO	Multiple User MIMO
NB-IoT	Narrow Band Internet of Things
NR	New Radio
O-CU	O-RAN Centralized Unit as defined by O-RAN
$O\text{-}DU_x$	A specific O-RAN Distributed Unit having fronthaul split option x where x may be 6, 7-2 (as defined by WG4) or 8
O-RAN	Open-Radio Access Network
$O\text{-}RU_x$	A specific O-RAN Radio Unit having fronthaul split option x, where x is 6, 7-2 (as defined by WG4) or 8, and which is used in a configuration where the fronthaul interface is the same at the $O\text{-}DU_x$

$O\text{-}RU_y$	A specific O-RAN Radio Unit having fronthaul split option y, where y is 7-2 (as defined by WG4) or 8, and which is used in a configuration where the fronthaul interface at O-RU is different than that at $O\text{-}DU_x$
POE	Power Over Ethernet
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
Rel-x	Release number: where x is the actual release number
RF	Radio Frequency
RFFE	RF Front End
RU	Radio Unit as defined by 3GPP
Rx	Receiver
SDU	Service Data Unit
SON	Self Organized Network
SU-MIMO	Single User MIMO
TDD	Time division Duplex
TR	Technical Report
TRP	Transmission Reception Point
TS	Technical Specification
Tx	Transmitter
UE	User Equipment
UL	Uplink
UPF	User Plane Function
URLLC	Ultra-Reliable and Low Latency Communications
WG	Working Group

1.4 Objectives

Openness is one of the key principles for O-RAN Alliance. To take full advantage of the economies of scale offered by an open computing platform approach, O-RAN Alliance reference designs will specify high performance, spectral and energy efficient white-box base station hardware. Reference platforms support a decoupled approach and offer detailed schematics for hardware and software architecture to enable both the $O\text{-}DU_x$ and $O\text{-}RU_x$.

The promotion of white box hardware is a potential way to reduce the cost of 5G deployment, which will benefit both the operators and vendors. The objective of the white-box hardware workgroup is to specify and release a complete reference design, thereby fostering a decoupled software and hardware platform. Currently, there is no open base station reference design architecture, making it impossible for operators and vendors to develop software for optimizing their network operation in various application scenarios. Therefore, it is further envisioned that the group will do research on all related content to build valuable reference designs.

The main objective of this document is to aid in development of base station HW architecture and requirements specification, and consequently, the HW reference design specification for white boxes based on the identified deployment scenarios within this specification.

Chapter 2 Deployment Scenarios

2.1 General

In this chapter we present the deployment scenarios as identified by the operator group within O-RAN. The detailed reference base station specification for each identified scenario and their classifications case will be provided in the following chapters. The use case scenarios will include:

- eMBB (enhanced Mobile BroadBand)
- URLLC (Ultra-Reliable and Low Latency Communications)

2.1.1 Base Station Architecture: Background

For any deployment scenarios, the base station architecture falls into two categories: 1) Split Architecture or 2) Integrated architecture. The split architecture is illustrated in

Figure 2-1 where O-CU and O-DU$_x$ are connected via a switch or an optional fronthaul gateway (FHGW) to multiple O-RU$_x$s. Note that the term optional is used to indicate there may be a deployment case where a switch or FHGW may not be needed.

Depending on how much intelligence one requires to place in O-RU$_x$ or O-DU$_x$, there will be a functional split that splits up functions of PHY layer between O-DU$_x$ and O-RU$_x$. O-CU and O-DU$_x$ may be designed to be integrated into one hardware box or as two separate boxes. For downlink, FHGW broadcasts the data to all the O-RU$_x$s. For uplink, it shall combine all the uplink data from subtending O-RU$_x$s according to the cell sets. Within working group 7 (and therefore all specifications stemming from it), all fronthaul interfaces are based on the following three criteria. A fronthaul interface that meets one of the following criteria can be defined as an open fronthaul interface:

1. O-RAN WG4 (open fronthaul interface group) released interfaces; or
2. O-RAN approved publicly (e.g., small cell forum or etc.) available external interfaces; or
3. Fronthaul interfaces made available and published as part of an O-RAN approved WG7 reference design.

