Maple Specification

Compal confidential

2024 Jan

Version v0.2

Copyright

Notice

The document is subject to update from time to time owing to the product version upgrade or other reasons. Unless otherwise specified, the document only serves as the user guide. All the statements, information and suggestions contained in the document do not constitute any explicit or implicit guarantee.

Version Record

Version	Update date	Remark
V0.1	April 10, 2023	Draft version
V0.2	January 12, 2024	Add O1、E2 Interface for O-RN RAN Intelligent Controller(RIC)

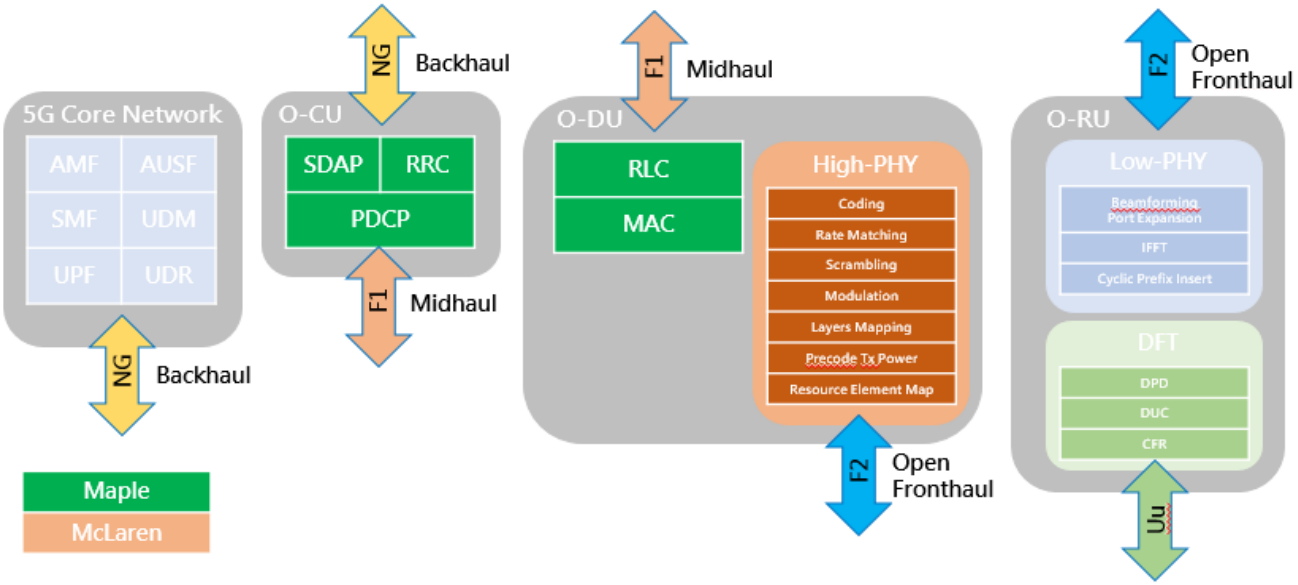
Contents

1. About this document

This document provides

- Instructions and requirements for installing the COMPAL O-CU/O-DU Solutions into a server
- Instructions for running built-in self-tests using the auto-deployment tools

Figure 1. O-RAN Architecture



1.1. Acronym List

Acronym	Expansion	Description
NGAP	Next Generator Application Protocol	A logical node hosting RRC (Radio Resource Control)、PDCP (Packet Data Convergence)、SDAP (Service Data Adaptation Protocol)；
O-CU	O-RAN Central Unit	A logical node hosting RRC (Radio Resource Control)、PDCP (Packet Data Convergence)、SDAP (Service Data Adaptation Protocol)；
O-DU	O-RAN Distributed Unit	A logical node hosting RLC (Radio Link Control)、MAC (Medium Access Control)、High-PHY layers based on LLS；
O-RU	O-RAN Radio Unit	A logical node hosting a Low-PHY layer (e.g. FFT/IFFT、PRACH) and RF-based on LLS (Lower-Layer Split)；
Non-RT RIC	Non-real-time RAN Intelligent Controller	A logical function that enables non-real-time control and optimization of RAN elements and resources, AI/ML workflow including model training and updates, and policy-based guidance of applications/features in near-RT RIC
Near-RT RIC	Near-real-time RAN Intelligent Controller	A logical function that enables near-real-time control and optimization of O-RAN elements and resources via fine-grained data collection and actions over E2 interface.

