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Technical Specification

O-RAN Fronthaul Working Group

Fronthaul Interoperability Test Specification (IOT)

Revision History

Date	Revision	Description
2019.09.16	01.00	First published version for Fronthaul Interoperability Test Specification (IOT)

Contents

Chapter 1 Introductory Material

1.1 Foreword

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

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

Release x.y.z

where:

x the first digit is incremented for all changes of substance, ie, 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.

1.2 Scope

1.2.1 General

The present document specifies the interoperability testing (IOT) for O-DU and O-RU from different vendors connected using the O-RAN fronthaul (FH) interface. It is noted however that the same content can be utilized for the IOT for O-DU and O-RU from the same vendor connected using the O-RAN FH interface.

A guiding principle defining the tests in this document shall be that any test must exercise the fronthaul interface to a greater extent than the test prerequisite so that the test is a proper test of some fronthaul functionality or performance.

All tests focus on testing the fronthaul interface, but due to the non-intrusive nature of the tests, system-level aspects of the O-DU and O-RU are inevitably part of the interoperability tests too. Because of this, it is recognized that positive test outcomes indicate successful interoperability, but negative results may not be attributed solely to problems in the FH interface and additional investigation may be required.

It is also noted that additional test scenarios are required for comprehensive testing of the FH interface functionality and performance, which shall be considered in future WG4 test specification versions.

In general, unless otherwise stated, the tests cover LTE (Stand-Alone), NR Non-Stand-Alone (NSA) and NR Stand-Alone (SA). The tests shall be executed using whichever IOT profile(s) are appropriate for the DUTs. See Annex A for details on the IOT profiles.

1.2.2 Summary of Test Scenarios

The following set of interoperability test cases are defined for the current version of WG4 FH IOT specification.

- FH tests focused on the M-Plane:
  - Start-up (O-RU start-up from the power-on of O-RU to the availability of service)
- FH tests focused on the S-plane:
  - Synchronization status detection
  - Frequency and time error (performance)
- FH tests focused on the C/U-Planes:
  - Radio Layer 3 C-Plane establishment and Initial Radio U-Plane data transfer

- Radio downlink U-Plane data transfer (Downlink throughput performance)

1.2.3 Future Enhancements

Additional test cases are under consideration for the future versions of this specification. A non-exhaustive list of candidate test cases for future versions is provided below:

- FH tests focused on the M-Plane:
  - Software management (O-RU software update)
  - Fault management
  - File management
- FH tests focused on the C/U-plane:
  - Beamforming (testing the actual characteristics of the radiated/received signals at O-RU)
  - Compression (testing different compression methods and IQ bitwidth and validating expected performance)
  - Delay Management (testing FH delay management functionality under different FH delays)

  Note: beamforming, compression and delay management features are tested as part of the IOT cases already specified in Chapter 2.2 and the relevant IOT profiles (refer to Annex A for more details). The test cases above extend the capability to test the fronthaul interface in respect of these features.

  - Radio U-Plane uplink data transfer (Uplink throughput performance)
  - Multiple O-RUs
  - Multiple UEs

1.3 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] O-RAN WG4 Control, User and Synchronization Specification Version 2, July 2019

[3] O-RAN WG4 Management Plane Specification Version 2, July 2019

[4] O-RAN Management Plane Yang Models Version 2, July 2019

[5] ITU-T G.8275.1 (Amendment 2), Precision time protocol telecom profile for phase/time synchronization with full timing support from the network, ITU, March 2018

[6] ITU-T G.8275.2 (Amendment 2), Precision time protocol telecom profile for phase/time synchronization with partial timing support from the network, ITU, March 2018

[7] ITU-T G.8271.1 (Amendment 1), “Network limits for time synchronization in packet networks”, ITU, March 2018

[8] ITU-T G.8271.2 (Amendment 1), “Network limits for time synchronization in packet networks with partial timing support from the network”, ITU, March 2018

[9] ITU-T G.8273, “Framework of phase and time clocks”, ITU, March 2018

[10] ITU-T G.8261, “Timing and synchronization aspects in packet networks”, ITU, August 2013

[11] eCPRI Specification v2.0 “Common Public Radio Interface: eCPRI Interface Specification”, May 2019

[12] 3GPP TS 36.104, “Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception”

[13] 3GPP TS 38.104, “NR; Base Station (BS) radio transmission and reception”

[14] 3GPP TS 36.211, “Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation”

[15] 3GPP TS 38.211, “NR; Physical channels and modulation”, 3GPP, (v15.4.0) December 2018

[16] 3GPP TS 36.331, “Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC)”

[17] 3GPP TS 38.331, “NR; Radio Resource Control (RRC); Protocol specification”

[18] 3GPP TS 36.141, “Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing”, 3GPP, (v15.5.0) December 2018

[19] 3GPP TS 38.141-2, “NR; Base Station (BS) conformance testing Part 2: Radiated conformance testing”, 3GPP, (v15.0.0) December 2018

[20] 3GPP TS 23.401, “General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access”, 3GPP, (v15.6.0) December 2018

[21] 3GPP TS 23.502, “Procedures for the 5G System (5GS)”, 3GPP, (v15.4.1) January 2019

[22] 3GPP TS 37.340, “Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity”, 3GPP, (v15.4.0) December 2018

[23] 3GPP TS 38.214, “NR; Physical layer procedures for data”, 3GPP, (v15.4.0) December 2018

1.4 Definitions and Abbreviations

1.4.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

C-Plane	Control Plane: refers specifically to real-time control between O-DU and O-RU, and should not be confused with the UE’s control plane
DL	DownLink: data flow towards the radiating antenna
eNB	eNodeB (applies to LTE) <E-UTRAN NodeB / Evolved NodeB>
fm-pm	Fault Management, Performance Management role
gNB	gNodeB (applies to NR) <Next Generation NodeB>
M-Plane	Management Plane: refers to non-real-time management operations between the O-DU and the O-RU
NETCONF	Network Configuration Protocol. For details see: RFC 6241, “Network Configuration Protocol (NETCONF)”, IETF, June 2011
NSA	Non-Stand-Alone network mode that supports operation of SgNB attached to MeNB
O-CU	O-RAN Central Unit – a logical node hosting PDCP, RRC, SDAP and other control functions
O-DU	O-RAN Distributed Unit: a logical node hosting RLC/MAC/High-PHY layers based on a lower layer functional split. O-DU in addition hosts an M-Plane instance.

O-RU	O-RAN Radio Unit <O-RAN Radio Unit: a logical node hosting Low-PHY layer and RF processing based on a lower layer functional split. This is similar to 3GPP's "TRP" or "RRH" but more specific in including the Low-PHY layer (FFT/iFFT, PRACH extraction).>. O-RU in addition hosts M-Plane instance.
PTP	Precision Time Protocol (PTP) is a protocol for distributing precise time and frequency over packet networks. PTP is defined in the IEEE Standard 1588.
PDCCH	Physical Downlink Control Channel applies for LTE and NR air interface
PBCH	Physical Broadcast Channel applies for LTE and NR air interface
SA	Stand-Alone network mode that supports operation of gNB attached to a 5G Core Network
SCS	OFDM Sub Carrier Spacing
SSB	Synchronization Signal Block, in 5G PBCH and synchronization signal are packaged as a single block
sudo	Super-User Do role
S-Plane	Synchronization Plane: Data flow for synchronization and timing information between nodes
SyncE	Synchronous Ethernet, is an ITU-T standard for computer networking that facilitates distribution of clock signals over the Ethernet physical layer
T-BC	Telecom Boundary Clock
TWAMP	Two-Way Active Measurement Protocol
UDP	User Datagram Protocol
UE	User Equipment terminology for a mobile device in LTE and NR
UL	UpLink: data flow from the UE towards the core network, that is from the O-RU towards in the O-DU in a Fronthaul context.
U-Plane	User Plane: refers to IQ sample data transferred between O-DU and O-RU

1.4.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

5GS	5G System, comprises the access network, core network and user equipment
ARFCN	Absolute Radio Frequency Channel Number
CC	Component Carrier
CN	Core Network
C/U-Plane	C-Plane and U-Plane
DHCP	Dynamic Host Configuration Protocol
DL	DownLink
DUT	Device Under Test
eNB	eNodeB
EARFCN	E-UTRA ARFCN
EVM	Error Vector Magnitude
FH	Fronthaul
fm-pm	Fault Management, Performance Management role
GSCN	Global Synchronization Channel Number

gNB	gNodeB
MeNB	Master eNB
NETCONF	Network Configuration Protocol
NMS	Network Management System
nms	NMS role
NSA	Non-Stand-Alone
O-CU	O-RAN Central Unit
O-DU	O-RAN Distributed Unit
O-RU	O-RAN Radio Unit
OTA	Over the Air
PBCH	Physical Broadcast Channel
PCI	Physical Cell Identity
PRTC	Primary Reference Time Clock
RF	Radio Frequency
RSRP	Reference Signal Received Power
SA	Stand-Alone
SCS	Sub Carrier Spacing
SDAP	Service Data Adaptation Protocol
SgNB	Secondary gNB
SSB	Synchronization Signal Block
sudo	Super User Do role
swm	Software fault management role
UE	User Equipment
UL	UpLink
U-Plane	User Plane

1.5 Introduction

1.5.1 General

O-RAN WG4 has specified and published the O-RAN FH interface specifications (CUS-plane [2] and M-plane [3]) with the objective to enable interoperability of O-DU and O-RU from different vendors. The aim of this document is to further facilitate such multi-vendor IOT using the O-RAN FH interface by defining standard test configurations, IOT profiles and interoperability test cases.

It shall be possible to perform interoperability testing in a non-intrusive manner; that is, in a manner in which the network elements under test are not required to support any functionality or mode of operation beyond that required for normal operation in a telecommunication network. However, making the endpoints of the FH interface between the O-DU and O-RU visible would require definition of new interfaces which may entail caching and transport of data. Furthermore, and more importantly, operators require that the total radio system function and perform adequately when integrating O-DU and O-RU from different vendors. Consequentially, this specification approaches interoperability testing by means of system level testing.

FH interoperability testing by way of system test involves creation of a stimulus in the O-DU to O-RU direction using an actual or emulated O-CU, potentially with CN support/emulation, and measurement of the result at the output of the O-RU in the RF domain by an actual or emulated UE together with an RF signal/spectrum analyzer as required.

Likewise, in the reverse direction, the stimulus to probe the FH in the O-RU to O-DU direction is provided by an actual or emulated UE and is measured at the output of the O-DU by an actual or emulated O-CU with CN support/emulation as required.

Inasmuch as the interoperability testing by way of system test involves configuring and collecting results from the O-RU it shall be effected by means of the M-Plane FH interface. For elements that fall outside of this scope, such as the O-DU, the configuration and collection of data and status information for testing purposes may be accomplished by NMS.

Interoperability involves testing the FH interface in terms of M-Plane, S-Plane, C-Plane and U-Plane. Some aspects of these planes may be tested independently. However, some tests, such as those that require the devices to be brought into service and a call established entail simultaneous activity across multiple planes.

1.5.2 Fronthaul M-plane Architectural options

As described in the “O-RAN WG4 Management Plane Specification” [3], two architectural models are supported, namely a “hierarchical” and a “hybrid” model. As a general guideline the following apply,

1. Hierarchical model. The O-RU is entirely managed by one O-DU (sudo) using a NETCONF based M-Plane interface.

2. Hybrid model: The architecture allows one or more direct logical interface(s) between management system(s) (performing different roles, nms, fm-pm, swm, etc) and O-RU in addition to a logical interface between O-DU (sudo role) and the O-RU.

In the current version of WG4 FH IOT Specification, only the Hierarchical model is addressed. The hybrid model is considered for future versions of the WG4 FH IOT Specification.

1.5.3 Fronthaul Synchronization options

Various synchronization options have been defined in the O-RAN WG4 CUS-Plane Specification [2] (LLS-C1, LLS-C2, LLS-C3 and LLS-C4). Depending on the specific O-RAN deployment being considered, not all of them might be relevant. When testing the S-Plane, the System Integrator shall identify which of the test cases are relevant depending on the specific deployment scenarios addressed. As a general guideline the following applies:

1. Direct connection between O-DU and O-RU:

   LLS-C1 is generally the main sync option to be validated

   LLS-C4 may be considered as an alternative or as a complement to LLS-C1

2. Bridged network between O-DU and O-RU

   LLS-C2 for cases where the synchronization is delivered to the O-RU via the O-DU and over the bridged network. In this case the PRTC/PRC may be embedded in the O-DU or may be located anywhere in the network (connected via backhaul or FH transport).

   LLS-C3 for cases when the synchronization is distributed to the O-RU without involving the O-DU In this case the PRTC/PRC may be located anywhere in the network (connected via backhaul or FH transport) and may also be co-located with the O-DU.

   LLS-C4 may be considered as alternative or as a complement to LLS-C2/LLS-C3. LLS-C4 is considered for future versions of the specification.

The FH focused tests for S-plane for the current version of this specification covers LLS-C1, LLS-C2 and LLS-C3 using the ITU-T G.8275.1 [5] profile (Full Timing Support). FH focused tests for S-Plane for LLS-C1, LLS-C2 and LLS-C3 using the ITU-T G.8275.2 [6] profile (Partial Timing Support), and LLS-C4 are for future study.