Within this specification, "dashed boxes" are representative of white boxes. In some cases, the figures use specific O-DU$_x$ and O-RU$_y$ or O-DU$_x$ and O-RU$_x$ terminologies to demonstrate an example split option configuration. The first case is where the FHGW$_{x\rightarrow y}$ translates split option x from an O-DU$_x$ to split option y to an O-RU$_y$, Only the following split option with a fronthaul translation and the associated terminologies will be used throughout all WG7 specifications:

1- O-DU$_{7\text{-}2}$↔FHGW$_{7\text{-}2\rightarrow 8}$↔ O-RU$_8$

In the case where the fronthaul gateway does not perform a protocol translation, the terminology FHGW$_x$, O-DU$_x$ and O-RU$_x$ are used, and the following split options and the associated terminologies will be used throughout all specifications:

1- O-DU$_6$↔FHGW$_6$↔ O-RU$_6$
2- O-DU$_{7\text{-}2}$↔FHGW$_{7\text{-}2}$↔ O-RU$_{7\text{-}2}$
3- O-DU$_8$↔FHGW$_8$↔ O-RU$_8$

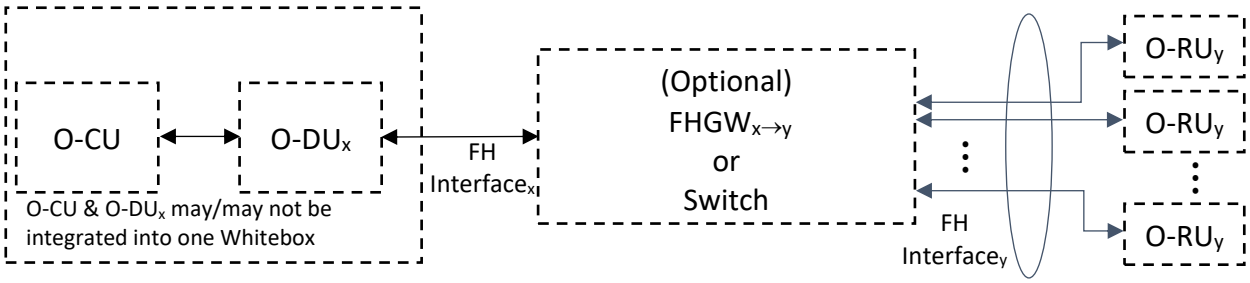

Figure 2-1: Base Station with Split Architecture

Note that within WG7 and therefore all specifications stemming from it, O-DU$_{7\text{-}2}$ and O-RU$_{7\text{-}2}$ refer to O-DU and O-RU as defined by WG4.

Since in split Architecture O-DU$_x$ and O-RU$_x$ are physically separated from one another by FH interface, therefore, depending on the split option, certain functions of base stations may either be performed in O-DU$_x$ or O-RU$_x$. There are 8 different FH split options available (as defined by 3GPP); however, within this specification only the following split options will be considered:

1. Split option 6: All PHY functions will reside in O-RU$_x$ while MAC functions will be performed in O-DU$_x$. In other words, only un-coded user data is on FH. In this case the terminology O-DU$_6$ and O-RU$_6$ is used.
2. Split option 7-2, the PHY is split into High and Low PHY functions; where High PHY functions (coding, rate matching, scrambling, modulations and layer mapping) are performed in O-DU$_x$ while O-RU$_x$ performs the Low PHY functions (precoding, remapping, digital beamforming, IFFT and CP insertion). All I/Q samples are in frequency domain. In this case the terminology O-DU$_{7\text{-}2}$ and O-RU$_{7\text{-}2}$ is used.
3. Split Option 8: All PHY functions are performed in O-DU$_x$. This means that O-RU$_x$ function is limited to RF to baseband conversion and vice versa. The I/Q samples on FH interface are in time-domain. In this case the terminology O-DU$_8$ and O-RU$_8$ is used.

Integrated Architecture is defined as where O-DU$_x$ and O-RU$_x$ are physically located in one hardware box and as such no FH interface is required to connect them. Figure 2-2 illustrates the base station having an integrated architecture. For the integrated architecture, open F1 interface is between O-CU and O-DU$_x$ (which is discussed in O-RAN WG5).

