OpenRAN 5G NR Base Station Platform

Requirements Document

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2. Introduction

This document describes the technical specifications for a white box 5G NR base station that operators can deploy in their mobile networks to provide 5G NR connectivity. The document describes the necessary requirements for deployment by participating operators.

2.1. Goal

The OpenRAN 5G NR group in TIP, and this technical specification aim to define an open and disaggregated platform based on commercial off-the-shelf components and disaggregated software that can replace traditional proprietary RAN solutions; reducing deployment and operational costs while providing the scalability required for the 5G evolution.

2.2. Scope of the document

The aim of this document is:

- To describe the platform architecture and requirements that will need to be met by the system in terms of HW and SW features.
- To describe the end-to-end network architecture covering interconnecting aspects between the RAN and the rest of the network.
- To describe the management plane of this product.

This document captures the technical specifications used to develop an Open RAN reference architecture design that is utilized for the technical discussion with candidate platform HW & SW developers

2.3. Document Structure

This document is structured as follows:

- Chapter 2: Introduction
- Chapter 3: Platform Architecture & HW/SW specifications
- Chapter 4: Glossary

3. Platform Architecture & Hardware/Software Specifications

3.1. Use case and Assumptions

There are two use cases for this 5G NR whitebox base station. One is for small cell with 16T16R, and the other is for the macro cell with 64T64R.

For the 16T16R outdoor small cell, it shall support multi user MIMO up to eight layers in the downlink and four layers in the uplink per cell. For the 64T64R macro cell, it shall support multi user MIMO 16/8 layers in the downlink and 8/4 layers in the uplink per cell. Both small and macro cell shall support sub 6 GHz, n41 spectrum for up to 100MHz bandwidth with NSA and SA architecture. The high level use case parameter and requirements are shown in the table below:

Attribute	Unit	Specification
Site Type		Small Cell /Macro Cell
Air Interface		5G NR
Duplexing		TDD, FC2
Carrier Frequency		N41, 2.5GHz
Number of Tx/Rx		16T16R/64T64R
MIMO Layers		For 16T16R, up to 8/4 DL/UL multiuser layers, 4/2 DL/UL SU layers
		For 64T64R, 16/8 DL/UL MU layers, 4/2 DL/UL SU layers
Carrier Bandwidth	MHz	20/40/50/60/80/100
EIRP	dBm	For 16T16R, ~61 dBm; 64T64R, 84.6 dBm
RAN Architecture		Split Architecture
Use Case		5G Outdoor

Table 1 Use Case Assumptions

3.2. Platform Architecture

This platform is designed based on an open interface RAN architecture. The RAN split includes two parts. First part is the lower layer RAN split between the antenna integrated Radio Unit (RU) and the Distributed Unit (DU). The second part is the higher layer RAN split, a 3GPP standard F1 interface between the DU and the Centralized Unit (CU). The F1 interface shall comply with 3GPP F1 interface specifications.

For deployment, DU and CU could be in different locations, or in the same location and in the same box. The current design selects the former as a way of implementation. The below diagram shows the high level architecture:

