OCUDU Knowledge Base

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Knowledge Base

This section covers the 5G NR and O-RAN architecture concepts that underpin OCUDU: how a gNB is structured, how its components interact, and how the interfaces between them are defined.

If you are new to the architecture, start with the O-RAN Overview. The other articles build on that foundation.

O-RAN Overview

The architecture of an O-RAN compliant gNB, split 7.2, and how OCUDU implements it.

CU/DU Components

The roles and protocol layers of the CU, DU, and RU, and the boundaries between them.

gNB Interfaces

The purpose, message types, and connected components for the E1, E2, F1, FAPI, NG, O1, and Open FrontHaul interfaces.

Supported E2 Metrics

E2SM-KPM report styles and metrics supported by OCUDU, with source nodes, units, and label restrictions.

COTS UEs

Commercial UEs tested with OCUDU, with confirmed bands, configurations, and user-reported working devices.

Glossary

5G NR and O-RAN terms and abbreviations used throughout the OCUDU documentation.

O-RAN Overview

This document aims to provide a basic understanding of O-RAN compliant gNBs, and how we have implemented this with OCUDU. A further deep dive can be found in our Developer Guide.

Introduction

5G Radio Access Networks (RANs) introduce the gNodeB (gNB), the next evolution of the eNodeB found in LTE networks. With Release 15, 3GPP introduced a flexible architecture to the 5G RAN. This splits the gNB into the Centralized Unit (CU), the Distributed Unit (DU) and the Radio Unit (RU).

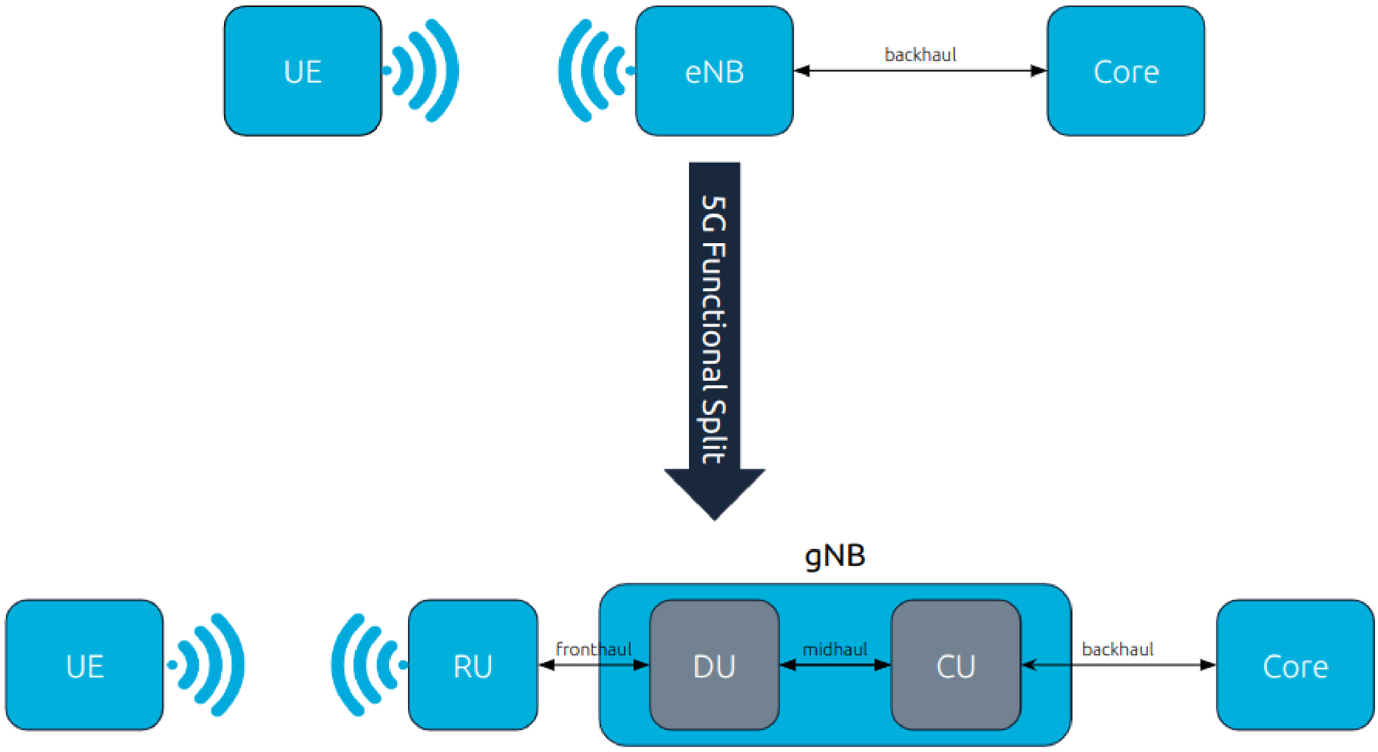
This new architecture brings multiple new interfaces: the CU and DU communicate over the F1 interface, gNBs communicate with each other over the Xn interface and the RAN and the Core communicate over NG interface. Within this new release there are 8 functional splits, which dictate how and where the RAN is split in the CU, DU and RU.