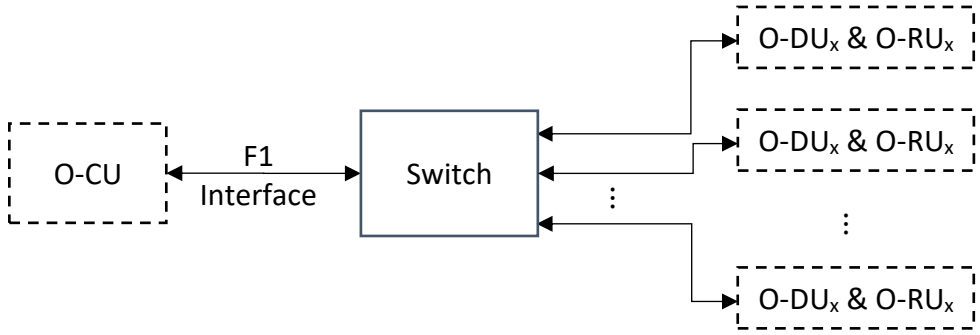

Figure 2-2: Base Station with Integrated Architecture

2.2 Deployment Scenarios

Deployment scenarios for use-cases described in section 2.1 will be provided in this section. These scenarios are based on reported scenarios as reported by service providers. Scenarios in this specification do not preclude any other scenario. Other scenarios may be added as a change request to this specification.

2.2.1 Indoor Picocell

The indoor deployment scenario is mainly for small coverage per site within buildings, open spaces, etc. A key characteristic of this deployment scenario is consistent indoor user experience, high user density within buildings an open office and high capacity.

Some of its attributes are listed in Table 2-1 below.

Table 2-1: Attributes for FR1 Picocell Indoor.

Attributes	Values or Assumptions
Carrier Frequency [(a)]	n2, n4, n5, n13, n41, n48, n66, n77, n78, n79
System Bandwidth[(b)]	Up to 100MHz (DL+UL)
Cell Layout	Single layer
Mounting options	Above ceiling (Plenum rated) and/or on the wall; Open Office
ISD	20m
BS MIMO Configuration[(c)]	2TX/2RX or 4TX/4RX
Output power (conducted)	2TX/2RX: ≤27dBm (per channel); 4TX/4RX: ≤24dBm (per channel)
Coverage[(d)]	Omni
Key Architecture Features	Split Architecture (split options: 6, 7-2 and 8 are supported and each option is further described in Section 2.1.1) and Integrated Architecture.

Notes:

(a) The options noted here are for the first stage, and do not preclude the study of other spectrum options, e.g. mmWave. Certain technology bands have specific regulatory requirements that must be followed

(b) The system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate. It is also allowed to have an aggregated bandwidth totalling up to the system bandwidth. "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.
- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna), are not precluded.

2.2.2 Outdoor Picocell

Two scenarios have been identified for picocell outdoor scenario; 1) FR1 and 2) FR2. While both deployment scenarios have integrated architecture (See Figure 2-2), they do have different attributes and as such they have been listed separately in Table 2-2 and Table 2-3.

Table 2-2: Attributes for FR1 Picocell Outdoor

Attributes	Values or Assumptions
Carrier Frequency[(a)]	n2, n4, n5, n13, n41, n48, n66, n77, n78, n79
System Bandwidth[(b)]	≥100 MHz (DL+UL)
Cell Layout	single layer Two layers: - Macro or Micro layer - Pico layer: random locations
Mounting Options	Rooftop, Side of Building (wall), Pole, under overhang
ISD	200 m
BS MIMO Configuration[(c)]	Up to 4TX/4RX
EIRP	≥35 dBm
Coverage[(d)]	Omni
Key Architecture Features	Integrated Architecture. See Figure 2-2.

Notes:

(a) The options noted here are for the first stage, and do not preclude the study of other spectrum options, e.g. mmWave. Certain technology bands have specific regulatory requirements that must be followed

(b) The system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate. It is also allowed to have an aggregated bandwidth totalling up to the system bandwidth. "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.

- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna), are not precluded.

Table 2-3: Attributes for FR2 Picocell Outdoor

Attributes	Values or Assumptions
Carrier Frequency[(a)]	n257, n258, n260, n261
System Bandwidth[(b)]	up to 800 MHz (DL+ UL)
Layout	single layer Two layers: - Macro or Micro layer - Pico layer: random locations
Mounting Options	Rooftop, Side of Building (wall), Pole, under overhang
ISD	200 m
BS MIMO Configuration[(c)]	Up to 4TX/4RX
EIRP	50-55 dBm
Coverage[(d)]	Omni
Key Architecture Features	Integrated Architecture. See Figure 2-2.