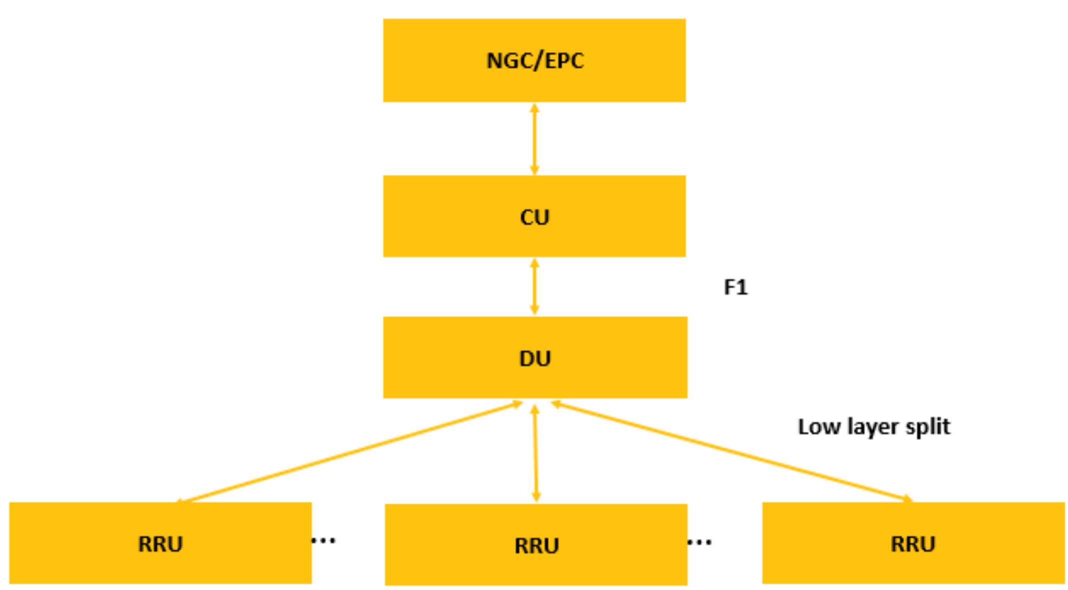

Figure 1 High Level Architecture Block Diagram

Below is a diagram that shows an example architecture of the use case for small cell 5G NR supporting both NSA and SA architecture (as an underlay to the existing macro cell architecture providing LTE and NR services):

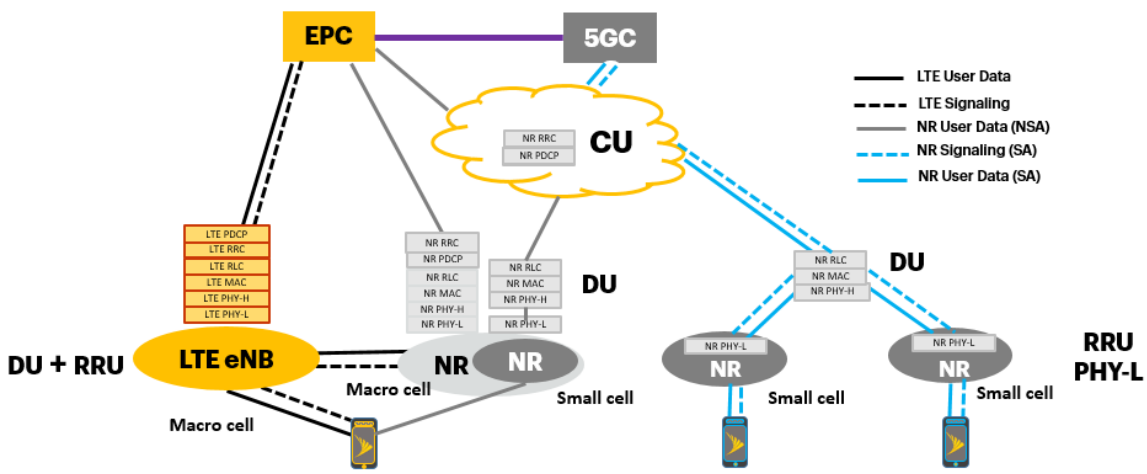

Figure 2 Example Architecture of Use Case Deployment Scenario

3.3. Radio Unit

The Radio Unit (RU) needs to operate anywhere in the 2496-2690 MHz spectrum of n41 band with total bandwidth of 194 MHz. It will use TDD mode with 5 ms uplink/downlink frame structure as DSUDD, and S subframe in the format of 9DL:3GP:2UL.

The panel antenna has the beamforming capability implemented through phased weights applied to the antenna configuration , to support multi user MIMO up to 16/8 layers in the downlink and 8/4 layers in the uplink per cell. The specific antenna design in terms of the number of antenna elements and antenna gains, as well as the output of the power amplifier are not specified here and it is left for vendor implementation as long as it meets the EIRP requirement. Below is the table for the RU parameters:

	Unit	Specification
Operating Frequency	MHz	2496-2690 (n41)
Duplexing		TDD, FC2
Cell Configuration		Sector
Number of Tx/Rx		16T16R/64T64R
Numerology		SCS=15KHz, 30KHz
Operation Total BW		194MHz, contiguous
Carrier Bandwidth	MHz	20/40/50/60/80/100
Regulatory Requirement		Meet OOBE spectrum mask requirements at full Tx with FCC certification

Table 2 Radio Unit Parameters

3.3.1. Radio Unit Performance

The peak data rates shown in the table below are based on the assumptions of 100 MHz BW, 8 layer downlink and 4 layer uplink multi-user MIMO and the frame structure in section 3.3. For the single user MIMO, up to four layers in the downlink and up to two layers in the uplink are required. Modulation and block floating compression are mandatory features in this specification.