The Open-RAN (O-RAN) Alliance defined option 7.2x, which is a low-level split for Ultra Reliable Low Latency Communication (URLLC) and near-edge deployments. O-RAN standards also introduce the non-Real Time and near-Real Time RAN Intelligence Controller, or nonRT-RIC and nearRT-RIC, to the 5G RAN. This splits the gNB further, into the DU-low, DU-high, CU-CP and CU-UP

The aim of O-RAN is to promote virtualized and disaggregated RANs, with a highly interoperable, multi-vendor approach.

Split 7.2x Architecture

As outlined in the introduction, Release 15 introduces the “Functional Split” to the 5G gNB. This separates the gNB into the CU and DU. A simplified outline of this change is illustrated in the following figure.



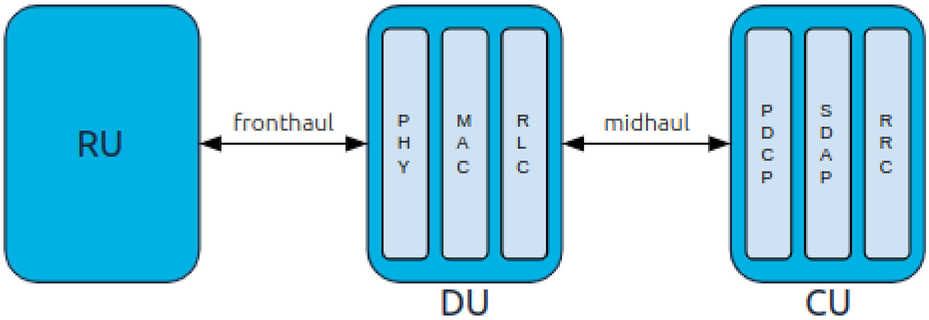
O-RAN standards further define split 7.2x. This informs how the CU and DU are separated, and which layers of the stack are contained in each. Before looking into Split 7.2x further, it is worth examining the CU/ DU split at a higher level.

At a basic level the CU and DU layer functions are split as follows:

CU/ DU Split

CU	DU
RRC	RLC
SDAP	MAC
PDCP	PHY

The above shows which layers are located in the CU and DU. This is shown graphically below.