Chapter 2 Interoperability Measurements

2.1 Interoperability Standard Test Definitions

2.1.1 Standard Test Configurations

Interoperability testing is performed to prove that the end-to-end functionality between the O-DU and O-RU is as required by the O-RAN FH CUS-Plane [2] and M-Plane [3] specifications on which these components are based. This requires system level testing with O-DU and O-RU as an integrated system.

2.1.1.1 Device Under Test (DUT)

The case where the O-DU and O-RU are provided by different vendors is the focus of this document, but the case where both are from the same vendor is also valid.

The O-DU and O-RU, with their interconnecting FH, is considered as the DUT. This is the same whether the O-CU and O-DU are implemented as a combined node, or as stand-alone nodes.

For simplicity and without prejudice the tests in the following sections are defined with reference to a stand-alone O-DU. However, the tests apply equally when the O-DU is replaced by the O-DU functionality of a combined O-CU/O-DU and where the Layer 2 and Layer 3 radio processing on the network side is provided by the O-CU functionality of the combined-node. Any differences to the test due to replacement of the stand-alone O-DU with a combined O-CU/O-DU are detailed as they arise.

The simplest test configuration involves a single O-DU and a single O-RU. In this configuration, the O-DU and O-RU are labelled as DUT1(O-DU) and DUT1(O-RU) respectively.

More advanced test configurations will involve defining the cardinality between the 1…M O-DU(s) and 1…N O-RU(s) as part of the test scenario which will determine the configuration required.

An example of such test configuration is to have a single O-DU connected to multiple N O-RUs. In this example, the O-DU is labelled as DUT1(O-DU) and the O-RU(s) are labelled as DUT1(O-RU) ... DUTN(O-RU) accordingly.

A second example is to have multiple M O-DUs connected to multiple N O-RUs. In this second example, the O-DUs are labelled as DUT1(O-DU) … DUTM(O-DU) and the O-RU(s) are labelled as DUT1(O-RU) ... DUTN(O-RU) accordingly. However, deployment scenarios where a single O-RU is managed and used by more than one O-DU is not addressed in this version of the WG4 FH IOT Specification.

External physical connection between the O-DUs and O-RUs are to be specified in the IOT profiles (eg. number of 10/25/40GE, physical medium eg. fiber), see Annex A for details.

IOT test cases defined in the following sections of this specification shall be executed using whichever IOT profile(s) that are appropriate for the DUTs. See Annex A for more details on the IOT profiles.

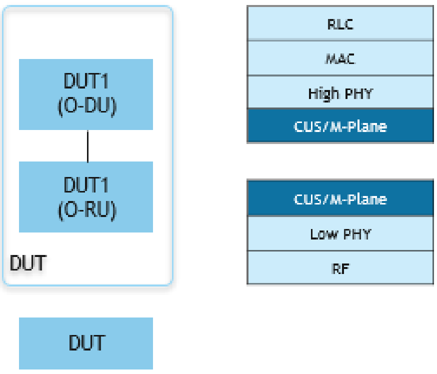

Figure 2-1: The simplest DUT configuration

2.1.1.2 Network Management System (NMS)

Network Management System (NMS) is required to support M-Plane testing particularly in the Hybrid architecture model as the O-RU has logical connection with the NMS [3]. In the hierarchical model, the NMS manages the O-DU and the O-DU manages the O-RU respectively.

External physical connection between the NMS and O-DUs and O-RUs are to be specified in the IOT profiles (eg. number of 10/25/40GE, physical medium eg. fiber), see Annex A for details.

Only the Hierarchical architecture model is in scope in the current release of the WG4 FH IOT Specification.

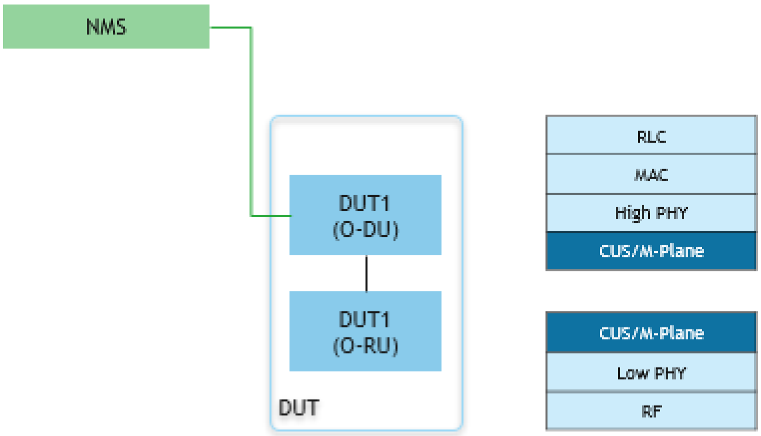

Figure 2-2: The relationship between DUT and NMS

2.1.1.3 Testing Tools

One of the key objectives of interoperability testing is to validate the functionality of production grade DUTs. Hence it is important to ensure that the DUTs are not negatively impacted with the utilization of internal functions solely to support interoperability testing. ie, DUTs are not expected to be testing tools when deployed in production networks and therefore DUTs should not be used as testing tools during interoperability tests.

Interoperability tests are performed with a set of testing tools which are used to both apply active stimulus and as well as passive monitoring and measurements of the DUTs.

The test is applicable to deployment scenarios where the O-CU and O-DU are implemented as separate nodes connected by an F1 interface and scenarios where they are implemented as a combined node without an accessible F1 interface.

The deployment scenario where the 4G LTE eNB is implemented as separate 4G O-CU and 4G O-DU nodes connected by a W1 interface is considered for future versions of the WG4 FH IOT Specification when 3GPP standardization work for the W1 interface is complete.

Active stimulus testing tools

- **5G NR O-CU or O-CU emulator** either as a separate node or as a combined node with O-DUs (DUT): used to provide Layer 2 and Layer 3 radio processing on the network side. In case of stand-alone nodes, terminates the 3GPP 5G F1 interface with the O-DU (DUT).
  - O-CU and O-CU emulator can be connected to either a real Core network or emulated Core. An emulated Core can be simpler to deploy for interoperability testing purposes.
  - External physical connection between the O-CU or O-CU emulator with the O-DU (DUT), if any, will be lab setup dependent either through physical or wireless medium
- **4G LTE MeNB or MeNB emulator**: used to terminate the 3GPP EN-DC X2 interface with the 5G NR O-CU or O-CU emulator
  - Required when the DUTs (O-DU and O-RU) are configured to operate 5G NR NSA option 3/3a/3x.

- 4G LTE MeNB or MeNB emulator can either have physical or logical connection with the Test UE or UE emulator. RF connection between the 4G LTE MeNB or MeNB emulator with the Test UE or UE emulator will be either through cabled connection or Over the Air (OTA).

- **Test UEs and/or UEs emulator**: used to generate stateful device connections and traffic to validate the O-DU and O-RU implementation of the O-RAN FH interface protocols as these are stimulated by the 3GPP upper layer protocols.
  - Required so that the O-RU which is the DUT does not need to be put into a "test mode" which does not happen in live deployments.
  - Test UEs will require SIM cards which are pre-provisioned with subscriber profiles. UEs used for testing can be simpler to setup but given that these Test UEs are designed to be commercial UEs with possibly certain diagnostic functions enabled for logging purposes, they are limited in terms of configurability.
  - UEs emulator will require SIM profile configuration with the subscriber's profiles. UEs emulator can be used in test scenarios which require multiple UEs' sessions, more flexibility and configurability to help drive test scenarios.
  - RF connection between the Test UEs or UEs emulator with the O-RU (DUT) will be either through cabled connection or OTA.

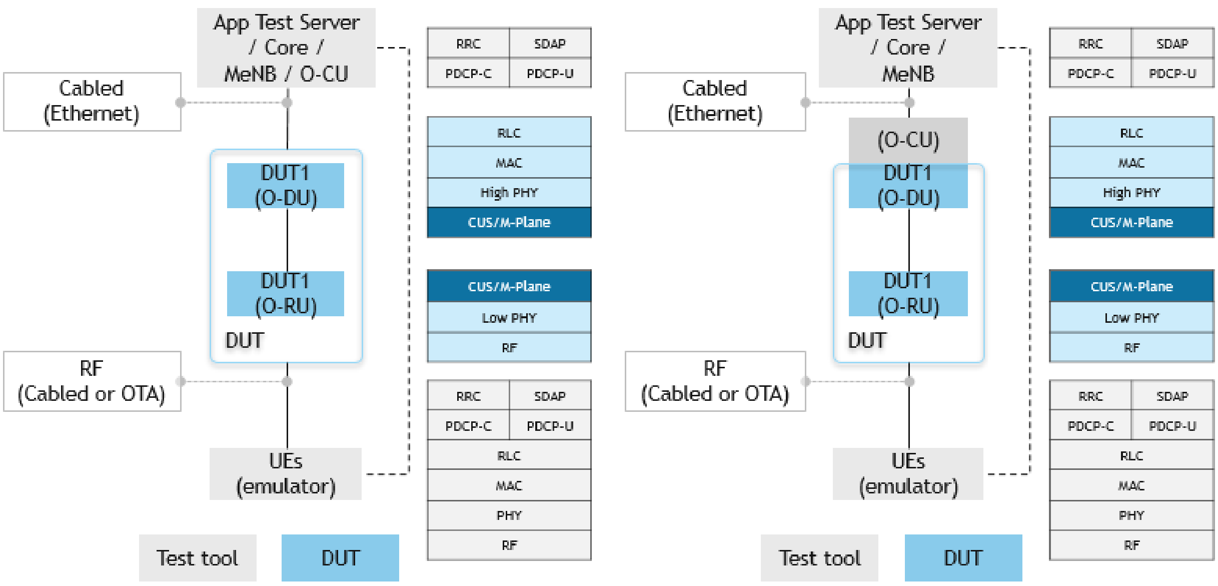

Figure 2-3: Test set-up for stand-alone (left) and combined (right)

Passive monitoring and measurements testing tools

- **Test UEs and/or UEs emulator**: used to produce measurements and logs
  - Measurements and KPIs logs for test case validation and reporting
  - Diagnostics logs for troubleshooting purposes which can help with test setup validation and root cause analysis for failed test cases
  - Diagnostics mode must be enabled on the Test UEs for diagnostic logging purposes. Device logging tools must be connected to the Test UEs for logging purposes.
  - UEs used for testing can be simpler to setup but given that given that these Test UEs are designed to be commercial UEs, they are limited in terms of diagnostic logging capabilities due to limited processing and buffer space.

- UEs emulator can be used in test scenarios which require extensive diagnostics capabilities.

- **Application Test Server**: An endpoint application test traffic emulator which can be used to generate and/terminate various traffic streams to or from the Test UEs/UEs emulator respectively. May provide one or more of these options,
    - Stateful traffic, eg. TCP, TWAMP
    - Stateless traffic eg. UDP
    - Required to place traffic load on the DUT
    - External physical connection between Application Test Server and O-CU/O-CU emulator is out of scope of the specification
- **Test results and KPIs reporting** which can be provided through one or more of these options
    - UE logging tools which are connected to the Test UEs
    - Device emulator reporting dashboards typically built in as part of the Device emulator solution
    - External dashboard and reporting applications
- **FH Protocol Analyzer**: used for protocol analysis of O-RAN FH protocols to achieve the following
    - Test case validation and troubleshooting purposes which can help with test setup validation and root cause analysis for test cases which fail
    - Decode and validation of M-Plane flow sequencing prior to SSH secure connection establishment
    - Monitoring traffic from the O-RAN FH typically through a tap or span port. Taps are typically preferred as span ports are less reliable but can be used if taps are not readily available in the test lab. Connectivity specifics (eg. number of 10/25/40GE) are to be specified in the IOT profiles (see Annex A for details).
- **RF Spectrum and Beam Signal Analyzer**: used for RF and Beam power and quality analysis for,
    - Test case validation and troubleshooting which can help with test setup validation and root cause analysis for test cases which fail

      Eg. the Beam Signal Analyzer can be used to validate that the O-RUs (DUT) are in-service, configured and operating correctly, which in case of 5G, includes validating that the SS/PBCH blocks (SSB) are configured with the correct Sub Carrier Spacing (SCS), transmitted at the correct frequency locations (can be offset from the center frequency), and in case of both 4G and 5G, burst periods with the correct Physical Cell Identities (PCI), Beam Identifiers and, expected power and quality.
    - RF Spectrum and Beam Signal Analyzer performs OTA RF measurements and signal analysis
- **O-CU or O-CU emulator**
- **MeNB or MeNB emulator**
- **Core or Core emulator**
    - Used to produce measurements and diagnostics logs for troubleshooting purposes which can help with test setup validation and root cause analysis for test cases which fail