Notes:

(a) The options noted here are for the first stage, and do not preclude the study of other spectrum options, e.g. mmWave. Certain technology bands have specific regulatory requirements that must be followed

(b) The system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate. It is also allowed to have an aggregated bandwidth totalling up to the system bandwidth. "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.
- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna) are not precluded.

2.2.3 Outdoor Microcell

There are two deployment scenario proposals for outdoor microcell by operators' group. The architectures for both microcell deployment scenarios are the same and it is illustrated in

Figure 2-1.

The base station attributes for FR1 are listed in Table 2-4. The attributes for FR2 microcell outdoor deployment scenario are listed in Table 2-5. It shall be noted that all frequencies are given as NR operating bands in either in FR1 or FR2.

Table 2-4: Attributes for FR1 Microcell Outdoor

Attributes	Values or Assumptions
Carrier Frequency[(a)]	n2, n4, n5, n13, n41, n48, n77, n66, n78, n79
System Bandwidth[(b)]	Up to 100MHz (DL+UL)
Cell Layout	single layer Two layers: - Macro or Micro layer - Pico layer: random locations
Mounting Options	Rooftop, Side of Building (wall), Pole
ISD	700 m
BS MIMO Layers[(c)]	Up to 16TX/16RX
EIRP	~61 dBm
Coverage[(d)]	Omni
Key Architecture Features	Split architecture (O-RAN WG4 split option 7-2). See Figure 2-1

Notes:

(a) The options noted here are for the first stage, and do not preclude the study of other spectrum options, e.g. mmWave. Certain technology bands have specific regulatory requirements that must be followed

(b) The system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate. It is also allowed to have an aggregated bandwidth totalling up to the system bandwidth. "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.
- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna) are not precluded.

Table 2-5: Attributes for FR2 Microcell Outdoor

Attributes	Values or Assumptions
Carrier Frequency[(a)]	n257, n258, n260, n261
System Bandwidth[(b)]	Up to 1.2 GHz (DL+UL)
Cell Layout	single layer Two layers: - Macro or Micro layer - Pico layer: random locations
Mounting Options	Rooftop, Side of Building (wall), Pole
ISD	200 m
BS MIMO Layers[(c)]	Up to 4TX/4RX
EIRP	>60 dBm
Coverage[(d)]	Sectorized
Key Architecture Features	Split Architecture (O-RAN WG4 split option 7-2). See Figure 2-1

Notes:

(a) The options noted here are for the first stage, and do not preclude the study of other spectrum options, e.g. mmWave. Certain technology bands have specific regulatory requirements that must be followed

(b) The system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate. It is also allowed to have an aggregated bandwidth totalling up to the system bandwidth. "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.
- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna) are not precluded.

2.2.4 Integrated access and backhaul (IAB)

A key benefit of Integrated Access and Backhaul (IAB) is enabling flexible and very dense deployment of NR cells without densifying the transport network proportionately. Various deployment scenarios have been proposed including support for outdoor small cell deployments, indoors, or even mobile relays (e.g. on buses or trains). The IAB architecture is shown in Figure 2-3 below. IAB specifications as well as F1* interface can be found in [3].