Below is the table for the RU performance:

	Unit	Specification
Peak Data Rate	Gbps	DL/UL 6.68/0.86 (100MHz BW, 16/8 DL/UL layer)
		DL/UL 3.34/0.43 (100MHz BW, 8/4 DL/UL layer)
MIMO support		MU-MIMO (DL/UL, up to 16/8 layers), SU-MIMO (DL/UL, 4/2 layers)
Modulation DL		QPSK, 16QAM, 64QAM, 256QAM
Modulation UL		BPSK, QPSK, 16QAM, 64QAM
Connected users		1024
Compression Support		Modulation compression, block floating compression

Table 3 Radio Unit Performance Parameters

3.3.2. Radio Unit Interface & Architecture

This 5G NR radio unit shall be connected to DU through fronthaul RAN low layer split. The DU shall be connected to the CU which connects to the 5G enabled EPC to work along with LTE eNB in Non StandAlone (NSA) mode. At a later time, when the 5G core is ready, the CU will connect to the 5G core as well to support StandAlone (SA) mode Option 2.

For the local display Status Indicator LED in the radio unit, it shall have at least the following status indicators:

- One for fronthaul transport interface (optical fiber or wireless) indicating on/off status
- One for power supply to show on/off status
- One for radio transmission link on/off status

Below is the Table 4 for the RU interface & Architecture requirement:

	Unit	Specification
RAN Architecture		SA Option 2, NSA Option 3x
Synchronization		GPS
Fronthaul Protocol		RAN split option 7-2x
Data Interface		eCPRI
Fronthaul Connectivity		For small cell, 1x10GE, SFP+ or MW; for macro cell, 1x25 GE, SFP+ or MW
Local Connectivity		RJ45
Display		Status indicators

Table 4 RU Interface & Architecture Requirements

3.3.3. Radio Unit Form Factor, Environmental and Power Supply Requirements

This radio unit is designed for the outdoor with a phased array panel which can be mounted on the wall or on a pole. Table 5 is for the power supply, power consumption, weight and environmental specifications:

	Unit	Specification
Form Factor/mounting		Outdoor, panel, pole/wall mount
Nominal size & Weight		For small cell, < 23 Liter & < 20 lb; For macro cell, < 91 Litre, < 55 Kg
Power consumptions		For small cell, <120 W; for macro cell <2KW
Power supply		For small cell, 110 AC mandatory, -48 DC optional; for macro cell, -48DC
Temperature		-40 °C to +55 °C
Ingress Protection		For small cell, IP66; for macro cell IP67
EMC		In compliance with 3GPP TS 38.113

Table 5 RU Form Factor, Environment, Power Supply Requirements

3.3.4. Radio Unit Hardware

The radio unit shall be designed in a modular format that each module is connected through a standard interface such as PCIe. The RU is composed of RF front end, digital front end, Ethernet fronthaul transport, synchronization and lower PHY layer baseband processing. The RU functional module diagram is shown in Figure 3:

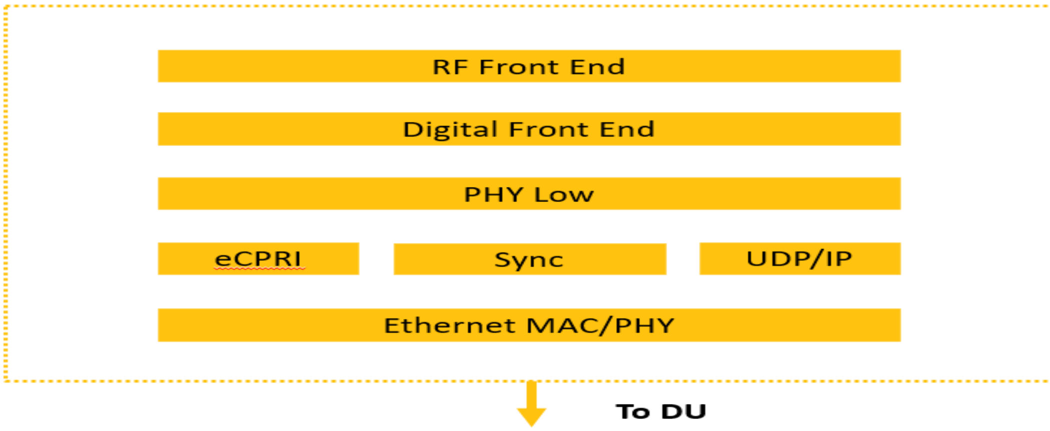

Figure 3 Radio Unit Functional Module

The lower PHY layer processing shall be done by using FPGAs or ASICs. It includes functions of FFT/iFFT, CP addition, PRACH and digital beamforming. The RF front end is composed of antenna element arrays, bandpass filters, power amplifiers, low noise amplifiers, digital analog converters, and analog digital converters. The digital front end consists of digital up converter, digital down converter, digital predistortion and crest factor reduction. The RU hardware architecture is shown in Figure 4:

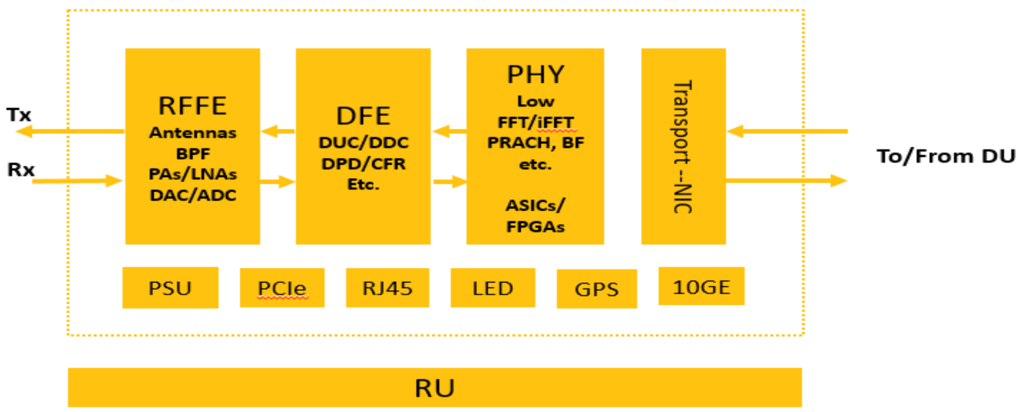

Figure 4 Radio Unit Hardware Architecture

3.3.5. Radio Unit Beamforming

The radio unit shall support the following functions in beamforming:

	Unit	Specification
3D Antenna Beamforming		Support both horizontal and vertical beamforming
Calibration		Support Tx/Rx calibration for beamforming
Pcell beamforming on gNB		Support SRS based beamforming, Rel. 15 CSI-RS based beamforming, Class B Type 1, Hybrid SRS+CSI-RS based beamforming
Scell beamforming on gNB		Rel. 15 CSI-RS based beamforming, Class B Type 1, Hybrid SRS+CSI-RS based beamforming
Beamforming on control channel		5G NR shall support beamforming on control channel per user with switched beamforming
EMS		EMS shall support for calibration cycle configuration

3.4. Distributed Unit

The Distributed Unit (DU) connects to multiple radio units in the southbound interface, and to the Centralized Unit (CU) in the northbound interface. The DU has a centralized, virtualized baseband pool that performs the functions of high PHY layer, MAC and RLC, synchronization, OAM, Ethernet, as well as F1 interface function. The DU function module diagram is shown in Figure 5:

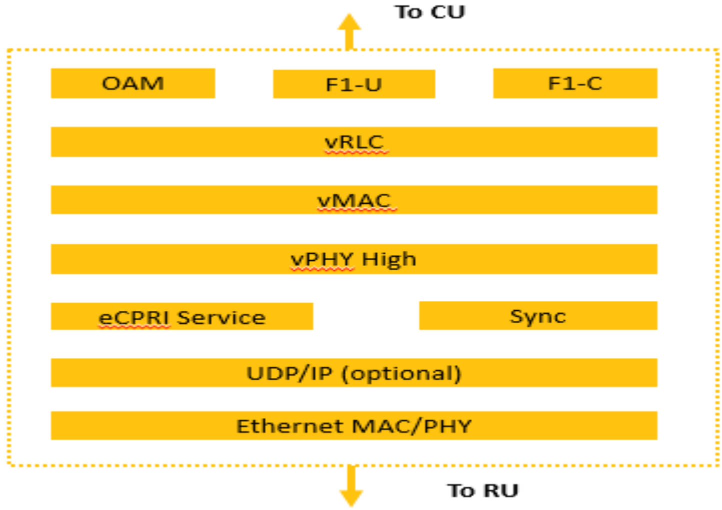

Figure 5 Distributed Unit Functional Module Diagram

3.4.1. Distributed Unit Performance

The DU shall support each RU that is connected with a multi user MIMO with up to eight layers in the downlink and four layers in the uplink and single user MIMO with up to four layers in the downlink and two layers in the uplink. Table 6 shows DU performance, interface and architecture requirements:

	Unit	Specification
MIMO support		MU-MIMO (DL/UL, 16/8 layers), SU-MIMO (DL/UL, 4/2 layers)
Modulation DL		QPSK, 16QAM, 64QAM, 256QAM
Modulation UL		BPSK, QPSK, 16QAM, 64QAM
Latency		Control plane <20ms, user plane <4ms DL/UL
RAN Architecture		SA Option 2, NSA Option 3x
Synchronization		IEEE1588v2, GPS optional
Fronthaul Protocol		RAN split option 7-2x
Data Interface		eCPRI
Data Throughput	1U server	min. 4x10GE, scalable by adding more U

Table 6 DU Performance, Interface, Architecture Requirements

3.4.2. Distributed Unit Capacity and Software Support

The distributed unit is the baseband processing unit that handles high physical layer, MAC and RLC layer with network function virtualization. The operating system for DU shall support RHEL CentOS 7.x, Ubuntu 16.xx or later release versions. RAN performance KPIs shall be guaranteed under the virtualization implementation. Features such as DPDK, SR-IOV are required to enhance the performance. Given the maturity and security, virtualization shall be implemented in VM. Implementation in container will be considered in the future when it becomes mature. Table 7 is the requirements for the DU capacity and software support:

	Unit	Specification
Baseband pooling		One DU supports 20 RUs, min 8 RUs
Baseband processing		Support PHY-Hi/MAC/RLC layer processing on GPP
Baseband Virtualization		Support PHY-Hi/MAC/RLC layer network function virtualization
Operating System		Support RHEL CentOS 7.x, Ubuntu 16.xx ->18.xx
VM Support		Support KVM hypervisor, VMware ESXi 5.x
Containers Support		Support Docker, K8s, LXC/LXD
SW Feature Support		DPDK, SR-IOV

Table 7 DU Capacity and Software Support

3.4.3. Distributed Unit Form Factor, Environment and Power

The distributed unit form factor shall be designed for both outdoor and indoor scenarios. For the outdoor case, an enclosure shall be provided for the wall mount or pole mount. For the indoor case, a standard 19" rack mount shall be used. When deployed outdoor, the environment temperature requirement shall be met. Table 8 shows the requirements:

	Unit	Specification
Form Factor		Outdoor enclosure pole mount or indoor 19" rack mount
Nominal size & Weight	1U	For outdoor size <45 Liter, weight < 35 lb, scalable to more than 1U
Power consumption		<400 W
Power supply		-48 DC or 110 AC
Temperature		−40 °C to +55 °C
EMC		In compliance with 3GPP TS 38.113

Table 8 DU Form Factor, Environment and Power Requirements

3.4.4. Distributed Unit Hardware

The distributed unit hardware architecture is shown in Figure 6 below:

FPGA shall be used to process the FEC function with CPU cores to process the high physical, MAC, and RLC layer.