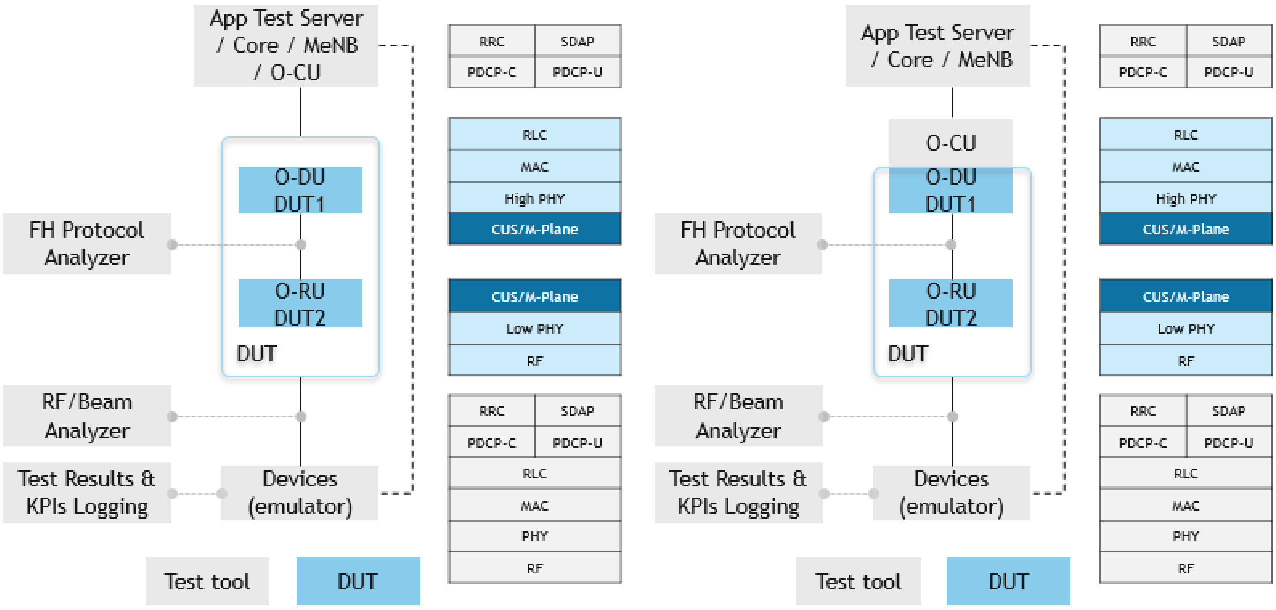

Figure 2-4: Test set-up for stand-alone (left) and combined (right)

2.1.1.4 Time Synchronization

All the components including the DUTs (O-DUs and O-RUs) and the Testing Tools are required to be synchronized to a common system time and master time source unless otherwise stated.

Synchronization Plane (S-Plane) configuration for the DUTs is specified in the IOT profiles (see Annex A for details).

Test tools shall be time synchronized to the master timing source with PTP.

2.1.1.5 Assumptions

In this version of the WG4 FH IOT specifications, the following assumptions apply

- All wireline transport interfaces and the air interface is assumed to conform to ideal conditions (no impairments).
- All wireless connection assumed to adopt 3GPP approaches for “ideal” RF environment for test setup.
- O-DU and O-RU comply to the same version of the O-RAN FH interface specifications.
- All elements in the interoperability test and the supporting test environment, where 3GPP support is relevant, comply to the same version of the 3GPP Specification.
- All O-RUs involved in a test are of the same category; all A or all B.

2.1.1.6 Specifications to be used for testing

In this version of the WG4 FH IOT specifications, the following sets of specifications and releases/versions shall be supported

- O-RAN FH
  - Control, User and Synchronization Plane Specification [2]
  - Management Plane Specification [3]
  - Management Plane Yang Models [4]
- eCPRI

- eCPRI Specification V2.0 “Common Public Radio Interface: eCPRI Interface Specification” [11]

  It is important to ensure that all DUTs (O-DU and O-RU) and Testing Tools use compatible release/version of the O-RAN FH and eCPRI specifications [11] which in this version of the WG4 FH IOT Specification is ensured by use of the same version.

- 3GPP
  - Release 15 December 2018 and later versions specifications

    It is important to ensure that all DUTs (O-DU and O-RU) and Testing Tools use compatible release/version of the 3GPP specifications, which in this version of the WG4 FH IOT Specification is ensured by use of the same version.

2.1.1.7 Interoperability (IOT) Test Profiles

The IOT Profiles are included in Annex A. Additional Profiles will be added in future releases of WG4 FH IOT Specification.

2.1.1.8 Measurements of interest

- Availability (eg. are the DUTs in service)
- Accessibility (eg. can the device connect to the network)
- Retainability (eg. can the device connection be maintained)
- Mobility (eg. moving between two O-RUs)
- Integrity (eg. data transfers between the device and the network)

2.1.2 Standard Test Data Configurations

The test data configurations are defined as part of the IOT profiles in Annex A.

2.1.3 Standard Test Execution

Most interoperability tests will follow a standard execution plan although individual tests are expected to deviate from this in some way. By defining the standard execution plan an understanding of how tests are arranged can be gained, thereafter examining individual tests can reveal how deviations from the standard execution plan may be defined.

2.2 Interoperability Test Cases

The following set of IOT cases are defined in this document

M-Plane IOT Test

1. Startup Installation: O-DU and O-RU getting in Service

S-Plane IOT Tests

1. Functional test of O-DU + O-RU using ITU-T G.8275.1 profile (LLS-C1)
2. Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.1 profile (LLS-C2)
3. Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.1 profile (LLS-C3)
4. Performance test of O-DU + Two O-RUs using ITU-T G.8275.1 profile (LLS-C1)
5. Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.1 profile (LLS-C2)
6. Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.1 profile (LLS-C3)

C/U-Plane IOT Tests

1. Radio Layer 3 C-Plane establishment and Initial Radio U-Plane data transfer
2. Radio U-Plane downlink data transfer (Downlink throughput performance)

2.2.1 M-Plane IOT Test

2.2.1.1 Start-up

2.2.1.1.1 Test Description and Applicability

This scenario is MANDATORY.

The DUT is composed of single O-DU and single O-RU.

Test scenario refers to Chapter 3 “Start-up” in hierarchical architecture for M-Plane [3].

2.2.1.1.2 Minimum Requirements

Single O-DU (DUT1(O-DU)) and a single O-RU (DUT1(O-RU))

- Must be connected through the O-RAN FH

Assumptions which are required for this test scenario

1. DHCP server is configured for test purposes (either function served by O-DU or external DHCP server with O-DU or router as relay – that should have no impact on test scenario). In case of external DHCP server - Configuration of DHCP server and DHCP procedures are excluded from validation of IOT.
2. As IPv6 support is optional, only IPv4 transport connection for M-Plane is used in this test.
3. A combination of VLAN identity and MAC address is only used for C/U- Plane connectivity.
4. Network between O-DU and O-RU allows for connectivity between actors.
5. O-RU has account configured with sudo access privilege. O-DU knows credentials of sudo account available at O-RU.
6. Appropriate software file for O-RU is pre-installed in O-RU and corresponding manifest.xml is located in O-DU. No software upgrade is required during startup test sequence of O-RU for this IOT test case.

Testing tools which are required for this test scenario

1. FH Protocol Analyzer monitoring traffic between O-DU and O-RU is used for validation of M-Plane procedural flows and contents of messages prior to the establishment of the SSH connection for M-Plane and when certain procedures do not use encryption (eg. loopback messages and responses of IEEE 802.1Q).

2.2.1.1.3 Test Purpose

Purpose of this test is to validate the startup sequence of O-RU and the interface to DHCP server and NETCONF client in O-DU for the start-up scenario.

The detailed steps outlined in this test case are for informational purposes and can be useful for troubleshooting purposes in the event that the test case fails. Procedures which are not encrypted with SSH can be observed with the FH Protocol Analyzer for validation of the test progress.

Notwithstanding this being an M-Plane test, correct evaluation of the success of the M-Plane operation requires also that the fronthaul C-Plane and U-Plane also be operational, at least in the DL direction.

2.2.1.1.4 Testability requirements imposed on O-RU and O-DU

The appropriate software runs on the O-RU and O-DU for the test purpose.

2.2.1.1.5 Initial Conditions

1. There is physical connectivity between O-RU and O-DU
2. O-DU is powered up and in service or running
3. DHCP server is connected and available
4. O-RU is powered up for this start-up test scenario
5. The credential information (default username and password) is commonly pre-installed in O-DU and O-RU as one of test assumptions in 2.2.1.1.2.

2.2.1.1.6 Procedure: M-Plane start up test

2.2.1.1.6.1 Step: Transport layer initialization

1. Depending on initial condition – either power-on to O-RU or physical network connection is enabled between O-RU and O-DU.
2. FH Protocol Analyzer observation: DHCP Discovery coming from O-RU's MAC address

   Note: message is sent as part of VLAN scan procedure, hence it can be in serial sequence "VID after VID with timer in between" or in parallel sequence "burst to subset of VIDs, timer, another burst to different subset of VIDs". FH Protocol Analyzer confirms that the O-RU includes vendor class (option 60) or vendor-identifying vendor class (option 124) in the DHCP DISCOVER.
3. FH Protocol Analyzer observation: VLAN scan continues until response from DHCP server is received.
4. FH Protocol Analyzer observation: O-RU continues DHCP procedure using only the VID on which response from DHCP server has been received.
5. FH Protocol Analyzer observation: DHCP procedure is finished by DHCP Acknowledgement message sent towards O-RU. As a result of DHCP procedure, O-RU obtains its own IP details plus IP (option 43) or FDQN of corresponding NETCONF Client in O-DU.

2.2.1.1.6.2 Step: RU calls home to NETCONF client (TCP connection establishment)

1. FH Protocol Analyzer observes Call Home – a TCP session establishment initiated by O-RU towards O-DU

2.2.1.1.6.3 Step: SSH Secure connection establishment

1. SSH session establishment initiated by O-DU towards O-RU.

2.2.1.1.6.4 Step: NETCONF Capability discovery

1. NETCONF Hello message sent by O-RU towards O-DU. The message exposes capability of ietf-yang-library
2. NETCONF Hello message sent by O-DU towards O-RU
3. <rpc><get> message sent by O-DU to O-RU. The <rpc><get> has <modules-state xlsnm = "urn:ietf:params:xml:ns:yang:ietf-yang-library"> subtree filter imposed
4. <rpc><reply> message sent by O-RU to O-DU. The message contains content of leaf "modules-state" of ietf-yang-library.yang module

2.2.1.1.6.5 Step: Optional provisioning of new management accounts

Note: this step is intentionally omitted as pre-provisioned O-RU is expected for IOT (meaning: no need to perform optional step and configure supplementary management accounts).

2.2.1.1.6.6 Step: Initial process of NETCONF Subscribe for each stream

1. NETCONF “create-subscription” RPC message(s) sent by O-DU towards O-RU. Number of NETCONF subscriptions is up to O-DU.

   Note: O-DU can subscribe itself to default event stream or to specific streams of events. In case no subscription to default stream is performed, then O-DU shall subscribe itself at least to event streams “supervision-notification” and “alarm-notif”. Subscription to other streams is optional, however not prohibited.

2. NETCONF “create-subscription” RPC Reply messages sent by O-RU for each RPC message

2.2.1.1.6.7 Step: Supervision of NETCONF connection

1. Periodic sequence of NETCONF messages:
   a. supervision-notification sent by O-RU towards O-DU
   b. RPC supervision-watchdog-reset sent by O-DU towards O-RU
   c. RPC reply sent by O-RU towards O-DU

Note: in above sequence following timers shall be respected: “supervision-notification-interval”, “guard-timer-overhead” sent as parameters in RPC supervision-watchdog-reset (O-DU -> O-RU) and “next-update-at” sent as parameter in RPC reply (O-RU -> O-DU).

2.2.1.1.6.8 Step: Retrieval of O-RU information and Additional configuration

1. O-DU sends <rpc><get><filter=”subtree”> to get each yang module listed in ietf-yang-library.yang in O-RU, for example
   - ietf-hardware augmented by o-ran-hardware
   - ietf-interface augmented by o-ran-interfaces
   - o-ran-operations
   - o-ran-transceiver
   - o-ran-sync
   - o-ran-mplane-int
   - o-ran-lbm
   - o-ran-performance-management
   - o-ran-delay-management
   - o-ran-module-cap
   - o-ran-alarm-id
   - o-ran-fan
   - o-ran-supervision
   - o-ran-user mgmt
2. O-RU responds with <rpc-reply><data> for each yang module per <rpc><get>

3. O-DU sends <rpc><edit-config> to each configurable yang module for additional configuration to O-RU whenever it is necessary
4. O-RU responds with <rpc-reply><ok/>

Note: The configurable yang modules are o-ran-sync, o-ran-lbm, o-ran-operations and others (up to O-DU implementation) except o-ran-uplane-conf, o-ran-processing-element, ietf-interface augmented by o-ran-interfaces. Additional configuration of step 3 and 4 can be examined between Chapters 2.2.1.1.6.9 and 2.2.1.1.6.10.

2.2.1.1.6.9 Step: Software management

1. O-DU sends <rpc><get><filter="subtree"> to get o-ran-software-management.yang
2. O-RU responds with <rpc-reply><data> for <software-inventory>< software-slot>. At least 2 slots are contained in software-inventory

Note: software update is not applied as the pre-condition that appropriate software file for O-RU is pre-installed in O-RU and corresponding manifest.xml is located in O-DU.