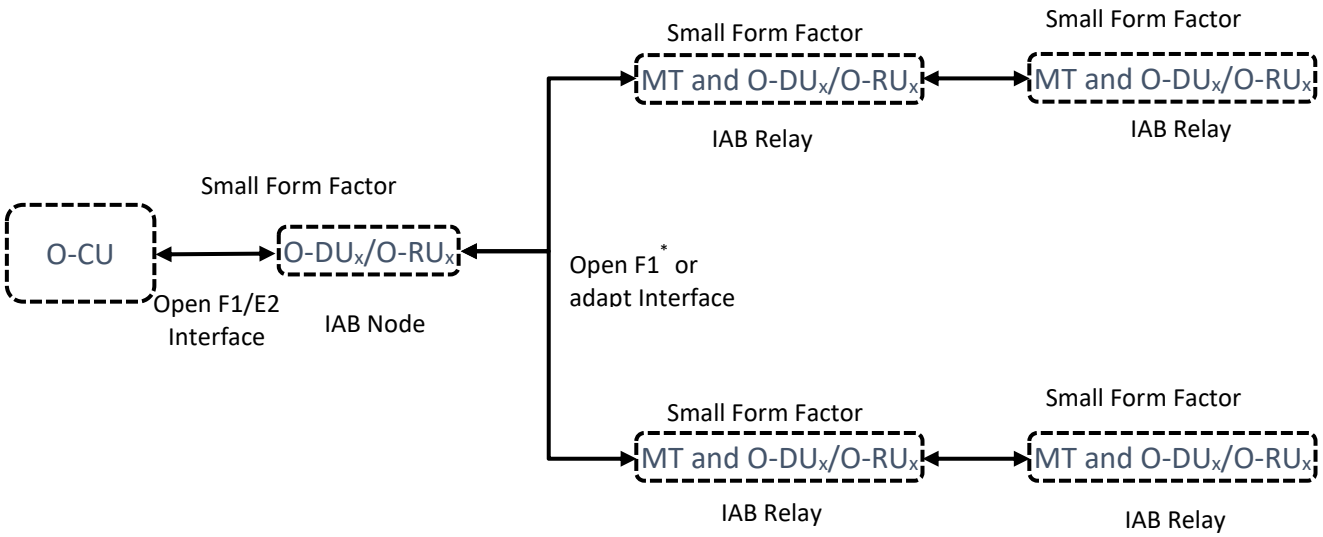

Figure 2-3: IAB integrated architecture.

Some of the attributes of integrated access and backhaul are listed in Table 2-6.

Table 2-6: Attributes for Integrated Access and Backhaul

Attributes	Values or assumptions
Carrier Frequency[(a)]	n257, n258, n260, n261
System Bandwidth[(b)]	n257, n258, n261: 100 – 400 MHz (DL+ UL), n260: 400 – 800 MHz (DL+ UL)
Cell Layout	Single or HetNet, single hop to multi-hop
Mounting Options	Rooftop, Side of Building (wall), Pole, under overhang, vehicle (bus)
ISD	200 m
BS MIMO Layers[(c)]	Up to 4TX/4RX
EIRP	50-55 dBm, to be confirmed after 3GPP RAN4 confirmation
Coverage [(d)]	Omni
Key Architecture Features[(e)]	Integrated Architecture (O-DU + MT functionality)

Notes:

(a) The options noted here is for the first stage, and do not preclude the study of other spectrum options.

(b) "DL + UL" refers to either of the following two cases:

- FDD with symmetric bandwidth allocations between DL and UL.
- TDD with the aggregated system bandwidth used for either DL or UL via switching in time-domain.

(c) The options noted here are typical configurations.

(d) Other options (e.g. Sectorized with directional antenna) are not precluded.

(e) MT is the UE function in each IAB node that allows it to communicate with parent node.

Chapter 3 Base Station Type Classification

3.1 General

The base stations for each usage scenario in chapter 2 apply to Wide Area Base Stations, Medium Range Base Stations and Local Area Base Stations. The definition for the three BS classes is given in subsection 4.4 of [2]. The BS classes for each deployment scenario described in this document are defined in Table 3-1 below.

Table 3-1: Base Station Classes for Deployment Scenarios

Deployment Scenario	FR1/FR2	Base Station Class
Indoor Picocell Split Architecture	FR1	Local Area/Medium Area
Indoor Picocell Integrated Architecture	FR1	Local Area/Medium Area
Outdoor Picocell Integrated Architecture	FR1	Medium Area
	FR2	Medium Area
Outdoor Microcell	FR1	Medium Area
	FR2	Medium Area
Integrated Access and Backhaul	FR2	Medium Area

3.2 Indoor

For indoor coverage, the base station can be identified as Local Area Base Station, and there are two key architecture types, namely, the split architecture and the integrated architecture.

NOTE: The hardware design may consider the co-location of MEC and UPF part in O-CU/O-DU functionality if needed.

3.2.1 The split architecture

Descriptions of the indoor split architecture are listed in Table 3-2.