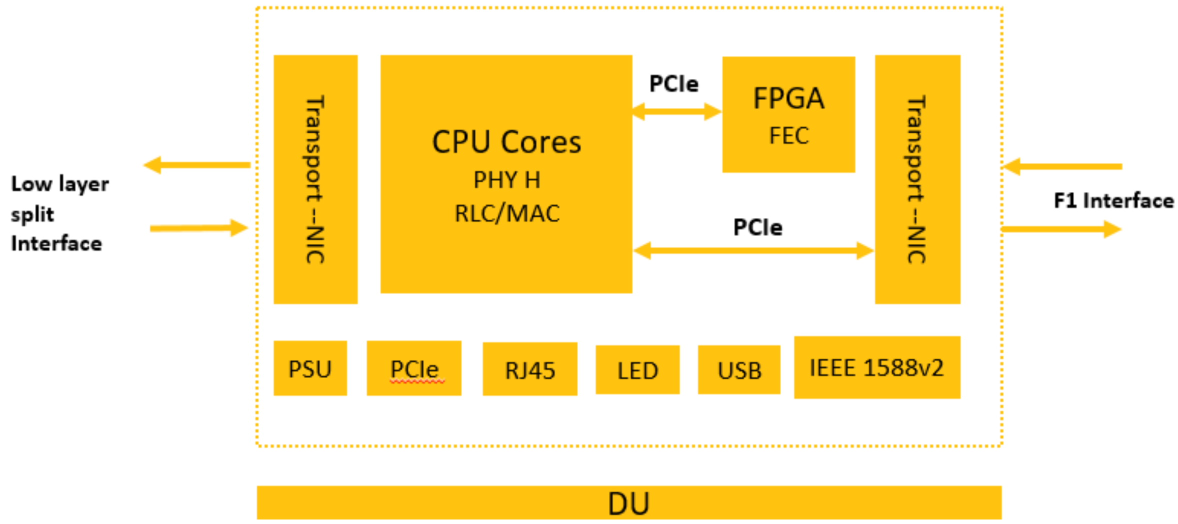

Figure 6 DU Hardware Architecture

3.5. Centralized Unit

The Centralized Unit (CU) shall perform the layer three functions such as the functions of RRC, PDCP, SDAP, X2-U, F1-U, NG-U, S1-U, X2AP (X2-C), F1AP (F1-C), NGAP (NG-C), S1AP (S1-C) and OAM . Figure 8 is the diagram that shows the functions that the CU will perform:

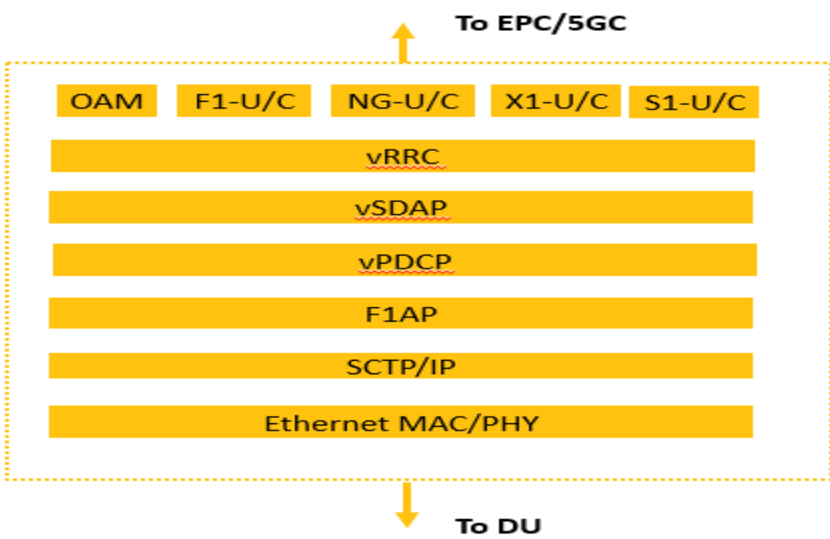

Figure 7 CU Functional Modules Diagram

NG-U/C interface is used to connect with the 5G core network while the S1-U/C interface is used to connect to the 5G enabled EPC. The simultaneous connection with both core networks is required in order to support different UE capabilities. The initial implementation with connecting to EPC only for NSA architecture is accepted.