2. Software and Hardware Requirements

This chapter provides the information on the software and hardware requirements to bring up the 5G NR gNB CU-DU solutions ◦

2.1. Software requirements

This section provides the software requirements for gNB CU and gNB DU that are compatible with the Intel 21.11 L1 ◦

Component	Version
OS for 5G NR gNB CU-DU on OTA Setup	CenOS version 7.9.2009 with GCC version 5.4.0
RT Linux Patch on OTA Setup	3.10.0-1160.11.1.rt56.1145.e17.x86_64

2.2. System requirements

This following table lists the server configuration recommended and tested for the gNB CU and gNB DU solutions ◦

Category	Description
Server	Intel® Server System SuperMicro SYS-220HE-FTNRD 2U Rackmount SuperMicro SYS-E403-12P-FN2T Fan-based Embedded
Processor	Single Socket 3rd Gen Intel® Xeon®Scalable Processors
Memory	128 GB 2666 Reg ECC 1.2V DDR4
	480 GB SSD
Networking Device	40GbE NIC-XL710AWQDA2
	10GbE NIC-X710DA4FH
QAT Accelerator Card	Intel® QuickAssist Adapter 8970
DU Inline Accelerator Card	Compal DU Inline Accelerator Card
SFP module	Intel SFP+ Transceiver Module E10GSFPSR

3. Key Features

The COMPAL 5G O-RAN solution supports the control and data plane functionalities of the 3GPP 5G Radio Access Network (RAN)。This section describes the solution overview and features developed by COMPAL on x86。

Following are the main components of the gNB Centralized Unit (CU)。

- 5G NR Radio Protocols
  - Radio Resource Control (RRC)
  - Service Data Adaptation Protocol (SDAP)
  - Packet Data Convergence Protocol (PDCP)
  - F1 Application Protocol (F1AP)
  - Xn Application Protocol (XnAP)
  - Next Generation Application Protocol (NGAP)

Following are the main components of the gNB Distributed Unit (DU)。

- 5G NR Radio Protocols
  - Radio Link Control (RLC)
  - Medium Access Control (MAC)

Following are the main components of the RAN Intelligent Controller (RIC)。

- RAN Intelligent Controller
  - Non-Real-Time RAN Intelligent Controller (Non-RT RIC)
  - Near-Real-Time RAN Intelligent Controller (Near-RT RIC)

3.1. Protocol Conformance

This section describes the functional and message compliance of the 5G NR O-RAN。The protocol layersd of 5G NR solution functionally comply to the standards mentioned in **Table 1**。For more details on the supported functionalities，see the **Features** section。

Table 1-1. Functional and Message Compliance

Protocol Layer	Specification
RRC	3GPP TS 38.331 v16.2.0
SDAP	3GPP TS 37.324 v16.1.0
PDCP	3GPP TS 38.322 v15.3.0
RLC	3GPP TS 38.322 v15.5.0
MAC	3GPP TS 36.321 v15.3.0
XnAP	3GPP TS 38.423 v16.3.0
NGAP	3GPP TS 38.413 v16.3.0
PDU Session User Plane Protocol	3GPP TS 38.415 v15.2.0

Table 1-2. Functional and Message Compliance

Function	Specification
O-RAN E2 General Aspects and Principles (E2GAP)	O-RAN.WG3.E2GAP-R003-v04.01
O-RAN E2 Application Protocol (E2AP)	O-RAN.WG3.E2AP-R003-v04.00
O-RAN E2 Service Model (E2SM)	O-RAN.WG3.E2SM-R003-v04.00
O-RAN E2 Service Model (E2SM) KPM	O-RAN.WG3.E2SM-KPM-R003-v04.00
O-RAN E2 Service Model (E2SM) RAN Control	O-RAN.WG3.E2SM-RC-R003-v04.00
O-RAN E2 Service Model (E2SM) Cell Configuration and Control	O-RAN.WG3.E2SM-CCC-R003-v04.00
O-RAN Use Cases and Requirements	O-RAN.WG3.UCR-R003-v04.00
O-RAN Near-RT RIC Architecture	O-RAN.WG3.RICARCH-R003-v05.00
O-RAN O1 Interface Specification for Near Real Time RAN Intelligent Controller	O-RAN.WG3.O1-Interface-for-Near-RT-RIC-R003-v01.00
O-RAN E2 Interface Test Specification	O-RAN.WG3.E2TS-R003-v02.00
O-RAN Near-RT RIC APIs Specification	O-RAN.WG3.RICAPI-R003-v01.00
O-RAN Near Real Time RAN Intelligent Controller E2 Service Model(E2SM), RAN Funcstion Network Interface (NI)	O-RAN.WG3.E2SM-NI-v01.00