2.2.1.1.6.10 Step: C/U-Plane transport connectivity check between O-DU and O-RU

1. O-DU configures by <rpc><edit-config> vlan-id for the usage of C/U-Plane in ietf-interface augmented by o-ran-interfaces to O-RU. O-RU responds with <rpc-reply><ok/>
2. O-DU sends loopback message to O-RU with MAC address and vlan-id periodically. The O-RU MAC address and vlan-id used in LBM is same as the one that set in ietf-interface augmented by o-ran-interfaces.
3. O-RU sends loopback response to O-DU per received loopback message respectively

2.2.1.1.6.11 Step: U-Plane configuration between O-DU and O-RU

1. O-DU sends <rpc><get><user-plane-configuration> to determine the presence of following instances: multiple static-low-level-[tr]x-endpoints, multiple [tr]x-arrays and the relations between them. O-RU replies <rpc-reply><data> including key information on number of endpoints, band number, number of arrays and polarization.
2. O-DU sends <rpc><edit-config> to create low-level-[tr]x-endpoints, with the same name as static-low-level-[tr]x-endpoints. The uniqueness of eaxc-id is mandatory within all endpoints related to same interface elements that have relationship to low-level-rx-endpoint elements or low-level-tx-endpoint elements. Number of instances of low-level-[tr]x-endpoints depend on contents of selected test profile eg. for number of CCs. It may be less than number of instances of static-low-level-[tr]x-endpoints. O-RU replies <rpc-reply><ok/></rpc-reply>.
3. O-DU sends <rpc><edit-config> to create [tr]x-array-carriers. Number of created instances of [tr]x-array-carriers is equivalent to number of CCs times number of arrays, where number of CCs is defined by operator. Appropriate values are configured to absolute-frequency-center, channel-bandwidth, gain, and so on. The leaf "active" is 'INACTIVE' for all just created [tr]x-array-carriers. O-RU replies <rpc-reply><ok/></rpc-reply>.
4. O-DU sends <rpc><edit-config> to create processing-elements related to interfaces offering access to desired endpoints. The key information such as MAC address is configured according to selected transport flow, eg. o-ru-mac-address, o-du-mac-address and vlan-id for C/U-Plane in case of Ethernet flow. O-RU replies <rpc-reply><ok/></rpc-reply>.
5. O-DU sends <rpc><edit-config> to create low-level-[tr]x-link(s) to make relationship between low-level-[tr]x-endpoint(s), [tr]x-array-carriers and processing elements belonging to transport. The number of instance(s) for low-level-[tr]x-links is equivalent to that of instance(s) of low-level-[tr]x-endpoints.

2.2.1.1.6.12 Step: Fault Management activation

1. O-DU sends <rpc><get><filter="subtree"> to get o-ran-fm.yang
2. O-RU responds with <rpc-reply><data> for <active-alarm-list><active-alarms>

Note: subscription to NETCONF default event stream fulfils the condition to signal notification alarm-notif when O-RU detects any alarm.

2.2.1.1.6.13 Step: Performance measurement activation (if required at start-up timing)

Note: Step for Retrieval of O-RU information may cover the configuration of o-ran-performance-management.yang if it is required at start-up installation timing.

2.2.1.1.6.14 Step: Retrieval of O-RU state, including synchronization information, from O-RU

1. O-DU sends <rpc><get><sync> to O-RU
2. S-Plane in O-RU has been locked, sends <rpc-reply><data> <sync-status><sync-state> LOCKED

2.2.1.1.6.15 Step: Configuring the O-RU operational parameters: carrier activation

S-Plane has to be operational (sync-state != FREERUN, preferable sync-state = LOCKED) prior to running this step

1. O-DU sends <rpc><edit-config> to perform activation by setting the value of the parameter “active” at [tr]x-array-carriers to “ACTIVE”. O-RU sends <rpc-reply><ok/>
2. O-RU sends notification [tr]x-array-carriers-state-change that indicates all [tr]x-array-carriers’ names with “state” = “READY”

Note: C/U-Plane service is available at this step.

2.2.1.1.7 Test Requirement (expected result)

Observe that both the O-DU and O-RU get in service successfully by monitoring correct transmission of synchronization signals and broadcast channel (ie, PSS/SSS and PBCH for LTE and SSB for NR).

Record downlink carrier frequency (EARFCN for LTE as defined in 3GPP TS 36.104 [12] and GSCN/NR-ARFCN for NR as defined in 3GPP TS 38.104 [13]), cell (PCI for LTE and for NR as defined in 3GPP TS 36.211 [14] and TS 38.211 [15], respectively) and system information (MIB for LTE and NR as specified in 3GPP TS 36.331 [16] and TS 38.331 [17], respectively). In case that beam sweeping is applied to SSB, system information should be recorded for each of the SSB indices detected.

The parameter values for downlink carrier frequency, cell, system information and SSB indices are part of the radio test setup configuration. This test is considered successful if the recorded measurements values match up with the values which are used for the radio test setup configuration.

2.2.1.1.8 Test Report (Failure)

If the test case fails, vendor specific methods will be relied on to assist with troubleshooting the root cause(s) which led to the failure. The steps outlined in this test case can be used to guide the troubleshooting process.

2.2.2 S-Plane IOT Functional Test

This Section provides a high-level list of the items that are expected be covered in order to validate the functional interoperability with the relevant standard:

- The below tests apply to both 4G(LTE) and 5G(NR) and are applicable to all O-RAN IOT profiles listed in Annex A.
- The CUS-Plane Specification [2] Section validated is §9.3.2.
- All tests shall be done in lab at constant temperature.
- SyncE Master test case is optional and only valid when the SyncE slave (eg. O-RU) takes advantage of it. Therefore, the related SyncE Master test cases are optional.

- For validation of synchronization information, the test cases in this Section use the FH M-Plane interface for the O-RU, and other interfaces such as NMS for O-DU.
- Retrieving sync-state of O-DU using the NMS is FFS
- A test equipment might be needed to generate a reference S-Plane signal
- Several test cases involve configuring the O-DU or O-RU.
- Test cases below involve using the M-Plane to retrieve the sync-state of the O-RU:
    - M-Plane connection must be established, meaning whole protocol stack ETH/IP/TCP/SSH is up and running, Capabilities are exchanged between NETCONF Client and Server, Subscriptions to notifications are created.
    - O-RU reports over M-Plane the degraded received clock-class and clock-accuracy as well as locked state; details are for further study.
- Several test cases involve the configuration and collection of status of T-BC. However, as this is not defined in the Management Plane Specification [3], the parts of the tests below that require such functionality are FFS in this release of the specification.

  For the purpose of functional test, excepting C1 that excludes T-BC, the test configuration shall use from 1 up to the maximum number of T-BCs specified in section 2.2.3 (S-Plane IOT Performance test) according to the preference of the tester.
- Further work needs to be done to align and refine the definition of the states in the CUS [2] and M-Plane [3] specifications for the next releases.

2.2.2.1 Functional test of O-DU + O-RU using ITU-T G.8275.1 profile (LLS-C1)

2.2.2.1.1 Test Description and Applicability

This test validates that O-RU is synchronizing from an O-DU that incorporates a PTP grand master and SyncE Master with ITU-T G.8275.1 [5] profile and is traceable to a PRTC.

This test involves one O-DU and one O-RU.

2.2.2.1.2 Minimum Requirements (Prerequisites)

1. O-RU is connected to O-DU via direct fiber O-RAN links.
2. The O-DU is connected to a PRTC traceable time source, directly (GNSS Receiver connected to the O-DU) or via PTP.

2.2.2.1.3 Purpose and Scope

The O-RU is synchronizing from the O-DU with the ITU-T G.8275.1 [5] profile. This test case validates the correct synchronization status of the O-RU.

2.2.2.1.4 Testability Requirements imposed on O-RU and O-DU

Requirements for M-Plane: must be properly operating (as defined in 2.2.1.1).

Synchronization requirement: O-DU must be connected to a local PRTC/source traceable to PRTC.

2.2.2.1.5 Test Methodology

These tests use the O-RAN M-Plane and O-DU NMS features.

The O-DU must act as a PTP master compliant with the ITU-T G.8275.1 [5] profile.

Three conditions must be covered:

- startup
- nominal
- degraded

2.2.2.1.5.1 Startup conditions

1. Not yet configured.

   External frequency and time source are available to the O-DU and deliver nominal status

   O-DU is not yet configured to select the time source and align its frequency and time to it

   O-DU not yet configured to act as PTP master on the FH ports

2. Configured.

   O-DU is configured to align to the selected frequency and time source

3. Until disciplining

   Until O-DU disciplining of the frequency and time to the selected source has completed, Startup conditions persists

   The O-RUs are configured to synchronize from PTP in ITU-T G.8275.1 [5] profile and report their status

2.2.2.1.5.2 Nominal conditions

1. O-DU is configured to start acting as a PTP master compliant with the ITU-T G.8275.1 [5] profile on selected FH ports.
2. O-DU acts as a PTP grand master or as a boundary clock with ports towards the FH interface in Master state, compliant with the ITU-T G.8275.1 [5] profile advertising “nominal” status.
3. O-DU reports status, acting as PTP master clock towards the FH interface.

2.2.2.1.5.3 Degraded conditions

1. O-DU is configured to enter HOLDOVER based on local oscillator frequency.
2. O-DU acts as configured clock, with PTP ports in master state, compliant to ITU-T G.8275.1 profile advertising HOLDOVER status with degraded clockClass and clockAccuracy as specified by ITU-T G.8275.1 [5].
3. O-DU is configured to exit HOLDOVER and resumes normal frequency and phase disciplining using the source.
4. O-DU acts as configured clock, with PTP ports towards the FH interface in master state compliant to ITU-T G.8275.1 [5] in “nominal” status.

2.2.2.1.6 Test Requirements and expected results

2.2.2.1.6.1 Startup conditions

The acceptance criterion is that the following status is observed for steps 1 to 3 (2.2.2.1.5.1 above):

- the FREERUN sync-state of the O-RU using the M-Plane
- the UNLOCKED PTP lock-state of the O-RU using the M-Plane
- the UNLOCKED SyncE lock-state of the O-RU using the M-Plane (optional)
- the FREERUN sync-state of the O-DU using the NMS

2.2.2.1.6.2 Nominal conditions

The acceptance criterion is that the following status is observed for steps 1 to 3 (2.2.2.1.5.2 above):

- the LOCKED sync-state of the O-DU using the NMS
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional)
- the LOCKED sync-state of the O-RU using the M-Plane
- the LOCKED PTP lock-state of the O-RU using the M-Plane
- the LOCKED SyncE lock-state of the O-RU using the M-Plane (optional)

2.2.2.1.6.3 Degraded conditions

The acceptance criterion is that the following status is observed for all steps 1 to 2 (2.2.2.1.5.3 above) (for steps 3 and 4, same criterion as "Nominal conditions" apply):

- the HOLDOVER sync-state of the O-DU using the NMS
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional)

The following points are for further study in this release of the specification and require a clarification to the M-Plane Specification [3]

- the sync-state of the O-RU using the M-Plane is FFS if the received clockClass (or optional SSM) value matches the configured list of accepted values
- the PTP lock-state of the O-RU using the M-Plane is FFS if the received clockClass matches the configured list of accepted values
- the SyncE lock-state (optional) of the O-RU using the M-Plane is FFS if the received SSM matches the configured list of accepted values

2.2.2.2 Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.1 profile (LLS-C2)

2.2.2.2.1 Test Description and Applicability

This test validates that O-RU is synchronizing from an O-DU via a chain of T-BC using ITU-T G.8275.1 [5] profile.

This test involves one O-DU, one O-RU and multiple T-BCs.

The configuration, management and retrieval of status of the T-BC will be considered for a future release.

2.2.2.2.2 Minimum Requirements (Prerequisites)

1. O-RU is connected to O-DU via a chain of T-BCs.
2. The T-BCs are class B. The slave port of the first T-BC is connected to O-DU. The master clock of the last T-BC is connected to the O-RU.
3. The O-DU is connected to a PRTC traceable time source, directly (GNSS Receiver connected to the O-DU) or via PTP.

2.2.2.2.3 Purpose and Scope

The O-RU is synchronizing from the O-DU with the ITU-T G.8275.1 [5] profile over a bridged network that can deploy several T-BCs. This test case validates the correct synchronization status of the O-RU.

2.2.2.2.4 Testability Requirements imposed on O-RU and O-DU

Requirements for M-Plane: must be properly operating (as defined in 2.2.1.1).

Synchronization requirement: O-DU must be connected to a local PRTC/source traceable to PRTC.

2.2.2.2.5 Test Methodology

These tests use the O-RAN M-Plane and O-DU NMS features.

Three conditions must be covered:

- startup
- nominal
- degraded

2.2.2.2.5.1 Startup conditions

1. Not yet configured.

   External frequency and time source are available to the O-DU and deliver nominal status.

   O-DU is not yet configured to select the time source and align its frequency and time to it.

   O-DU not yet configured to act as PTP master on the FH ports.

2. Configured.

   O-DU is configured to align to the selected frequency and time source.

3. Until disciplining

   Until O-DU disciplining of the frequency and time to the selected source has completed, Startup conditions persists.

   The O-RUs are configured to synchronize from PTP in ITU-T G.8275.1 [5] profile and report their status.

2.2.2.2.5.2 Nominal conditions

1. O-DU is configured to start acting as a PTP master compliant with the ITU-T G.8275.1 [5] profile on selected FH ports.
2. O-DU acts as a PTP grand master or as a boundary clock with ports towards the FH interface in Master state, compliant with the ITU-T G.8275.1 [5] profile advertising “nominal” status.
3. O-DU reports status, acting as PTP master clock towards the FH interface.