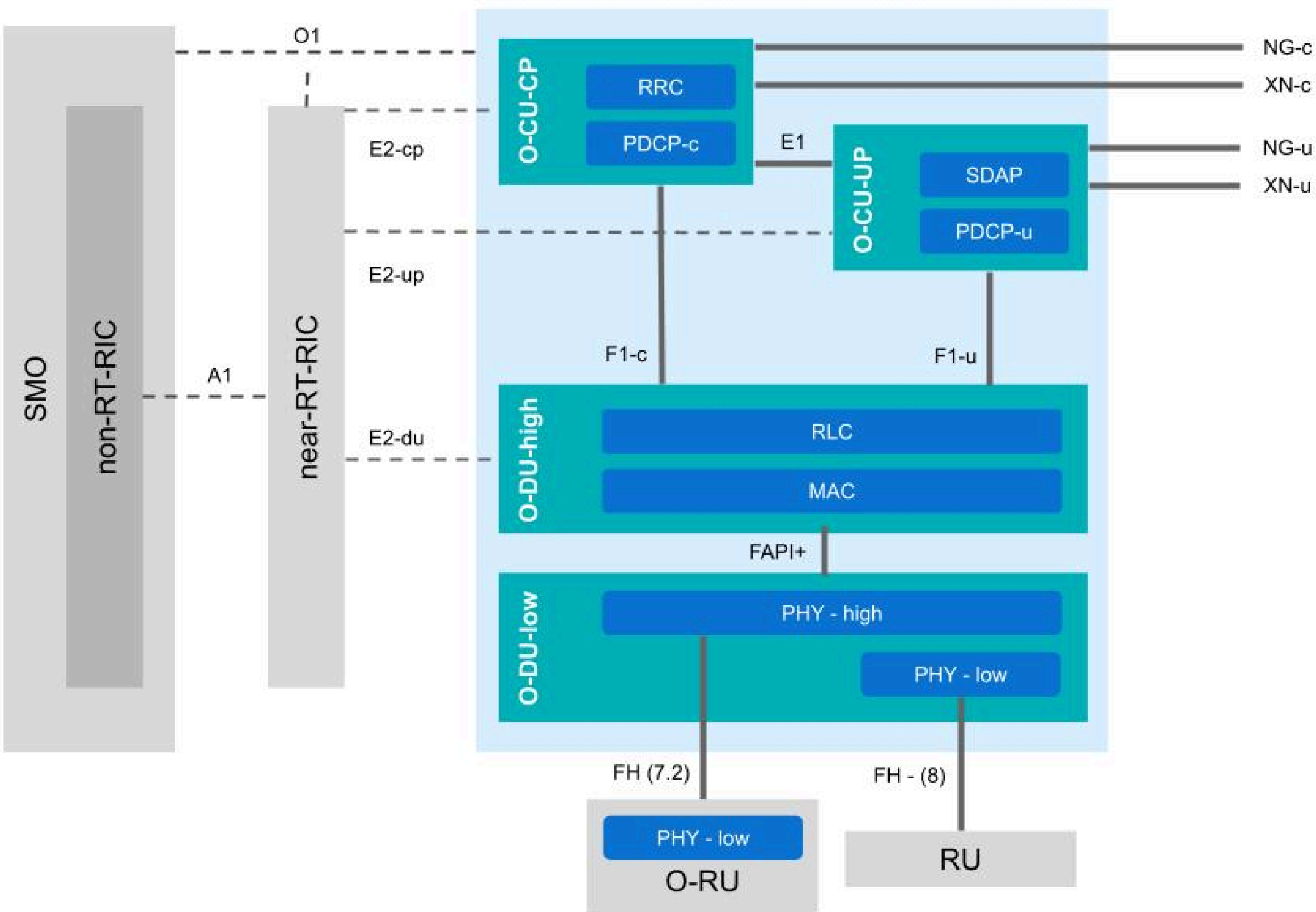
This is an overly simplified view of how the CU and DU might look. In practice, the CU and DU are split further, with multiple interfaces between them.

We will now look specifically at Split 7.2x. In this, the CU is split into the control plane and the user plane, resulting in two elements - the CU-CP and CU-UP. The O-RAN DU is split into the DU-high and DU-low. Not only are the CU and DU split, but the layers they contain are also separated to allow for further control and acceleration of certain procedures - e.g. PDCP and PHY.

The further separation of the RAN components means more interfaces must be introduced to facilitate communication between them. These interfaces are as follows:

- The CU-CP, CU-UP and DU-high will be connected to the nearRT-RIC via the **E2** interface.
- Backhaul from the CU-UP/CP will be done via the **NG** and **XN** and interfaces.
- The CU elements will communicate via the **E1** interface
- The CU-UP and CU-CP will communicate with the DU-high via the **F1-u** and **F1-c** interfaces respectively.
- The DU-high and DU-low communicate via a **FAPI+** interface.

The following figure shows the complete architecture of an O-RAN compliant gNB, implementing Split 7.2x.