3.2. Features

This section describes the features supported of O-RAN O-CU、O-DU and RIC。

3.2.1. RRC

The following table describes the status of features and procedures supported for RRC。

Table 2. RRC Features

Procedure / Feature	Message / Functionality
RRC Connection Establishment	● RRC Setup Request ● RRC Setup ● RRC Setup Complete
Initial Security Activation	● Security Mode Command ● Security Mode Complete
RRC Reconfiguration	● RRC Reconfiguration ● RRC Reconfiguration Complete
RRC Connection Re-establishment (Cause : Radio Link Failure Detection)	● RRC Re-establishment Request ● RRC Re-establishment ● RRC Re-establishment Complete
System Information	SIB1、SIB2、SIB3、SIB4、and SIB5 encoding and transmission
Paging	Paging encoding and transmission
Measurements	Basic configuration for A1、A2、A3、and A4 events and report handling
Security	Integrity、Ciphering、and Deciphering (NIA0、NIA1、NIA2、NIA3、NEA0、NEA1、NEA2、and NEA3)
DL and UL Information Transfer	● DL Information Transfer ● UL Information Transfer

3.2.2. SDAP

The following table describes the status of features and procedures supported for SDAP。

Table 3. SDAP Features

Procedure / Feature	Message / Functionality
Data Transfer : Receive Operation	Receive Operation
Data Transfer : Transmit Operation	Transmit Operation
Non-GBR Bearer Rate Limiting in DL	PDU session Aggregate Maximum Bit Rate (AMBR) and UE AMBR enforcement for non-GBR bearer
Protocol Data Units (PDU)	Data PDU
QoS Flow to DRB Mapping	Configuration
SDAP Entity Handling	● SDAP Entity Establsihment ● SDAP Entity Release during UE Release ● SDAP Entity Modification

3.2.3. PDCP

The following table describes the status of features and procedures supported for PDCP。

Table 4. PDCP Features

Procedure / Feature	Message / Functionality
Ciphering and Deciphering	DL ciphering and UL deciphering
Data Radio Bearer (DRB)	● Unacknowledged Mode (UM) DRB ● Acknowledged Mode (AM) DRB
Protocol Data Units	● Data PDU with 12 bits PDCP SN ● Data PDU with 18 bits PDCP SN
Data Transfer : Transmit Operation	● Transmit Operation ● Sequence Numbering
Data Transfer : Receive Operation	Receive Operation。Re-ordering is NOT supported。
PDCP PDU Routing (for Split Bearers)	For split bearers，routing is performed in the transmitting PDCP entity
Handling of unknown，Unforeseen，and Erroneous Protocol Data	Handling of PDCP that contains reserved or invalid values
Status Reporting Functionality	● Transmit Operation ● Receive Operation
Integrity Protection and Verification	DL integrity protection and UL integrity verification。Excluding short MAC-1 generation for SRB。
PDCP Entity Handling	● PDCP Entity Establishment ● PDCP Entity Re-establishment

3.2.4. RLC

The following table shows the status of features and procedures supported for RLC。

Table 5. RLC Features

Procedure / Feature	Message / Functionality
Data Transfer Procedure : UM Mode	● Transmit Operations : Segmentation ● Receive Operations : Reassembly
Data Transfer Procedure : AM Mode	● Transmit Operations : Segmentation ● Receive Operations : Reassembly ● Automatic Repeat Request (ARQ) Procedures : Retransmission，Polling，and status reporting

Handling of Unknown · Unforceseen · and Erroneous Protocol Data	Reception of PDU with reserved or invalid values
RLC Entity Handling	● RLC Entity Establishment ● RLC Entity Re-establishment

3.2.5. MAC

The following table shows the status of features and procedures supported for MAC。