2.2.2.2.5.3 Degraded conditions

1. O-DU is configured to enter HOLDOVER based on local oscillator frequency.
2. O-DU acts as configured clock, with PTP ports in master state, compliant to ITU-T G.8275.1 profile advertising HOLDOVER status with degraded clockClass and clockAccuracy as specified by ITU-T G.8275.1 [5].
3. O-DU is configured to exit HOLDOVER and resumes normal frequency and phase disciplining using the source.
4. O-DU acts as configured clock, with PTP ports towards the FH interface in master state compliant to ITU-T G.8275.1 [5] in “nominal” status.

2.2.2.2.6 Test Requirements and expected results

2.2.2.2.6.1 Startup conditions

The acceptance criterion is that the following status is observed for steps 1 to 3 (2.2.2.2.5.1 above):

- the FREERUN sync-state of the O-DU using the NMS
- the FREERUN sync-state of the O-RU using the M-Plane
- the UNLOCKED PTP lock-state of the O-RU using the M-Plane
- the UNLOCKED SyncE lock-state of the O-RU using the M-Plane (optional)

2.2.2.2.6.2 Nominal conditions

The acceptance criterion is that the following status is observed for steps 1 to 3 (2.2.2.2.5.2 above):

- the LOCKED sync state of the O-DU using the NMS
- the LOCKED PTP lock-state of the O-DU using the NMS
- the “Master Enabled” SyncE status of the O-DU using the NMS (optional)
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional)
- the LOCKED sync-state of the O-RU using the M-Plane
- the LOCKED PTP lock-state of the O-RU using the M-Plane
- the LOCKED SyncE lock-state of the O-RU using the M-Plane (optional)
- the synchronization status of the deployed T-BC using the respective NMS

2.2.2.2.6.3 Degraded conditions

The acceptance criterion is that the following status is observed for all steps 1 to 2 (2.2.2.2.5.3 above) (for steps 3 and 4, same acceptance criterion as “Nominal conditions” apply)

- the HOLDOVER sync-state of the O-DU using the NMS
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional)

The following points are for further study in this release of the specification and require a clarification to the M-Plane Specification [3]

- the sync-state of the O-RU using the M-Plane is FFS if the received clockClass (or optional SSM) value matches the configured list of accepted values.
- the PTP lock-state of the O-RU using the M-Plane is FFS if the received SSM matches the configured list of accepted values.

2.2.2.3 Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.1 profile (LLS-C3)

2.2.2.3.1 Test Description and Applicability

This test validates that both the O-DU and O-RU are synchronizing from a common PRTC via a chain of T-BCs using ITU-T G.8275.1 [5] profile.

This test involves one O-DU, one O-RU, a PRTC/T-GM and multiple T-BCs.

The configuration, management and retrieval of status of the T-BC will be considered for a future release of the specification.

2.2.2.3.2 Minimum Requirements (Prerequisites)

1. Both O-RU and O-DU are connected to a common PRTC via a chain of T-BCs that are either directly connected to a PRTC/T-GM in the FH network or are connected to another T-BC that is traceable to a PRTC.
2. The T-BCs are class B. The slave port of the first T-BC is connected to a PRTC/T-GM. The O-DU and O-RU are connected to master ports of either the same T-BC or different ones.

2.2.2.3.3 Purpose and Scope

Both O-DU and O-RU are synchronized via a chain of T-BC from a common PRTC/T-GM located in the FH networks using ITU-T G.8275.1 [5] profile. This test case validates the correct synchronization status of the O-RU and O-DU.

2.2.2.3.4 Testability Requirements imposed on O-RU, O-DU and bridged network

Requirements for M-Plane: shall be properly operating (as defined in 2.2.1.1)

Synchronization requirement: The T-BC must be connected to a local PRTC or to another T-BC that is traceable to a PRTC.

2.2.2.3.5 Test Methodology

These tests use the O-RAN M-Plane and O-DU NMS features.

Three conditions must be covered:

- startup
- nominal
- degraded

2.2.2.3.5.1 Startup conditions

1. Not yet configured.

   External frequency and time source are available to the PRTC/T-GM and deliver nominal status.

   PRTC/T-GM is not yet configured to select the time source and align its frequency and time to it.

   PRTC/T-GM not yet configured to act as PTP master on the FH ports.

2. Configured.

   PRTC/T-GM is configured (eg. via proprietary) interface to align to the selected frequency and time source.

3. Until disciplining

   Until PRTC/T-GM disciplining of the frequency and time to the selected source has completed, Startup conditions persists.

   The O-RUs are configured to synchronize from PTP in ITU-T G.8275.1 [5] profile and report their status.

2.2.2.3.5.2 Nominal conditions

1. PRTC/T-GM is configured to start acting as a PTP master compliant with the ITU-T G.8275.1 [5] profile on selected FH ports.

2. PRTC/T-GM acts as a PTP grand master towards the FH interface in Master state, compliant with the ITU-T G.8275.1 [5] profile advertising “nominal” status.
3. PRTC/T-GM reports status, acting as PTP master clock towards the FH interface.

2.2.2.3.5.3 Degraded conditions

1. PRTC/T-GM is configured to enter HOLDOVER based on local oscillator frequency.
2. PRTC/T-GM acts as configured clock, with PTP ports in master state, compliant to ITU-T G.8275.1 profile advertising HOLDOVER status with degraded clockClass and clockAccuracy as specified by ITU-T G.8275.1 [5].
3. PRTC/T-GM is configured to exit HOLDOVER and resumes normal frequency and phase disciplining using the source.
4. PRTC/T-GM acts as configured clock, with PTP ports towards the FH interface in master state compliant to ITU-T G.8275.1 [5] in “nominal” status.

2.2.2.3.6 Test Requirements and expected results

2.2.2.3.6.1 Startup conditions

The validation is done by checking the correct synchronization state is observed for steps 1 to 3 (2.2.2.3.5.1 above):

- the FREERUN sync-state of the O-DU using the NMS
- the UNLOCKED PTP lock-state of the O-DU using the NMS
- the UNLOCKED SyncE lock-state of the O-DU using the NMS (optional)
- the FREERUN sync-state of the O-RU using the M-Plane
- the UNLOCKED PTP lock-state of the O-RU using the M-Plane
- the UNLOCKED SyncE lock-state of the O-RU using the M-Plane (optional)
- the synchronization status of the deployed T-BC using the respective NMS

2.2.2.3.6.2 Nominal conditions

The validation is done by checking the correct synchronization state is observed for steps 1 to 3 (2.2.2.3.5.2 above):

- the LOCKED sync-state of the O-DU using the NMS
- the LOCKED PTP lock-state of the O-DU using the NMS
- the “Master Enabled” SyncE status of the O-DU using the NMS (optional)
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional).
- the LOCKED sync-state of the O-RU using the M-Plane
- the LOCKED PTP lock-state of the O-RU using the M-Plane
- the LOCKED SyncE lock-state of the O-RU using the M-Plane (optional)
- the synchronization status of the deployed T-BC using the respective NMS

2.2.2.3.6.3 Degraded conditions

The validation is done by checking the correct synchronization state is observed for all steps 1 to 2 (2.2.2.3.5.3 above) (for steps 3 and 4, same acceptance criterion as "Nominal conditions" apply):

- the HOLDOVER sync-state of the O-DU using the NMS
- the received PTP clockClass level of the O-DU using the NMS
- the received SyncE SSM level of the O-DU using the NMS (optional)
- the received PTP clockClass level of the O-RU using the M-Plane
- the received SyncE SSM level of the O-RU using the M-Plane (optional)

The following points are for further study in this release of the specification and require a clarification to the M-Plane Specification [3]

- the synchronization status of the deployed T-BC using the respective NMS - the sync-state of the O-RU using the M-Plane is FFS if the received clockClass (or optional SSM) value matches the configured list of accepted values.
- the PTP lock-state of the O-RU using the M-Plane is FFS if the received clockClass matches the configured list of accepted values.
    - the SyncE lock-state (optional) of the O-RU using the M-Plane is FFS if the received SSM matches the configured list of accepted values.

2.2.2.4 Functional test of O-DU + O-RU using ITU-T G.8275.2 profile (LLS-C1)

This test is For Further Study.

2.2.2.5 Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.2 profile (LLS-C2)

This test is For Further Study.

2.2.2.6 Functional test of O-DU + bridged network + O-RU using ITU-T G.8275.2 profile (LLS-C3)

This test is For Further Study.

2.2.2.7 Functional test of O-DU + bridged network + O-RU (LLS-C4)

This test case is For Further Study.

2.2.3 S-Plane IOT Performance Test

The following general notes apply to all IOT performance tests:

- The below tests apply to both 4G(LTE) and 5G(NR) and are applicable to all O-RAN IOT profiles listed in Annex A.
- The CUS-Plane Specification [2] Section validated is §9.3.2.
- Not all cases below are mandatory, a vendor or network operator may test either all or any of them
- All tests shall be done in lab at both constant and variable conditions of temperature to thermally stress the O-DU and O-RU:
  - the variable thermal profile is defined by ITU-T G.8273 [9]
  - the variable C/U-Plane profile (for example similar to the test case 13 shown in figure VI.11 of ITU-T G.8261 [10]) must be defined for this test.

- Several test cases involve the configuration and collection of status of T-BC. However, as this is not defined in the Management Plane Specification [3], the parts of the tests below that require such functionality are FFS in this release of the specification.

  For the purpose of performance tests, use the maximum number of T-BC devices as shown in CUS-Plane specification [2] in Annex H, Tables H-5 and H-6.

  Note: Annex H includes example deployment cases that capture the influence of factors including, target end-to-end timing error requirement, clock type used in the network, and characteristics of the O-RU clock. Additional cases are for further study including, addressing O-RUs with different levels of clock performance, and different noise accumulation models etc.

The acceptance criterion for the tests is to satisfy the 3GPP OTA TAE limits specified in 3GPP TS 36.141 [18] for 4G(LTE) and 38.141-2 [19] for 5G(NR), and summarized in eCPRI [11] and ITU-T G.8271 [7]:

- ±50 ppb maximum frequency error at the air interface
- ITU-T Level 4, eCPRI Cat C (mandatory): ± 1500ns maximum absolute time error at the O-RU air interface.
- ITU-T Level 6A, eCPRI Cat B (optional): ± 260ns maximum relative time error between the two O-RUs air interfaces.
- ITU-T Level 6B, eCPRI Cat A (optional) ± 130ns maximum relative time error between the two O-RUs air interfaces.
  Note: This level of accuracy assumes co-location of the O-RUs and O-DU.

2.2.3.1 Performance test of O-DU + Two O-RUs using ITU-T G.8275.1 profile (LLS-C1)

2.2.3.1.1 Test Description and applicability

This test validates that:
when the O-DU gets its synchronization from a PRTC using a local GNSS receiver,
and is connected to two O-RUs via direct FH links,
and distributes frequency and time to these O-RUs using the ITU-T G.8275.1 (SyncE + PTP) profile,

then the two O-RUs meet the 3GPP limits at their air interface.

Similar testing when the O-DU gets its synchronization from PTP over a Full Timing Support (respectively Partial Timing Support) network meeting the ITU-T G.8271.1 [7] (respectively ITU-T G.8271.2 [8]) limits is For Further Study.

2.2.3.1.2 Prerequisites

1. IOT Functional test 2.2.2.1 is successfully passed and all O-DU, bridged network elements and O-RUs report LOCKED status.
2. O-RUs are connected to the O-DU via direct fiber O-RAN links.
3. O-RUs are suitable for Case 1.1 or 1.2 as defined in eCPRI [11].

2.2.3.1.3 Purpose and scope

The O-DU synchronize the O-RUs with the ITU-T G.8275.1 profile [5]. This test validates that the frequency and time error on the O-RU air interfaces are within the limits of the 3GPP, in both constant and variable temperature and traffic load conditions.

Only LOCKED state is tested; HOLDOVER state test is For Further Study.

2.2.3.1.4 Testability Requirements imposed on O-RU and O-DU

Both O-DU and O-RU are running nominal software.

Requirements for M-Plane: must be “up and running.”

Synchronization requirement: O-DU and test equipment must be connected to a local PRTC or source traceable to PRTC.

Test 2.2.2.1.6.2 is successfully passed and both O-DU and O-RUs report LOCKED status.

2.2.3.1.5 Test Methodology

After O-DU and O-RUs are frequency and phase locked to their PRTC synchronization source using the LLS-C1 configuration, the frequency and phase errors are measured on the O-RUs air interface using a test equipment referenced to the same PRTC.

2.2.3.1.6 Test Requirement (expected result)

For both constant and variable conditions tests, the acceptance criterion is to measure with the test equipment:

- ±50 ppb maximum frequency error at the air interface
- ITU-T Level 4, eCPRI Cat C (mandatory): ± 1500ns maximum absolute time error at the O-RU air interface.
- ITU-T Level 6A, eCPRI Cat B (optional): ± 260ns maximum relative time error between the two O-RUs air interfaces.
  Note: This level of accuracy assumes an O-RU implementation suitable for Case 1.1 and case 1.2 as defined in eCPRI [11].
- ITU-T Level 6B, eCPRI Cat A (optional) ± 130ns maximum relative time error between the two O-RUs air interfaces~~.~~
  Note: This level of accuracy assumes an O-RU implementation suitable for Case 1.2 as defined in eCPRI [11]. It also assumes co-location of the O-RUs and O-DU.