The gNB is shown here in the blue shaded area. The CU-UP and CU-CP are clearly illustrated, as is the split between the high and low DU, and the interfaces between them. This diagram also shows how the nearRT-RIC is connected to the gNB and the nonRT-RIC. The RU is shown here in two versions, the RU (Split 7.2x) and a non-O-RAN RU (Split 8). Split 7.2 moves to low PHY out to the RU , while Split 8 keeps it within the DU-low. The frontHaul interface used here is typically eCPRI.

To be O-RAN compliant a gNB must implement the CU and DU as shown above, while also having support for the interfaces needed for the nearRT-RIC, nonRT-RIC, and the RU and RU.

OCUDU

OCUDU is fully O-RAN compliant. While users will still be able to stand up a monolithic gNodeB on a single machine in minutes, our new gNB also allows users to distribute the RAN functionality across the machines and geography of their choice. All of the elements in the blue shaded area above are implemented in OCUDU, along with all of the interfaces. This allows users to easily use third party RICs, PHY solutions and other O-RAN compliant hardware and applications with the gNB.

Further Reading

For further information and reading, you can take a look at the following resources:

- ShareTechnote: Open RAN
- O-RAN SC Docs
- O-RAN Alliance website

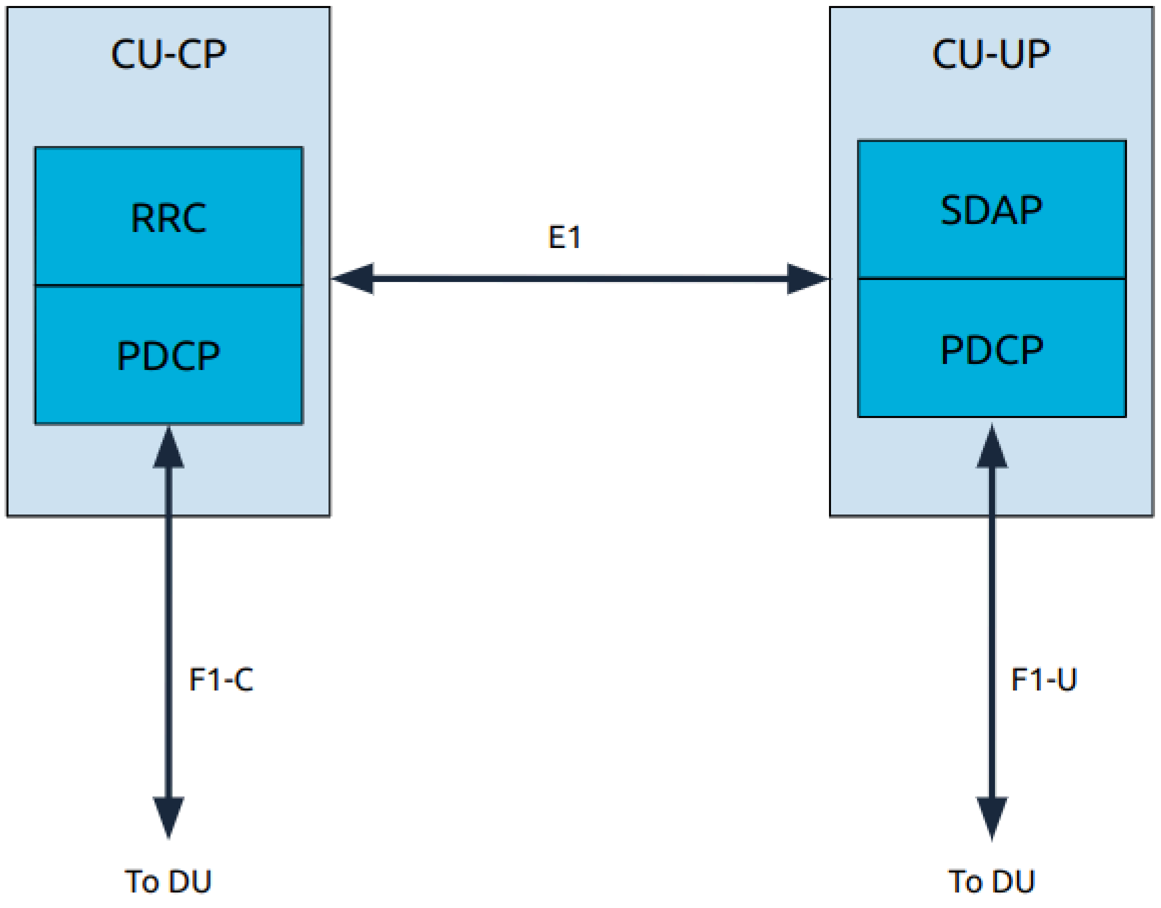
CU/DU Components

As outlined in the O-RAN Overview the 5G NR gNB introduces a flexible architecture. Splitting the gNB into the CU, DU and RU.

This section of our knowledge base aims to go through these components in further detail. Outlining the main functions of each, their layers and the interfaces between them.

Centralized Unit (CU)

The CU has the following architecture:



In the CU the user plane and control plane are split into two new submodules: the CU-CP and the CU-UP.

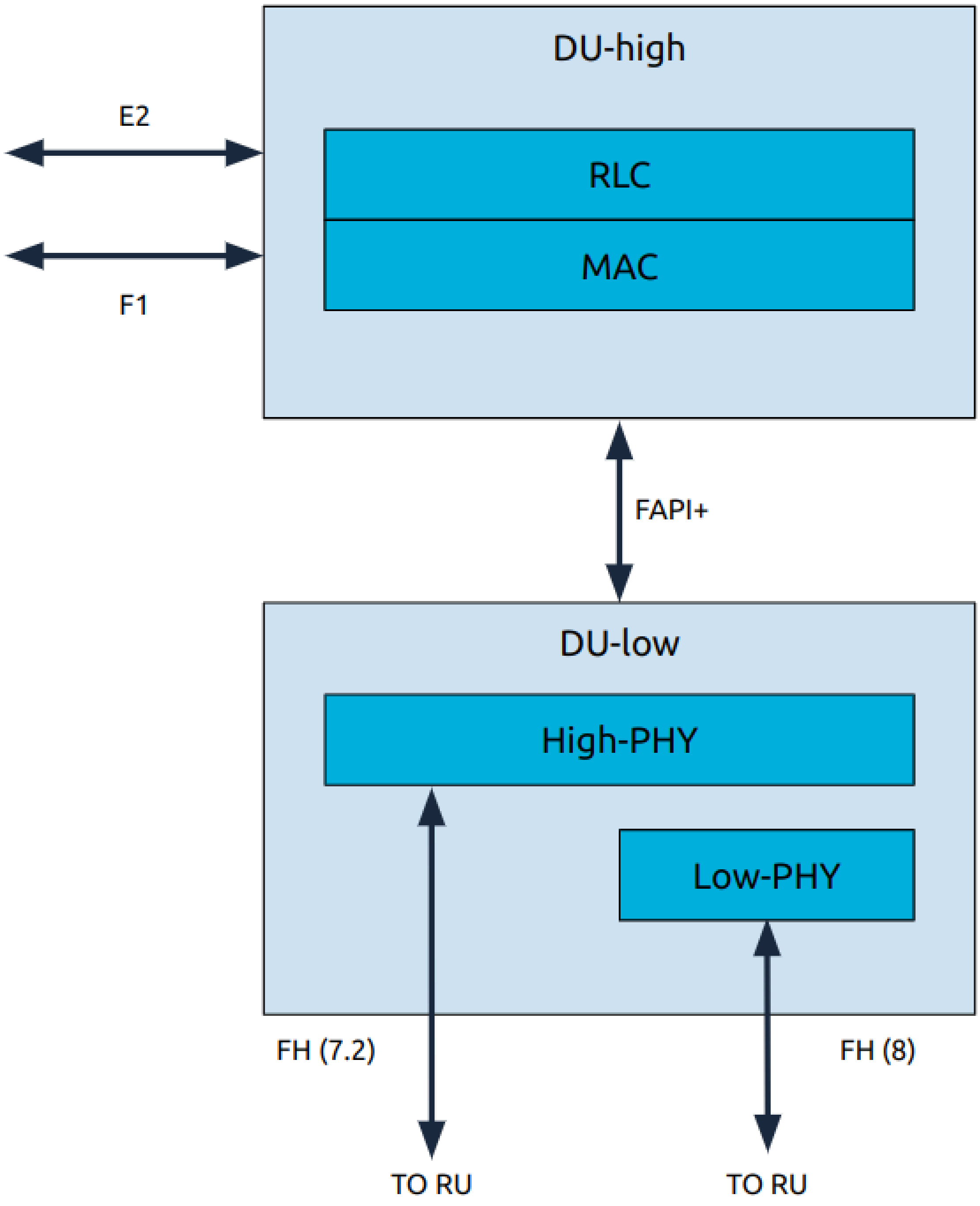
The key points are:

- The user plane contains the SDAP and PDCP layers.
- The control plane contains the RRC and PDCP layers.
- CU-UP and CU-CP are interconnected through the E1 interface; this interface is used for control signalling.

- CU-UP is connected to the DU(s) through the F1-U interface.
- CU-CP is connected to the DU(s) through the F1-C interface.

Distributed Unit (DU)

The DU has the following architecture:



The DU is composed of L1 and L2 functional blocks which communicate using the FAPI+ interface.

There are two approaches to how the low-PHY is implemented, it can either be in the DU-low or the RU. If split 8 is being used then the low-PHY will be located in the DU-low, if split 7.2x is being used it will be located in the RU.

DU-high

The DU-high contains L2 functional blocks, and communicates with the nearRT-RIC and CUs.

The main interfaces are:

- E2 Handler
  - Terminates the E2 interface from the near-RT RIC. Handles the following tasks:
  - E2/SCTP interface termination
  - E2AP protocol message send and receive
  - Configure KPI measurements in L2 and L1 modules
  - Metrics reporting over E2
  - Relays actions to other modules based on E2 messages
  - Relaying response over E2
- F1 Control plane
  - Performs tasks related to cell management, UE management and semi-static air interface resource management at the cell level.
- F1 User plane
  - Perform tasks related to tunnel management, DL and UL data transmission and DL flow control (RLC feedback).

The main components are:

- RLC
  - Transfers the control and data messages between MAC layer and CU.
- MAC
  - Uses the services of the PHY to send and receive, and multiplexing and de-multiplexing of data on the various logical channels.
  - Responsible for scheduling UL and DL resources for the cell and UE procedures.
  - Interfaces with the DU-low and handles L1 messaging.

DU-low

The DU-low executes the following tasks within L1 functional blocks:

- **L2 FAPI processing:** handle L2 interface request/response FAPI messages from the DU-high.
- **Timing events processing:** Handle timing related operations and triggers scheduled periodic tasks.
- **FEC acceleration processing:** handle FEC related operations and pass the FEC requests to hardware and invokes callback functions when the hardware finishes.
- **FrontHaul processing:** handle all of the front haul related TX/RX operations.
- UL Task scheduling
- DL Task scheduling
- PUSCH, PUCCH, PRACH processing (UL)
- PDSCH, PDCCH, PBCH processing (DL)

The high-PHY in particular is responsible for:

- **UL:** PUSCH, PUCCH, PRACH
- **DL:** PDSCH, PDCCH, PBCH
- UL/DL reference signals (DMRS, PTRS, SRS, PSS, SSS)
- Fronthaul handler
- FAPI handler
- Hardware accelerator handler
- Timing synchronization
- L1 Task control module

gNB Interfaces

As outlined in the O-RAN Overview the 5G NR gNB introduces a flexible architecture. Splitting the gNB and introducing multiple new interfaces.

This section of our knowledge base aims to go through these interfaces in further detail. Outlining the components they connect, the types of messages they carry and their purpose.

E1

The E1 interface connects the CU Control Plane (CU-CP) to the CU User Plane (CU-UP). The application protocol (E1AP) is implemented on top of SCTP using ASN1 messages. Its main function is the bearer context management.