Table 6. MAC Features

Procedure / Feature	Message / Functionality
Activation of Scell	SCell activation and deactivation Control Element (CE) based on the Buffer Occupancy (BO)
DL-SCH Data Transfer	Support for the following HARQ operations ● HARQ Entity ● HARQ Process new transmission ● HARQ Process retransmission ● Multiplexing and Assembly
UL-SCH Data Transfer	Suport for the following HARQ operations ● HARQ Entity ● HARQ Process new Transmission ● HARQ Process Retransmission ● De-multiplexing and Disassembly ● Buffer Status Reporting (BSR) Handling
Handling of Unknown · Unforeseen · and Erroneous Protocol Data	Protocol Error Handling
UL Time Alignment	● Timing Advance Command (TAC) CE ● Support for the Time Alignment Timer (TAT) to control the time duration at which the UE aligns to the uplink time。The uplink adjustment applies to PUSCH · PUCCH · and SRS
PDCCH Transmission Configuration Indicator (TCI) State Activation and Deactivation CE	PDCCH TCI activation CE
PDSCH TCI State Activation and Deactivation CE	PDSCH TCI activation CE
Power Headroom (PHR) CE	Type 1 PHR report with single and multiple entry
Random Access Procedure	● Contention-based ● Contention-free
Sounding Reference Signal (SRS)	SRS for non-codebook PUSCH Transmission
Supplementary Uplink (SUL) Operation	Data Handling for SUL
Synchronization Signal (SS) and Physical Broadcast Channel (PBCH)	SS PBCH Transmission

3.2.6. XnAP

The following table shows the status of features and procedures supported for XnAP。

Table 7. XnAP Features

Procedure / Feature	Message / Functionality
Xn Setup	● Xn Setup Request ● Xn Setup Response
Handover Preparation	● Handover Request ● Handover Request Acknowledge

SN Status Transfer	SN Status Transfer
UE Context Release	UE Context Release

3.2.7. F1AP

The following table shows the status of features and procedures supported for F1AP。

Table 8. F1AP Features

Procedure / Feature	Message / Functionality
F1 Setup	● F1 Setup Request ● F1 Setup Response
gNB-DU Resource Coordination	● gNB-DU Resource Coordination Request ● gNB-DU Resource Coordination Response
gNB-DU Configuration Coordination	● gNB-DU Configuration Update ● gNB-DU Configuration Update Acknowledge
UE Context Setup (Cause : Radio Link Failure Detection)	● UE Context Setup Request ● UE Context Setup Response
UE Context Modification (gNB-CU Initiated)	● UE Context Modification Request ● UE Context Modification Response
UE Context Release (gNB-CU Initiated)	● UE Context Release Command ● UE Context Release Complete
Initial UL RRC Message Transfer	Initial UL RRC Message Transfer
UL RRC Message Transfer	UL RRC Message Transfer
DL RRC Message Transfer	DL RRC Message Transfer
Paging	Paging (CN Initiated Idle Mode Paging)

3.2.8. NGAP

The following table shows the status of features and procedures supported for NGAP。

Table 9. NGAP Features

Procedure / Feature	Message / Functionality
NG Setup	● NG Setup Request ● NG Setup Response
PDU Session Resource Setup	● PDU Session Resource Setup Request ● PDU Session Resource Setup Response
Paging	Paging
NG Reset Initiated by the AMF	● NG Reset ● NG Reset Acknowledge
UE Context Release Request	UE Context Release Request
UE Context Release	● UE Context Release Command ● UE Context Release Complete
Uplink NAS Transport	Uplink NAS Transport
UE Radio Capability Check	● UE Radio Capability Check Request ● UE Radio Capability Check Response

3.2.9. E2SM Services

The following table shows the functions of the E2 Interface。

Table 10. Functions of the E2 Interface

Categories	Message / Functionality
RIC Services	● REPORT ● INSERT ● CONTROL ● POLICY ● QUERY
RIC Function Procedures	● RIC Subscription ● RIC Subscription Modification ● RIC Subscription Modification Required ● RIC Subscription Delete ● RIC Subscription Delete Required ● RIC Indication ● RIC Control ● RIC Query
E2 support service – Interface Management services supported by Global Procedures	● E2 Setup ● E2 Reset ● E2 Node Configuration Update ● E2 Removal ● Reporting of General Error Situations
E2 support service – RAN Function services supported by Global Procedures	● RIC Service Update ● RIC Service Query

3.2.10. O1 Interface

The **O1 interface** enables the management of all **O-RAN** components that need to be orchestrated and the associated O-RAN network functions。The components managed via O1 include the near-RT RIC，the O-CU，and the **O-DU** in 5G NR。

The figure below shows an extracted logical O-RAN architecture to illustrate the O1 interface and its influence on O-RAN Manage Eleemnts。

The following is O1 interface key point;

- The O1 is the interface between SMO and near-RT RIC，the O-CU，the O-DU and O-RU。
- O1 interface ensures the operation and management e.g. FCAPS，Software Management，and file management of O-RAN components。
- O1 interface does use standard protocols SSH，TLS，NETCONF。
- O1 interface use the Yang Data Model