2.2.3.2 Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.1 profile (LLS-C2)

2.2.3.2.1 Test Description and applicability

This test validates that:
when the O-DU gets its synchronization from a PRTC using a local GNSS receiver,
and is connected to two O-RUs via eCPRI FH links via bridged network elements acting as class B T-BCs,
and distributes frequency and time to these O-RUs using the ITU-T G.8275.1 (SyncE + PTP) profile [5],

then the two O-RUs are meeting the 3GPP limits at their air interface.

Similar testing when the O-DU gets its synchronization from PTP over a Full Timing Support (respectively Partial Timing Support) network meeting the ITU-T G.8271.1 [7] (respectively ITU-T G.8271.2 [8]) limits is For Further Study.

2.2.3.2.2 Minimum Requirements (Prerequisites)

1. IOT Functional Test 2.2.2.2 is successfully passed and all O-DU, bridged network elements and O-RUs report LOCKED status.
2. O-RUs are connected to O-DU via bridged network elements acting as ITU-T G.8275.1 class B T-BCs using O-RAN links [5].
3. O-RUs are suitable for Case 1.1 or 1.2 as defined in eCPRI [11].

2.2.3.2.3 Purpose and scope

The O-DU synchronizes the O-RUs with the ITU-T G.8275.1 [5] profile via the bridged network elements.

This test validates that the frequency and time error on the O-RU air interfaces are within the limits of the 3GPP, in both constant and variable temperature and traffic load conditions.

Only LOCKED state is tested; HOLDOVER state test is For Further Study.

2.2.3.2.4 Testability Requirements imposed on O-RU and O-DU

Both O-DU and O-RU are running nominal software.

Requirements for M-Plane: must be "up and running"

Synchronization requirement: O-DU and test equipment must be connected to a local PRTC or source traceable to PRTC.

Test 2.2.2.2.6.2 is successfully passed and both O-DU and O-RUs report LOCKED status.

2.2.3.2.5 Test Methodology

After O-DU and O-RUs are frequency and phase locked to their PRTC synchronization source using the LLS-C2 configuration, the frequency and phase errors are measured on the O-RUs air interface using a test equipment referenced to the same PRTC.

2.2.3.2.6 Test Requirement (expected result)

For both constant and variable conditions tests, the acceptance criterion is to measure with the test equipment:

- ±50 ppb maximum frequency error
- ITU-T Level 4, eCPRI Cat C (mandatory): ± 1500ns maximum absolute time error at the O-RU air interface.
- ITU-T Level 6A, eCPRI Cat B (optional): ± 260ns maximum relative time error between the two O-RUs air interfaces.
  Note: This level of accuracy assumes up to 1 (respectively 2) class B T-BC on the path between the branching one and each O-RU implementation suitable for case 1.1 (respectively case 1.2) as defined in eCPRI [11].
- ITU-T Level 6B, eCPRI Cat A (optional) ± 130ns maximum relative time error between the two O-RUs air interfaces~~.~~
  Note: This level of accuracy assumes direct fiber link between the branching class B T-BC and each O-RU implementation suitable case 1.2 as defined in eCPRI [11] (not supported by case 1.1). It also assumes co-location of the O-RUs and O-DU.

2.2.3.3 Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.1 profile (LLS-C3)

2.2.3.3.1 Test Description and applicability

This test validates that:
when both O-DU and O-RUs get their synchronization from a PRTC using SyncE + PTP over a Full Timing Support network (ITU-T G.8275.1 profile [5], ITU-T G.8271.1 network limits [7]),
the two O-RUs are meeting the 3GPP limits at their air interface.

2.2.3.3.2 Minimum Requirements (Prerequisites)

1. IOT Functional Test 2.2.2.3 is successfully passed and all O-DU, bridged network elements and O-RUs report LOCKED status.
2. O-RUs and O-DU are connected to bridged network elements acting as ITU-T G.8275.1 class B T-BCs using O-RAN links [5]. This FH network has a local PRTC distributing SyncE and PTP to both O-DU and O-RUs.
3. O-RUs are suitable for Case 1.1 or 1.2 as defined in eCPRI [11].

2.2.3.3.3 Purpose and scope

The FH network synchronizes all O-DU and O-RUs with the ITU-T G.8275.1 [5] profile via the bridged network elements.

This test validates that the frequency and time error on the O-RU air interfaces and O-DU are within the limits of the 3GPP, in both constant and variable temperature and traffic load conditions.

Only LOCKED state is tested; HOLDOVER state test is For Further Study.

2.2.3.3.4 Testability Requirements imposed on O-RU and O-DU

Both O-DU and O-RU are running nominal software.

Requirements for M-Plane: must be "up and running"

Synchronization requirement: FH network and test equipment must be connected to a local PRTC or source traceable to PRTC.

Test 2.2.2.3.6.2 is successfully passed and both O-DU and O-RUs report LOCKED status.

2.2.3.3.5 Test Methodology

After O-DU and O-RUs are frequency and phase locked to their PRTC synchronization source using the LLS-C3 configuration, the frequency and phase errors are measured at the O-RUs air interface using a test equipment referenced to the same PRTC.

2.2.3.3.6 Test Requirement (expected result)

For both constant and variable conditions tests, the acceptance criterion is to measure with the test equipment:

- ±50 ppb maximum frequency error (mandatory): at the O-RU air interface
- ITU-T Level 4, eCPRI Cat C (mandatory): ± 1500ns maximum absolute time error at the O-RU air interface.
- ITU-T Level 6A, eCPRI Cat B (optional): ± 260ns maximum relative time error between the two O-RUs air interfaces.
  Note: This level of accuracy assumes up to 1 (respectively 2) class B T-BC on the path between the branching one and each O-RU implementation suitable for case 1.1 (respectively case 1.2) as defined in eCPRI [11].
- ITU-T Level 6B, eCPRI Cat A (optional) ± 130ns maximum relative time error between the two O-RUs air interfaces~~.~~
  Note: This level of accuracy assumes direct fiber link between the branching class B T-BC and each O-RU implementation suitable case 1.2 as defined in eCPRI [11] (not supported by case 1.1). It also assumes co-location of the O-RUs and O-DU.

2.2.3.4 Performance test of O-DU + Two O-RUs using ITU-T G.8275.2 profile (LLS-C1)

This test is For Further Study.

2.2.3.5 Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.2 profile ((LLS-C2)

This test is For Further Study.

2.2.3.6 Performance test of O-DU + bridged network + Two O-RUs using ITU-T G.8275.2 profile (LLS-C3)

This test is For Further Study.

2.2.3.7 Performance test of O-DU + bridged network + Two O-RUs (LLS-C4)

This test is For Further Study.

2.2.4 C/U-Plane IOT Test

2.2.4.1 Radio Layer 3 C-Plane establishment and Initial Radio U-Plane data transfer

2.2.4.1.1 Test Description and Applicability

This is a Radio system level test which is used to validate the radio system functionalities, performance and multi-vendor interoperability of the O-DU and O-RU from different vendors connected using the O-RAN WG4 specified FH interface [2], [3].

This test validates if a UE can perform Radio Layer 3 C-Plane establishment and initial Radio U-plane data transfer procedures with the network which includes the O-DU and O-RU as an integrated system under test in this test setup.

Although there is no FH focused testing for C/U-plane in this test, it is still possible to observe successful interoperability via positive test outcomes for this test. ie, if radio system level test passes, it can be assumed that O-RAN WG4 specified FH interface C/U-plane is successfully working.

This scenario is MANDATORY.

The DUTs are a single O-DU (DUT1(O-DU)) and a single O-RU (DUT1(O-RU)).

This test shall be executed using whichever IOT profile(s) are appropriate for the DUTs. See Annex A for details on the IOT profiles.

2.2.4.1.2 Minimum Requirements

Single O-DU (DUT1(O-DU)) and a single O-RU (DUT1(O-RU))

- Must be connected through the O-RAN FH
- Must be synchronized with the common S-Plane configuration

Testing tools which are required for this test scenario

- Single Test UE or UE emulator: used to perform Radio Layer 3 C-Plane establishment and Radio U-Plane data transfers with the network
- O-CU or O-CU emulator either as a separate node or as a combined node with the O-DU(s) (DUT): used to provide Layer 2 and Layer 3 radio processing on the network side. In case of separate node, terminates the 3GPP 5G F1 interface with the O-DU(s) (DUT)
- 4G Core network or 4G Core network emulator: used to terminate UEs (emulator) NAS protocol in NSA mode
- 4G MeNB or 4G MeNB emulator: used to terminate the 3GPP EN-DC X2 interface with 5G CU in NSA mode
- 5G Core Network or 5G Core Network emulator: used to terminate UEs (emulator) NAS protocol in SA mode
- Application test server: used to generate and terminate application layer traffic (eg. UDP, TWAMP, etc) and provide application layer processing on the network side.

Testing tools which can be useful for this test scenario particularly for validating that the DUTs are configured and operating correctly during the test, troubleshooting and detailed validation purposes

- FH Protocol Analyzer: used for protocol analysis of O-RAN FH protocols in this specific test scenario, C/U-Plane procedural flows and contents

- RF Spectrum and Beam Signal Analyzer: used for RF and Beam power and quality analysis ensuring that the O-RU (DUT1(O-RU)) is transmitting correctly on the configured broadcast and synchronization signals on the downlink

2.2.4.1.3 Test Purpose

Purpose of this test is to validate key radio operation after M-Plane startup, ie, Radio Layer 3 C-Plane establishment and initial Radio U-Plane data transfer on system level with integration of O-DU and O-RU from different vendors.

Note that this test requires both Downlink and Uplink Radio Layer 3 C-Plane message. This means that this test also validates both transfer of Downlink and Uplink FH U-Plane message and related Downlink FH C-Plane messages.

2.2.4.1.4 Testability requirements imposed on O-RU and O-DU

Nominal software runs on the O-RU and O-DU.

2.2.4.1.5 Test Methodology

2.2.4.1.5.1 Initial Conditions

1. O-RU and O-DU are both in service, ie, M-Plane start-up procedure is completed and broadcast channels are being transmitted
2. Test UE or UE emulator has not yet been registered with the network

2.2.4.1.5.2 Procedure: Nominal test

Performs Radio Layer 3 C-Plane establishment procedure using the Test UE or UE emulator. Note that Radio Layer 3 C-Plane establishment procedure depends on the 5G NR operation mode. In the case when the DUTs are operating in NSA mode, Radio Layer 3 C-Plane establishment procedure includes Attach procedure and/or service request procedure specified in 3GPP TS 23.401 [20] and EN-DC setup procedure specified in 3GPP TS 37.340 [22]. In the case when the DUTs are operating in SA mode, Radio Layer 3 C-Plane establishment procedure includes Registration procedure and service request procedure specified in 3GPP TS 23.502 [21].

Performs data transfer from the application test server to the Test UE or UE emulator. The application test server generates and transmits 10 IP packets with each packet 32 bytes in size.

Note that data transfer depends on the operation mode. In the case when the DUTs are operating in NSA mode, data transfers can be performed over Default EPS bearer using SN terminated split bearer specified in 3GPP TS 37.340 [22]. In case when the DUTs are operating in SA mode, data transfers can be performed over PDU Session and QoS flow specified in 3GPP TS 23.502 [21].

This test case does not specify the test data pattern generated by the application test server, but it is recommended that the test data pattern should include some level of randomness (ie, avoiding all zeros).

2.2.4.1.6 Test Requirement (expected result)

Observe the Test UE or emulated UE can perform Radio Layer 3 C-Plane establishment successfully and can perform data transfers over the network particularly through the O-DU and O-RU.

Record Test UE or UE emulator logs that the Radio Layer 3 (eg. RRC/NAS) message flows are per 3GPP TS 23.401 [20] Sections 5.3.4, 5.4 and 3GPP TS 37.340 [22] in NSA mode and 3GPP TS 23.502 [21] Sections 4.2.3, 4.3 in SA mode.

Record Test UE or UE emulator Radio U-Plane logs that the data packets transferred by application test server (ie, 10 IP packets of 32 bytes) are received correctly.

2.2.4.2 Radio U-Plane downlink data transfer (Downlink throughput performance)

2.2.4.2.1 Test Description and Applicability

This scenario is MANDATORY.

The DUTs are a single O-DU (DUT1(O-DU)) and a single O-RU (DUT1(O-RU)).

This scenario allows to test if a UE can perform Radio U-plane data transfers with the network through O-DU and O-RU from different vendors.

This test shall be executed using whichever IOT profile(s) are appropriate for the DUTs. See Annex A for details on the IOT profiles.

2.2.4.2.2 Minimum Requirements

Single O-DU (DUT1(O-DU)) and a single O-RU (DUT1(O-RU))

1. Must be connected through the O-RAN FH
2. Must be synchronized with the common S-Plane configuration

Testing tools which are required for this test scenario

- Single Test UE or UE emulator: used to perform Radio U-Plane data transfers with the network
- O-CU or O-CU emulator either as a separate node or as a combined node with the O-DU(s) (DUT): used to provide Layer 2 and Layer 3 radio processing on the network side. In case of separate node, terminates the 3GPP 5G F1 interface with the O-DU(s) (DUT).
- 4G Core network or 4G Core network emulator: used to terminate UEs (emulator) NAS protocol in NSA mode
- 4G MeNB or 4G MeNB emulator: used to terminate the 3GPP EN-DC X2 interface with 5G CU in NSA mode
- 5G Core Network or 5G Core Network emulator: used to terminate UEs (emulator) NAS protocol in SA mode
- Application test server: used to generate and terminate application layer traffic (eg UDP, TWAMP, etc) and provide application layer processing on the network side.