Table 3-2: Descriptions of Attributes for the Indoor Picocell Split Architecture

Attributes	Description
Reference Figure	Figure 2-1
Interface[a]	Open fronthaul interface
Functionality [b]	Split Option 6: O-RU$_6$: RF, IF, PHY (Downlink and uplink digital processing, baseband signal conversion to/from RF signal) O-CU & O-DU$_6$: MAC, RLC, PDCP (Downlink and uplink baseband processing, supply system synchronization clock, signalling processing, OM function, interface with core network) Split Option 7-2: O-RU: RF, IF, PHY-LOW (Downlink and uplink digital processing, baseband signal conversion to/from RF signal) O-CU & O-DU: PHY-HIGH, MAC, RLC, PDCP (Downlink and uplink baseband processing, supply system synchronization clock, signalling processing, OM function, interface with core network) Split Option 8: O-RU$_8$: Downlink baseband signal convert to RF signal, uplink RF signal convert to baseband signal, interface with the fronthaul gateway O-CU &O-DU$_8$: Downlink and uplink baseband processing, supply system synchronization clock, signalling processing, OM function, interface with core network and the fronthaul gateway; Fronthaul gateway: Downlink broadcasting, uplink combining, power supply for O-RU$_8$, cascade with other fronthaul gateway, synchronization clock;
Transmission media[b]	From O-DU to Fronthaul gateway: Fiber; From Fronthaul gateway to O-RU: Fiber or Optical Electric Composite Cable From (O-DU&O-CU) to O-RU: Fiber or Optical Electric Composite Cable From (O-DU&O-CU) and core network: Fiber or Optical Electric Composite Cable; Trusted or Untrusted transport
Duplex[b]	TDD, FDD
Deployment location	Indoor
Cell Coverage	Omni
MIMO Configuration[b]	SU-MIMO/MU-MIMO; up to 4TX/4RX
User distribution[c]	20-200
Fronthaul Latency	Split Option 6: TBD Split Option 7-2: fronthaul dependent (refer to [8]) Split Option 8: 150us
Synchronization[b]	IEEE 1588, GPS, BDS
Power Supply Mode[b]	POE or by optical electric composite cables

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference.

3.2.2 The integrated architecture

Descriptions of the integrated architecture are listed in Table 3-3.

Table 3-3: Descriptions of Attributes for the Indoor Picocell Integrated Architecture

Attributes	Description
Reference Figure	Figure 2-2
Interface[a]	F1
Functionality[b]	O-DU+O-RU: Downlink and uplink baseband processing, supply system synchronization clock, signalling processing, OM function, interface with core network and, downlink baseband signal convert to RF signal, uplink RF signal convert to baseband signal
Transmission media[b]	Fiber or Optical Electric Composite Cable
Duplex[b]	TDD, FDD
Deployment location	Indoor
Cell Coverage	Omni
MIMO Configuration[b]	SU-MIMO/MU-MIMO; up to 4TX/4RX
User distribution[c]	100
Fronthaul Latency	Not Applicable
Synchronization[b]	IEEE 1588, Sniffer, GPS, BDS
Power Supply Mode[b]	POE or by optical electric composite cables

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference

3.3 Outdoor

For the outdoor scenario, the base station can be identified as a Medium Range Base Station, and there are two potential key architecture types, which are the split architecture and the integrated architecture.

Note: The hardware design may consider the co-location of MEC and UPF part in O-CU/O-DU functionality if needed.

3.3.1 Picocell

The base station architecture for Picocell incorporates an integrated O-DU/O-RU architecture, and its description is listed in Table 3-4.

Table 3-4: Descriptions of Attributes for the Outdoor Picocell Architecture

Attributes	Description
Reference Figure	Figure 2-2
Interface[a]	F1
Functionality[b]	O-DU+O-RU: Downlink and uplink baseband processing, supply system synchronization clock, signalling processing, OM function, interface with core network and, downlink baseband signal convert to RF signal, uplink RF signal convert to baseband signal
Transmission media[b]	Fiber or Optical Electric Composite Cable
Duplex[b]	TDD
Deployment location	Outdoor
Cell Coverage	Omni
MIMO Configuration[b]	SU-MIMO/MU-MIMO; up to 4TX/4RX
User distribution[c]	>200
Fronthaul Latency	Not Applicable
Synchronization[b]	GPS or IEEE1588
Power Supply Mode[b]	POE or by optical electric composite cables

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference

3.3.2 Microcell

The base stations for both micro cell scenarios incorporate a split RAN architecture. Their descriptions are listed in Table 3-5 and Table 3-6.