3.5.1. CP/UP Separation

TBD

3.6. 5G NR OpenRAN Hardware End to End Architecture

Figure 9 shows the 5G NR OpenRAN hardware end to end architecture.

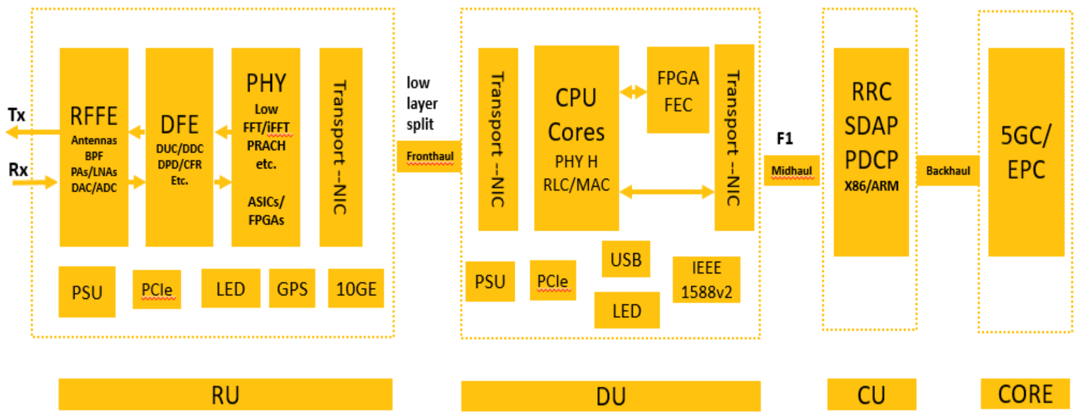

Figure 8 Hardware End to End Architecture

3.7. Management Interfaces and Miscellaneous

The Element Management System (EMS) of the 5G OpenRAN system shall provide interfaces that comply with 3GPP Integration Reference Points (IRP) specifications. The EMS shall provide management, configuration, monitoring, optimization and troubleshooting capabilities. The interface of 5G OpenRAN NR for the management shall be an IP based interface that supports management protocols such as NETCONF, YANG model etc.

For the management of the fronthaul interface between RU and DU, it shall comply with the O-RAN WG4 published management plane specifications. It shall be integrated with the EMS system.

3.7.1. Unified Management System

TBD

3.8. Software Architecture & Features

TBD

4. Reference

1. Control, User and Synchronization Plane Specifiction, ORAN-WG4.CUS.0-v02.00
2. Management Plane Specification, ORAN-WG4.MP.0-v02.00.00 (copyright © 2019 O-RAN Alliance and referenced with permission from O-RAN)

5. Glossary

BPF	Bandpass Filter
CFR	Crest Factor Reduction
CP	Control Plane
CU	Centralized Unit
DU	Distributed Unit
DDC	Digital Down Conversion
DUC	Digital Up Conversion
DFE	Digital Front End
DPD	Digital PreDistortion
EMS	Element Management System
FEC	Forward Error Correction
EPC	Evolved Packet Core
FPGA	Field Programmable Gate Arrays
IRP	Integration Reference Points
LNA	Low Noise Amplifier
MAC	Media Access Control
NETCONF	Network Configuration Protocol
NGC	Next Generation Core
NSA	Non Stand Alone
NIC	Network Interface Card
O-RAN	Open Radio Access Network
PCIe	Peripheral Component Interconnect Express
PDCP	Packet Data Convergence Protocol
PSU	Power Supply Unit
RFFE	Radio Frequency Front End

RLC	Radio Link Control
RRC	Radio Resource Control
RU	Radio Unit
SA	Stand Alone
SDAP	Service Data Adaptation Protocol
UP	User Plane