Testing tools which can be useful for this test scenario particularly for validating that the DUTs are configured and operating correctly during the test, troubleshooting and detailed validation purposes

- FH Protocol Analyzer: used for protocol analysis of O-RAN FH protocols in this specific test scenario, FH C/U-Plane procedural flows and contents
- RF Spectrum and Beam Signal Analyzer: used for RF and Beam power and quality analysis ensuring that the O-RU (DUT1(O-RU)) is transmitting correctly on the configured broadcast and synchronization signals on the downlink

2.2.4.2.3 Test Purpose

Purpose of this test is to validate key radio operation after Radio Layer 3 C-Plane establishment and initial Radio U-Plane data transfer, the Radio U-Plane data transfer including throughput performance on system level with integration of O-DU and O-RU from different venders.

Note that this test requires Maximum Layer 1 Radio data rate (with some margin). This means that this test also validates transfer of Downlink FH C/U-Plane message with higher MIMO layers and higher order modulation schemes.

2.2.4.2.4 Testability requirements imposed on O-RU and O-DU

Nominal software runs on the O-RU and O-DU.

2.2.4.2.5 Test Methodology

2.2.4.2.5.1 Initial Conditions

1. O-RU and O-DU are both in service, ie, M-Plane start-up procedure has been completed and broadcast channels are being transmitted.
2. Test UE or UE emulator has registered to the network, ie, Radio Layer 3 C-Plane establishment procedure is completed. Note that Radio Layer 3 C-Plane establishment procedure depends on operation mode. In case when the of DUTs are operating in NSA mode, Radio Layer 3 C-Plane establishment procedure includes means Attach procedure and/or service request procedure specified in 3GPP TS 23.401 [20] and EN-DC setup procedure specified in 3GPP TS 37.340 [22]. In case when the of DUTs are operating in SA mode, Radio Layer 3 C-Plane establishment procedure includes means Registration procedure and service request procedure specified in 3GPP TS 23.502 [21].

2.2.4.2.5.2 Procedure: Nominal test

Performs downlink data transfer from application test server to the Test UE or UE emulator. The application test server generates and transmits downlink data with data size large enough to achieve the maximum Layer 1 Radio data rate, which is specified in 2.2.4.2.6, for the duration of the test. The duration of the test is 20 seconds.

Note that data transfer depends on the operation mode. In case when the DUTs are operating in NSA mode, data transfers can be performed over Default EPS bearer using SN terminated split bearer specified in 3GPP TS 37.340 [22]. In case when the DUTs are operating in SA mode, data transfers can be performed over PDU Session and QoS flow specified in 3GPP TS 23.502 [21].

This test case does not specify the test data pattern generated by the application test server, but it is recommended that the test data pattern should include some level of randomness (ie, avoiding all zeros).

2.2.4.2.6 Test Requirement (expected result)

Observe that the Test UE or emulated UE can perform Radio U-Plane data transfers over the network particularly through the O-DU and O-RU at the target data rate.

Record the Test UE or UE emulator Radio U-Plane logs and determine that they contain measurements such as the measured Radio U-Plane data rates during the test. The acceptance criterion is that Radio U-Plane data rate on average during the test duration achieves the performance level defined as follows

Performance level

Target data rate = Maximum Layer 1 Radio data rate * (1 - Ratio of Radio resource overhead) * Margin,

where

Maximum Layer 1 Radio data rate is calculated based on 3GPP TS 38. 211 [15] and TS 38.214 [23] by using RAN parameters, ie, Total channel bandwidth, TDD configuration (when TDD), number of spatial/antenna streams, modulation order and coding rate. Note that these RAN parameters are defined in the IOT profiles (see Annex A for details).

Ratio of Radio resource overhead is calculated based on 3GPP TS 38.211 [15] by using Radio physical layer channel configurations, eg, PDCCH resource mapping, Reference signal resource mapping, and so on, assumed in the IOT setup. Note that the physical layer channel configurations are part of the radio test setup configuration.

Margin is assumed in order to account for issues other than the FH. The value of *Margin* is 0.8.

Annex A Profiles used for Interoperability Testing

This section contains the interoperability testing profiles.

A.1 M-Plane IOT Profile

A.1.1 M-Plane IOT Profile 1

Table A-1: M-Plane IOT Profile 1

Category	Item	Related O-RAN specification and section	
High Level Description	Architectural models	2.1.2 M-Plane architecture model	Hierarchical model
	IP version	2.1.3 Transport Network	IPv4
	Hash algorithm for data integrity	2.4 Security	SHA1
	Cyphering algorithm	2.4 Security	3DES-CBC
"Start up" installation	O-RU identification by DHCP option	3.1.1 O-RU identification in DHCP	DHCPv4(Option: 60)
	VLAN Discovery	3.1.2 Management Plane VLAN Discovery Aspects	support VLAN SCAN
	IP address assignment	3.1.3 O-RU Management Plane IP Address Assignment	IPv4 configuration using DHCPv4
	O-RU controller discovery	3.1.4 O-RU Controller Discovery	DHCPv4 option 43
	DHCP format of O-RU controller discovery	3.1.4 O-RU Controller Discovery	O-RU Controller IP Address
	NETCONF Call Home	3.2 NETCONF Call Home to O-RU Controller(s)	call home(port4334)
	SSH Connection Establishment	3.3 SSH Connection Establishment	password-based authentication
	TCP port for SSH establishment (for test purpose)	3.3.1 NETCONF Security	Default (port 830)
	NETCONF Authentication	3.3.2 NETCONF Authentication	password-based authentication

Category	Item	Related O-RAN specification and section	
	User Account Provisioning	3.3.3 User Account Provisioning	default sudo
	sudo	3.4 NETCONF Access Control	used
	nms	3.4 NETCONF Access Control	not used
	fm-pm	3.4 NETCONF Access Control	not used
	swm	3.4 NETCONF Access Control	not used
	NETCONF capability	3.5 NETCONF capability discovery	yang-library, Writable-running Capability, XPATH capability, Notifications, Interleave capability
	Watchdog timer	3.6 Monitoring NETCONF connectivity	used
O-RU to O-DU Interface Management	VLAN tagging for C/U/M-Plane	3.1.2 Management Plane VLAN Discovery Aspects 4.3 C/U Plane VLAN Configuration	used for C/U/M-Plane
	C/U Plane IP Address Assignment	4.4 O-RU C/U Plane IP Address Assignment	not used
	Definition of processing elements	4.5 Definition of processing elements	a combination of VLAN identity and MAC address
	C/U Plane Transport Connectivity	4.6 Verifying C/U Plane Transport Connectivity	Loop-back Protocol (LB/LBM)
	O-RU Monitoring of C/U Plane Connectivity	4.10 O-RU Monitoring of C/U Plane Connectivity	used
Configuration Management	Baseline configuration	6.1 Baseline configuration	2 phases
Fault Management	subscribe notification	8.2 Manage Alarms Request	default stream
Synchronization Aspects	Sync Capability Object	10.2 Sync Capability Object	CLASS_B
Details of O-RU Operations	Activation, deactivation and sleep	12.3.2 Activation, deactivation and sleep	used

A.2 CUS-Plane IOT Profiles

A.2.1 NR TDD

A.2.1.1 NR TDD IOT Profile 1 - NR-TDD-FR1-CAT-A-NoBF

Profile names

- NR-TDD-FR1-CAT-A-NoBF_[25Gbpsx1lane-PRACHB4-eAxCID2644]
- NR-TDD-FR1-CAT-A-NoBF_[10Gbpsx2lane-PRACHC2-eAxCID4246]

Table A-2: NR TDD IOT Profile 1 - NR-TDD-FR1-CAT-A-NoBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR TDD

	TDD configuration	-	pattern1{
			dl-UL-TransmissionPeriodicity ms3
			nrofDownlinkSlots 3
			nrofDownlinkSymbols 6
			nrofUplinkSlots 2
			nrofUplinkSymbols 4}
			
			pattern2{
			dl-UL-TransmissionPeriodicity ms2
			nrofDownlinkSlots 4
			nrofDownlinkSymbols 0
			nrofUplinkSlots 0
			nrofUplinkSymbols 0}

	Nominal sub-carrier spacing	-	30 kHz
	SSB sub-carrier spacing	-	30 kHz
	Nominal FFT size	-	4096
	Total channel bandwidth	-	100MHz x 1CC
	Number of spatial/antenna streams	-	4

Category	Item	Related O-RAN fronthaul specification and section	
	Fronthaul Ethernet link	-	Entry1: 25Gbps x 1lane Entry2: 10Gbps x 2lane
	PRACH preamble format	-	Entry1: B4 Entry2: C2
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category A
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 345us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 294us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 345us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 134us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 171us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 50us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 331us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 50us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 336us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us

Category	Item	Related O-RAN fronthaul specification and section	
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 336us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 2 Entry2: 4
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 6 Entry2: 2
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	4
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 4 Entry2: 6
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID

Category	Item	Related O-RAN fronthaul specification and section	
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	No beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based (always "0")
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	14
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE

Category	Item	Related O-RAN fronthaul specification and section	
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	lls-C1 (can also apply lls-C2)

A.2.1.2 NR TDD IOT Profile 2 - NR-TDD-FR1-CAT-A-DBF

Profile names

- NR-TDD-FR1-CAT-A-DBF

Table A-3: NR TDD IOT Profile 2 - NR-TDD-FR1-CAT-A-DBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR TDD

	TDD configuration	-	pattern1{
			dl-UL-TransmissionPeriodicity ms3
			nrofDownlinkSlots 3
			nrofDownlinkSymbols 6
			nrofUplinkSlots 2
			nrofUplinkSymbols 4}
			
			pattern2{
			dl-UL-TransmissionPeriodicity ms2
			nrofDownlinkSlots 4
			nrofDownlinkSymbols 0
			nrofUplinkSlots 0
			nrofUplinkSymbols 0}

	Nominal sub-carrier spacing	-	30 kHz
	SSB sub-carrier spacing	-	30 kHz
	Nominal FFT size	-	4096
	Total channel bandwidth	-	100MHz x 1CC

Category	**Item**	**Related O-RAN fronthaul specification and section**	
	Number of spatial/antenna streams	-	4
	Fronthaul Ethernet link	-	25Gbps x 1lane
	PRACH preamble format	-	B4
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category A
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 345us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 294us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 345us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 134us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 171us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 50us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 331us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 50us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 336us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us

Category	Item	Related O-RAN fronthaul specification and section	
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 336us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	2
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	6
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	4
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	4
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB

Category	Item	Related O-RAN fronthaul specification and section	
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	Digital beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	14
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	lls-C1 (can also apply lls-C2)

A.2.1.3 NR TDD IOT Profile 3 - NR-TDD-FR2-CAT-A-ABF

Profile names

- NR-TDD-FR2-CAT-A-ABF_[100MHz-SSB240kHz&PRACHC0-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[200MHz-SSB240kHz&PRACHC0-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[300MHz-SSB240kHz&PRACHC0-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[400MHz-SSB240kHz&PRACHC0-eAxCID2644]
-
- NR-TDD-FR2-CAT-A-ABF_[100MHz-SSB120kHz&PRACHA3-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[200MHz-SSB120kHz&PRACHA3-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[300MHz-SSB120kHz&PRACHA3-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[400MHz-SSB120kHz&PRACHA3-eAxCID2644]
- NR-TDD-FR2-CAT-A-ABF_[800MHz-SSB120kHz&PRACHA3-eAxCID2644]
-
- NR-TDD-FR2-CAT-A-ABF_[100MHz-SSB240kHz&PRACHC2-eAxCID4246]
- NR-TDD-FR2-CAT-A-ABF_[200MHz-SSB240kHz&PRACHC2-eAxCID4246]
- NR-TDD-FR2-CAT-A-ABF_[400MHz-SSB240kHz&PRACHC2-eAxCID4246]
- NR-TDD-FR2-CAT-A-ABF_[600MHz-SSB240kHz&PRACHC2-eAxCID4246]
- NR-TDD-FR2-CAT-A-ABF_[800MHz-SSB240kHz&PRACHC2-eAxCID4246]

Table A-4: NR TDD IOT Profile 3 - NR-TDD-FR2-CAT-A-ABF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR TDD
	TDD configuration	-	dl-UL-TransmissionPeriodicity: ms0p625 nrofDownlinkSlots: 3 nrofDownlinkSymbols: 10 nrofUplinkSlots: 1 nrofUplinkSymbols: 2
	Nominal sub-carrier spacing	-	120 kHz
	SSB sub-carrier spacing	-	Entry1: 240kHz Entry2: 120KHz

Category	Item	Related O-RAN fronthaul specification and section	
	Nominal FFT size	-	1024
	Total channel bandwidth	-	Entry1: 100MHz x 1CC Entry2: 100MHz x 2CC Entry3: 100MHz x 3CC Entry4: 100MHz x 4CC Entry5: 100MHz x 6CC Entry6: 100MHz x 8CC
	Number of spatial/antenna streams	-	2
	Fronthaul Ethernet link	-	25Gbps x 1lane for 100MHz x 1,2,3,4CC, 25Gbps x 2lane for 100MHz x 6,8CC
	PRACH preamble format	-	Entry1: C0 Entry2: A3 Entry3: C2
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category A
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 264us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 213us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 264us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 53us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	63 us