The following describes the management services supported via the O1 interface;

Table 11. Management Services supported via the O1 interface

Management Services	Description
Provisioning Management Services	● General NETCONF Requirements ● Creating，modifying and deleting MOIs (Managed Object Instances)

	● Reading MOI attributes ● Notification of changes to MOI attribute values ● Subscription control
Fault Supervision Management Services	● Fault Notification ● Fault Supervision Control
Performance Assurance Management Services	● Fiile Reporting and Streaming of Performance Data ● O-RAN defined Performance Measurements and Control of Measurement Jobs
Trace Management Service	● Call Trace and Streaming Trace ● Minimization of Drive Testing (NDT) ● Radio Link Failure (RLF) and RRC Connection Establishment Failure (RCEF) ● Trace Control
File Management Serice	● File Readiness Notification ● List Availa le Files and File Download ● Bi-directional transfer of files between the client and the file server
Heartbeat Management Service	● Heartbeat Notification ● Heartbeat Control
Start-up and Registration Management Service for Physical Network Functions (PNFs)	● PNF Plug-and-Play ● PNF Registration
Software Management Services for PNFs	● Software Package Naming and Content ● Download，Pre-check and Activation of Software
CNFs and VNFs Life Cycle	● Instantiation and Termination of CNFs/VNFs ● Scaling Management Services for CNFs/VNFs

The management functionalities are realized by using sandard protocols e.g. SSH，TLS，NETCONF and data models e.g YANG. with the help of the provisioning management service，the SMO framework can receive information (updates) from the MEs via the O1 interface e.g. on the current resource utilization and in return initiate an optimized configuration of the MEs。

4. Configuring O-CU and O-DU

The section describes how to configure O-CU and O-DU parameters to change Maple capacity。

4.1 Frame Pattern Configuration

Parameter Name	Sample Values	Supported Values/Range	Description
numDISlot	3	0 to 320	Indicates the number of downlink slots
numDISymbol	6	0 to 13	Indicates the number of downlink symbols for “s” slot format
numUISlot	2	0 to 320	Indicates the number of uplink slots
numUISymbol	4	0 to 13	Indicates the number of uplink symbols for “2” slot format
p2Pres	1	0, 1	Indicates the Pattern 2 (P2) presence value
numDISlot2	4	0 to 320	Indicates the number of P2 downlink slots
numDISymbolP2	0	0 to 13	Indicates the number of P2 downlink symbols for “s” slot format
numUISlot2	0	0 to 320	Indicates the number of P2 uplink slots
numUISymbolP2	0	0 to 13	Indicates the number of P2 uplink symbols for “s” slot format

For example，TDD slot pattern is DDDSUU DDDD

```
<CfgCmn>
        <numDISlot> 3 </numDISlot>
        <numDISymbol> 6 </numDISymbol>
        <numUISlot> 2 </numUISlot>
        <numUISymbol> 4 </numUISymbol>
        <p2Pres> 1 </p2Pres>
        <numDISlotP2> 4 </numDISlotP2>
        <numDISymbolP2> 0 </numDISymbolP2>
        <numUISlotP2> 0 </numUISlotP2>
        <numUISymbolP2> 0 </numUISymbolP2>
</CfgCmn>
```

4.2 DL and UL Modulation Configuration

Parameter Name	Sample Values	Supported Values/Range	Description
ulModulation	QAM64	QAM64, QAM256	Indicates the NR uplink modulation scheme
dlModulation	QAM256	QAM64, QAM256	Indicates the NR downlink modulation scheme

For example，QAM256

```
<macCfgCmn>
        <ulModulation> QAM64 </ulModulation >
        <dlModulation> QAM256 </dlModulation >
</macCfgCmn>
```

4.3 DL and UL Antenna Configuration

Parameter Name	Sample Values	Supported Values/Range	Description
dlRank	4	1 to 4	Indicates the maximum DL rank value

ulRank	2	1 to 4	Indicates the maximum UL rank value
dlNumAntPorts	4	1,2,4	Indicates the number of downlink antenna ports
ulNumAntPorts	2	1,2,4	Indicates the number of uplink antenna ports

For example · 4T2R

```
<macCfgCmn>
        <dlRank> 4 </dlRank>
        <ulRank> 2 </ulRank>
        <dlNumAntPorts> 4 </dlNumAntPorts>
        <ulNumAntPorts> 2 </ulNumAntPorts>
</macCfgCmn>
```