Table 3-5: Descriptions of Attributes for the FR1 Outdoor Microcell Architecture

Attributes	Description
Reference Figure	Figure 2-1
Interface[a]	Open fronthaul interface (WG4) (Option 7-2)
Functionality[b]	Provides lower layer split in RAN so that PHY-Hi, MAC/RLC/PDCP/SDAP/RRC could be centralized or virtualized and support CoMP features etc.
Transmission media[b]	Fiber, wireless to fiber
Duplex[b]	TDD
Deployment location	Outdoor
Cell Coverage	Omni
MIMO[b]	SU-MIMO/MU-MIMO; up to 16TX/16RX
User distribution[c]	>200
Fronthaul Latency	Split Option 6: TBD Split Option 7-2: fronthaul dependent (refer to [8]) Split Option 8: 150us
Synchronization[b]	GPS or IEEE1588
Power Supply Mode[b]	DC/AC

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference

Table 3-6: Descriptions of Attributes for the FR2 Outdoor Microcell Architecture

Attributes	Description
Reference Figure	Figure 2-1
Interface[(a)]	F1 interface between O-CU/O-DU (Split Option 2) Open fronthaul interface (WG4) between O-DU/O-RU (Option 7-2)
Functionality[(b)]	O-DU/O-RU: Downlink and uplink baseband processing, supply system synchronization clock, scheduling, signalling processing, OM function, interface with core network and, Downlink baseband signal convert to RF signal, uplink RF signal convert to baseband signal
Transmission media[(b)]	Fiber, wireless to fiber
Duplex[(b)]	TDD
Deployment location	Small cell, Outdoor, Urban/Suburban
Cell Coverage	Sectorized
MIMO Configuration[(b)]	SU-MIMO/MU-MIMO; up to 4TX/4RX
User distribution[(c)]	>100
Fronthaul Latency	Split Option 7-2: fronthaul dependent (refer to [8])
Synchronization[(b)]	GPS or IEEE1588
Power Supply Mode[(b)]	AC or POE or by optical electric composite cables

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference

3.3.3 Integrated access and backhaul (IAB)

The IAB base station uses an integrated architecture, and its attributes are listed in Table 3-7.

Table 3-7: Descriptions of Attributes for the IAB Architecture

Attributes	Description
Reference Figure	Figure 2-3
Interface[(a)]	F1 Interface (WG5) (split option 2) Open fronthaul interface (WG4) (split option 7-2)
Functionality[(b)]	Provides support for multi-hop relay per Rel. 16.
Transmission media[(b)]	Fiber, wireless to fiber
Duplex[(b)]	TDD
Deployment location	Outdoor mobile/fixed relays, Urban/Suburban
Cell Coverage	Omni or Sectorized
MIMO Configuration[(b)]	SU/MIMO and MU/MIMO; up to 4TX/4RX
User distribution[(c)]	30 - 40
Latency	4ms/hop for eMBB
Synchronization[(b)]	GPS, or OTA per Rel-16
Power Supply Mode[(b)]	AC, POE, or by optical electric composite cables

Notes:

(a) The option noted here is for the first stage, and do not preclude other interface options.
(b) The options noted here are for reference, and do not preclude other options.
(c) The number of users distribution refers to the active users in one base station, and the options are for reference

Chapter 4 Key performance indicators

4.1 Peak data rate

Peak data rate is the highest theoretical data rate which is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e., excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

Indoor	Outdoor		
Pico	Pico	Micro	IAB
0.75-1.33Gbps (DL); 0.25-0.67Gbps (UL); NOTE1	FR1: up to 6/12 Gbps (UL/DL) FR2: up to 15/30 Gbps (UL/DL)	FR1: up to 6/12 Gbps (UL/DL) FR2: up to 15/30 Gbps (UL/DL)	FR2: 3-12 Gbps (DL); 1.5-6 Gbps (UL) For n260: 12-24 Gbps (DL); 6-12 Gbps (UL)

NOTE1: This requirement is calculated based on the frame structure UL:DL=1:1 (TDD).

4.2 Peak spectral efficiency

Peak spectral efficiency is the highest theoretical data rate (normalized by bandwidth), which is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e., excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

Higher frequency bands could have higher bandwidth, but lower spectral efficiency and lower frequency bands could have lower bandwidth but higher spectral efficiency. Thus, peak data rate cannot be directly derived from peak spectral efficiency and bandwidth multiplication.

Peak spectral efficiency (bps/Hz) = Peak data rate (bps)/ bandwidth (Hz).