Category	Item	Related O-RAN fronthaul specification and section	
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 90us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 20us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 250us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 20us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 274us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 223us
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 274us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 63us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 2 Entry2: 4
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 6 Entry2: 2

Category	Item	Related O-RAN fronthaul specification and section	
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	4
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	Entry1: 4 Entry2: 6
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	Analog beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	14
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message

Category	Item	Related O-RAN fronthaul specification and section	
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	lls-C1 (can also apply lls-C2)

A.2.2 NR FDD

A.2.2.1 NR FDD IOT Profile 1 - NR-FDD-FR1(15kHzSCS)-CAT-B-DBF

Profile names

- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-8SS-PRACH0-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-8SS-PRACH0-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-16SS-PRACH0-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-16SS-PRACH0-9bitIQ-llsC2]

- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-8SS-PRACHC2-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-8SS-PRACHC2-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-16SS-PRACHC2-9bitIQ-llsC2]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-16SS-PRACHC2-9bitIQ-llsC2]

- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-8SS-PRACH0-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-8SS-PRACH0-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-16SS-PRACH0-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-16SS-PRACH0-12bitIQ-llsC3]

- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-8SS-PRACHC2-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-8SS-PRACHC2-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[20MHz-16SS-PRACHC2-12bitIQ-llsC3]
- NR-FDD-FR1(15kHzSCS)-CAT-B-DBF_[30MHz-16SS-PRACHC2-12bitIQ-llsC3]

Table A-5: NR FDD IOT Profile 1 - NR-FDD-FR1(15kHzSCS)-CAT-B-DBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR FDD
	TDD configuration	-	NA
	Nominal sub-carrier spacing	-	15 kHz
	SSB sub-carrier spacing	-	15 kHz
	Nominal FFT size	-	2048
	Total channel bandwidth	-	Entry1: 20MHz Entry2: 20MHz+10MHz
	Number of spatial/antenna streams	-	Entry1: 8 Entry2: 16
	Fronthaul Ethernet link	-	25Gbps x 1lane for 8 spatial streams, 25Gbps x 2lane for 16 spatial streams
	PRACH preamble format	-	Entry1: 0 Entry2: C2
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category B
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 437us

Category	Item	Related O-RAN fronthaul specification and section	
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 366us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 437us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 206us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 232us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 70us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 392us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 70us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 356us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 356us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE

Category	Item	Related O-RAN fronthaul specification and section	
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	2
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	8
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	Digital beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	Entry1: 9 Entry2: 12
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE

Category	Item	Related O-RAN fronthaul specification and section	
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	Entry1: lls-C2 Entry2: lls-C3

A.2.2.2 NR FDD IOT Profile 2 - NR-FDD-FR1-CAT-B-DBF

Profile names

- NR-FDD-FR1-CAT-B-DBF_[20MHz-8SS-9bitIQ-llsC2]
- NR-FDD-FR1-CAT-B-DBF_[30MHz-8SS-9bitIQ-llsC2]
- NR-FDD-FR1-CAT-B-DBF_[20MHz-16SS-9bitIQ-llsC2]
- NR-FDD-FR1-CAT-B-DBF_[30MHz-16SS-9bitIQ-llsC2]

- NR-FDD-FR1-CAT-B-DBF_[20MHz-8SS-12bitIQ-llsC3]
- NR-FDD-FR1-CAT-B-DBF_[30MHz-8SS-12bitIQ-llsC3]
- NR-FDD-FR1-CAT-B-DBF_[20MHz-16SS-12bitIQ-llsC3]
- NR-FDD-FR1-CAT-B-DBF_[30MHz-16SS-12bitIQ-llsC3]

Table A-6: NR FDD IOT Profile 2 - NR-FDD-FR1-CAT-B-DBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR FDD
	TDD configuration	-	NA
	Nominal sub-carrier spacing	-	30 kHz
	SSB sub-carrier spacing	-	30 kHz
	Nominal FFT size	-	1024
	Total channel bandwidth	-	Entry1: 20MHz Entry2: 20MHz+10MHz
	Number of spatial/antenna streams	-	Entry1: 8 Entry2: 16
	Fronthaul Ethernet link	-	25Gbps x 1lane for 8 spatial streams, 25Gbps x 2lane for 16 spatial streams
	PRACH preamble format	-	0
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category B
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 345us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 294us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 345us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 134us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 171us

Category	Item	Related O-RAN fronthaul specification and section	
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 50us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 331us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 50us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 336us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 336us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	2
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	8
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation

Category	Item	Related O-RAN fronthaul specification and section	
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	Digital beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	Entry1: 9 Entry2: 12
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE

Category	Item	Related O-RAN fronthaul specification and section	
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	Entry1: lls-C2 Entry2: lls-C3

A.2.2.3 NR FDD IOT Profile 3 - NR-FDD-FR1-CAT-A-NoBF

Profile names

- NR-FDD-FR1-CAT-A-NoBF_[20MHz-9bitIQ-llsC2]
- NR-FDD-FR1-CAT-A-NoBF_[30MHz-9bitIQ-llsC2]
- NR-FDD-FR1-CAT-A-NoBF_[20MHz-12bitIQ-llsC3]
- NR-FDD-FR1-CAT-A-NoBF_[30MHz-12bitIQ-llsC3]

Table A-7: NR FDD IOT Profile 3 - NR-FDD-FR1-CAT-A-NoBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	NR FDD
	TDD configuration	-	NA
	Nominal sub-carrier spacing	-	30 kHz
	SSB sub-carrier spacing	-	30 kHz
	Nominal FFT size	-	1024
	Total channel bandwidth	-	Entry1: 20MHz Entry2: 20MHz+10MHz
	Number of spatial/antenna streams	-	4

Category	Item	Related O-RAN fronthaul specification and section	
	Fronthaul Ethernet link	-	10Gbps x 1 lane
	PRACH preamble format	-	0
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category A
	LAA	-	FALSE
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 345us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 294us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 345us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 134us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 171us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 50us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 331us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 50us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 336us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 336us

Category	Item	Related O-RAN fronthaul specification and section	
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	2
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	8
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	No beamforming

Category	Item	Related O-RAN fronthaul specification and section	
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based (always "0")
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	Entry1: 9 Entry2: 12
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	Entry1: lls-C2 Entry2: lls-C3

1

A.2.3 LTE FDD

A.2.3.1 LTE FDD IOT Profile 1 - LTE-FDD-FR1-CAT-B-DBF

Profile names

- LTE-FDD-FR1-CAT-B-DBF_[20MHz-8SS-9bitIQ-llsC2]
- LTE-FDD-FR1-CAT-B-DBF_[30MHz-8SS-9bitIQ-llsC2]
- LTE-FDD-FR1-CAT-B-DBF_[20MHz-16SS-9bitIQ-llsC2]
- LTE-FDD-FR1-CAT-B-DBF_[30MHz-16SS-9bitIQ-llsC2]
-
- LTE-FDD-FR1-CAT-B-DBF_[20MHz-8SS-12bitIQ-llsC3]
- LTE-FDD-FR1-CAT-B-DBF_[30MHz-8SS-12bitIQ-llsC3]
- LTE-FDD-FR1-CAT-B-DBF_[20MHz-16SS-12bitIQ-llsC3]
- LTE-FDD-FR1-CAT-B-DBF_[30MHz-16SS-12bitIQ-llsC3]

Table A-8: LTE FDD IOT Profile 1 - LTE-FDD-FR1-CAT-B-DBF

Category	Item	Related O-RAN fronthaul specification and section	
General	Radio access technology	-	LTE FDD
	TDD configuration	-	NA
	Nominal sub-carrier spacing	-	15 kHz
	SSB sub-carrier spacing	-	15 kHz
	Nominal FFT size	-	2048
	Total channel bandwidth	-	Entry1: 20MHz Entry2: 20MHz+10MHz
	Number of spatial/antenna streams	-	Entry1: 8 Entry2: 16
	Fronthaul Ethernet link	-	25Gbps x 1lane for 8 spatial streams, 25Gbps x 2lane for 16 spatial streams
	PRACH preamble format	-	0
	RU category	ORAN-WG4.CUS.0-v02.00 section 2.1	Category B
	LAA	-	FALSE

Category	Item	Related O-RAN fronthaul specification and section	
Delay management	Network delay determination	ORAN-WG4.CUS.0-v02.00 section 2.3.3	Defined Transport Method
	RU adaptation of delay profile information (based on O-DU delay profile and transport delay)	ORAN-WG4.CUS.0-v02.00 section 2.3.3.2	FALSE
	O-DU timing advance type	ORAN-WG4.CUS.0-v02.00 section 2.3.4-2.3.5, Annex B	Fixed Timing Advance
	T1a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 437us
	T1a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 366us
	T2a_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 437us
	T2a_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 206us
	Tcp_adv_dl	ORAN-WG4.CUS.0-v02.00 section 2.3.2, Annex B	125 us
	Ta3_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 232us
	Ta3_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 70us
	Ta4_max_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	More than or equal to 392us
	Ta4_min_up	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	Less than or equal to 70us
	T1a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 356us
	T1a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 285us
	T2a_max_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	More than or equal to 356us
	T2a_min_cp_ul	ORAN-WG4.CUS.0-v02.00 section 2.3.2-2.3.3, Annex B	Less than or equal to 125us
	T12_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T12_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us

Category	Item	Related O-RAN fronthaul specification and section	
	T34_max	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	160 us
	T34_min	ORAN-WG4.CUS.0-v02.00 section 2.3, Annex B	0 us
	Non-delay managed U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 2.3.6	FALSE
C/U-plane transport	Transport encapsulation	ORAN-WG4.CUS.0-v02.00 section 3.1.1-3.1.2	Ethernet
	Jumbo frames	ORAN-WG4.CUS.0-v02.00 section 3.1.2	FALSE
	Transport header	ORAN-WG4.CUS.0-v02.00 section 3.1.3	eCPRI
	eCPRI concatenation	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1	FALSE
	eAxC ID DU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	2
	eAxC ID BandSector_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID CC_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	3
	eAxC ID RU_Port_ID bitwidth	ORAN-WG4.CUS.0-v02.00 section 3.1.3.1.6	8
	Fragmentation	ORAN-WG4.CUS.0-v02.00 section 3.5	Application layer fragmentation
	Transport prioritization across C/U/S/M-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	Default L2 CoS priority
	Transport prioritization within U-plane	ORAN-WG4.CUS.0-v02.00 section 3.3	False (Default U-plane priority applies)
	Separation of C/U-plane and M-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	VLAN ID
	Transport-based separation within C/U-plane traffic	ORAN-WG4.CUS.0-v02.00 section 3.4	FALSE
Digital Power Scaling	UL gain_correction	ORAN-WG4.CUS.0-v02.00 section 6.1.3.2	0dB
Beamforming	RU beamforming type	ORAN-WG4.CUS.0-v02.00 section 2.1	Digital beamforming
	Beamforming control method	ORAN-WG4.CUS.0-v02.00 section 5.4, Annex J	Beamforming ID based
IQ compression	U-plane data compression method	ORAN-WG4.CUS.0-v02.00 section 6, Annex A	Block floating point
	U-plane data IQ bitwidth	ORAN-WG4.CUS.0-v02.00 section 6, Annex D	Entry1: 9 Entry2: 12

Category	Item	Related O-RAN fronthaul specification and section	
	IQ data frame format not including udCompHdr field	ORAN-WG4.CUS.0-v02.00 section 6.3.3.13	TRUE
C-plane	Section Type 0	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 1	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 3	ORAN-WG4.CUS.0-v02.00 section 5.4.2	TRUE
	Section Type 5	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 6	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	Section Type 7	ORAN-WG4.CUS.0-v02.00 section 5.4.2	FALSE
	"symInc" flag	ORAN-WG4.CUS.0-v02.00 section 5.4.5.3	FALSE (always set to '0')
	C-plane for PRACH formats with preamble repetition	ORAN-WG4.CUS.0-v02.00 section 5.3.2	Single C-plane message
	Section extension 1	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 2	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 3	ORAN-WG4.CUS.0-v02.00 section 5.4.6	TRUE
	Section extension 4	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
	Section extension 5	ORAN-WG4.CUS.0-v02.00 section 5.4.6	FALSE
S-plane	G.8275.1	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	TRUE
	G.8275.2	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	GNSS based sync	ORAN-WG4.CUS.0-v02.00 section 3.2.3, 9	FALSE
	SyncE	ORAN-WG4.CUS.0-v02.00 section 9, Annex H	TRUE
	Topology configuration	ORAN-WG4.CUS.0-v02.00 section 9.2.2	Entry1: lls-C2 Entry2: lls-C3

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 O-RAN

Specification.

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

Section 3: FRAND LICENSE

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

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

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

Section 4: TERM AND TERMINATION

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

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

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

Section 5: CONFIDENTIALITY

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

Section 6: INDEMNIFICATION

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

Section 7: LIMITATIONS ON LIABILITY; NO WARRANTY

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

Section 8: ASSIGNMENT

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

Section 9: THIRD-PARTY BENEFICIARY RIGHTS

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

Section 10: BINDING ON AFFILIATES

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

Section 11: GENERAL

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

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

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

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

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

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