Indoor	Outdoor		
Pico	Pico	Micro	IAB
7.5-13.3 bps/Hz (DL); 2.5-6.7 bps/Hz (UP); NOTE1	30 bps/Hz (DL) 15 bps/Hz (UL) NOTE1	30 bps/Hz (DL) 15 bps/Hz (UL) NOTE1	30 bps/Hz (DL) 15 bps/Hz (UL) NOTE1

NOTE1: This requirement is calculated based on the frame structure UL:DL=1:1 (TDD).

4.3 Bandwidth

Bandwidth means the maximal aggregated total system bandwidth. It may be supported by single or multiple RF carriers. It is a quantitative KPI.

Indoor	Outdoor		
Pico	Pico	Micro	IAB
100 MHz	FR1: up to 200 MHz FR2: up to 800 MHz	FR1: up to 200 MHz FR2: up to 1.2 GHz	FR2: 100 – 400 MHz For n260: 400 – 800 MHz

4.4 Control plane latency

Control plane latency refers to the time for UE to move from a battery efficient state (e.g., IDLE) to start of continuous data transfer (e.g., ACTIVE).

Indoor	Outdoor		
Pico	Pico	Micro	IAB
10ms	10ms	10ms	10ms/hop

4.5 User plane latency

The time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point via the radio interface in both uplink and downlink directions, where neither device nor base station reception is restricted by DRX.

Indoor	Outdoor		
Pico	Pico	Micro	IAB
URLLC UL/DL(ms): 0.5ms eMBB: UL/DL(ms): 4ms	URLLC UL/DL(ms): 0.5ms eMBB: UL/DL(ms): 4ms	URLLC UL/DL(ms): 0.5ms eMBB: UL/DL(ms): 4ms	URLLC UL/DL(ms): 0.5ms/hop eMBB: UL/DL(ms): 4ms/hop

4.6 Mobility

Mobility means the maximum user speed at which a defined QoS can be achieved (in km/h).

Indoor	Outdoor		
Pico	Pico	Micro	IAB
3km/h	<60km/h	<400km/h (high speed train)	120 km/h

Annex ZZZ: O-RAN Adopter License Agreement

BY DOWNLOADING, USING OR OTHERWISE ACCESSING ANY O-RAN SPECIFICATION, ADOPTER AGREES TO THE TERMS OF THIS AGREEMENT.

This O-RAN Adopter License Agreement (the "Agreement") is made by and between the O-RAN Alliance and the entity that downloads, uses or otherwise accesses any O-RAN Specification, including its Affiliates (the "Adopter").

This is a license agreement for entities who wish to adopt any O-RAN Specification.

Section 1: DEFINITIONS

1.1 "Affiliate" means an entity that directly or indirectly controls, is controlled by, or is under common control with another entity, so long as such control exists. For the purpose of this Section, "Control" means beneficial ownership of fifty (50%) percent or more of the voting stock or equity in an entity.

1.2 "Compliant Implementation" means any system, device, method or operation (whether implemented in hardware, software or combinations thereof) that fully conforms to a Final Specification.

1.3 "Adopter(s)" means all entities, who are not Members, Contributors or Academic Contributors, including their Affiliates, who wish to download, use or otherwise access O-RAN Specifications.

1.4 "Minor Update" means an update or revision to an O-RAN Specification published by O-RAN Alliance that does not add any significant new features or functionality and remains interoperable with the prior version of an O-RAN Specification. The term "O-RAN Specifications" includes Minor Updates.

1.5 "Necessary Claims" means those claims of all present and future patents and patent applications, other than design patents and design registrations, throughout the world, which (i) are owned or otherwise licensable by a Member, Contributor or Academic Contributor during the term of its Member, Contributor or Academic Contributorship; (ii) such Member, Contributor or Academic Contributor has the right to grant a license without the payment of consideration to a third party; and (iii) are necessarily infringed by a Compliant Implementation (without considering any Contributions not included in the Final Specification). A claim is necessarily infringed only when it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of the art generally available at the date any Final Specification was published by the O-RAN Alliance or the date the patent claim first came into existence, whichever last occurred, to make, sell, lease, otherwise dispose of, repair, use or operate a Compliant Implementation without infringing that claim. For the avoidance of doubt in exceptional cases where a Final Specification can only be implemented by technical solutions, all of which infringe patent claims, all such patent claims shall be considered Necessary Claims.

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.

1