E2

The E2 interface connects the near-RT RIC to an E2 node (E2-du, E2-cp, E2-up). The application protocol (E2AP) is implemented on top of SCTP using ASN1 messages (similar to E1 interface defined by 3GPP). Its main functions are:

- Provide Near-RT RIC services:
  - Report
  - Insert
  - Control
  - Policy

Support functions include:

- Interface management
- RIC service updates

The main functions outlined above include the following procedures:

- **Report:** Subscription request to the E2 node with information to configure how reports should be sent by the node back to the RIC.
- **Insert:** Subscription request to the E2 node with information to configure an insert message which will be used to suspend an ongoing procedure in the node. The RIC then decides how to deal with the suspended procedure (override, cancel, ...).
- **Control:** Control message to the E2 node to instantiate a procedure or resume a previously suspended one.

- **Policy:** RIC requests a node to execute a specific policy during the normal functioning of the E2 node.

The E2 service model defines the functions in the E2 node which may be controlled by the RIC. For each exposed function in the service model, the RIC may monitor, suspend, stop, override or control via different policies the behavior of the E2 node.

The current specification (as of March 2021 specs) defines two service models which are specific implementations of the above points:

1. **Network Interface (NI):** exposure of network interfaces and modification of the messages.
2. **Key Performance Measurement (KPM):** Performance monitoring of set metrics within the RAN.

The KPM service model defines a catalogue of performance measurements that an xApp can subscribe to via the near-RT RIC. For the metrics currently exposed by OCUDU, see Supported E2 Metrics.

F1

The F1 interface connects the CU to the DU. Its is split into two interfaces. The F1-C connects the CU-CP to the DU, while the F1-U conntects the the CU-UP to the DU.

F1-C

The F1-C interface connects the CU-CP to the DU. The application protocol (F1AP) is implemented on top of SCTP using ASN1 messages. Its main functions are:

- UE context management
- RRC message transfer
- Warning message transmission
- System information
- Paging

F1-U

The F1-U interface connects the CU-UP to the DU. It transports user plane data as GTP-U packets over UDP/IP, with one GTP-U tunnel established per Data Radio Bearer (DRB). Each tunnel is identified by a Tunnel Endpoint Identifier (TEID). Tunnel endpoints are configured via E1AP (between CU-CP and CU-UP) and F1AP (between CU and DU). Its main functions are:

- Downlink user data transfer from CU-UP to DU
- Uplink user data transfer from DU to CU-UP
- Flow control and packet loss detection

FAPI

FAPI is an interface defined by the Small Cell Forum (SCF) between the MAC layer and the Physical (PHY) layer. The 5G FAPI specification (SCF222) defines two planes:

- **P5:** The control interface, responsible for PHY mode management including configuration, start, and stop procedures.
- **P7:** The data path interface, used for per-slot scheduling and data exchange. Key messages include DL_TTI.request (downlink scheduling), UL_TTI.request (uplink scheduling), TX_Data.request (downlink payload delivery), and RX_Data.indication (uplink payload reception).

NG

The NG interface connects the CU to the Core (AMF). Its is split into two interfaces. The NG-C connects the CU-CP to the AMF, while the NG-U conntects the the CU-UP to the AMF.

NG-C

The NG-C interface connects the CU-CP to the AMF. The application protocol (NGAP) is implemented on top of SCTP using ASN1 messages. Its main functions are:

- PDU session management
- UE context management
- UE mobility management
- Paging
- Transport of NAS messages
- Configuration transfer
- Warning message transmission
- NRPPa transport
- Trace
- Location reporting
- UE TNLA binding
- UE radio capability management
- Data usage reporting

NG-U

The NG-U interface connects the CU-UP to the UPF.

O1

The O1 interface is aligned to the 3GPP specifications for RAN element management. It connects the multiple elements of the gNB to the Service Management and Orchestration (SMO) platform. The following Fault, Configuration, Accounting, Performance and Security (FCAPS) functions are supported through the O1 interface:

- Performance management (PM)
- Configuration management (CM)
- Fault management (FM)
- File management
- Communication surveillance (heartbeat)
- Tracing
- Physical network function (PNF) discovery
- PNF software management

O1 provisioning operations use NETCONF for communication using YANG files for data exchange, while for CM notifications a RESTFUL HTTP-based solution is used. O1 is the communication protocol to support OAM.

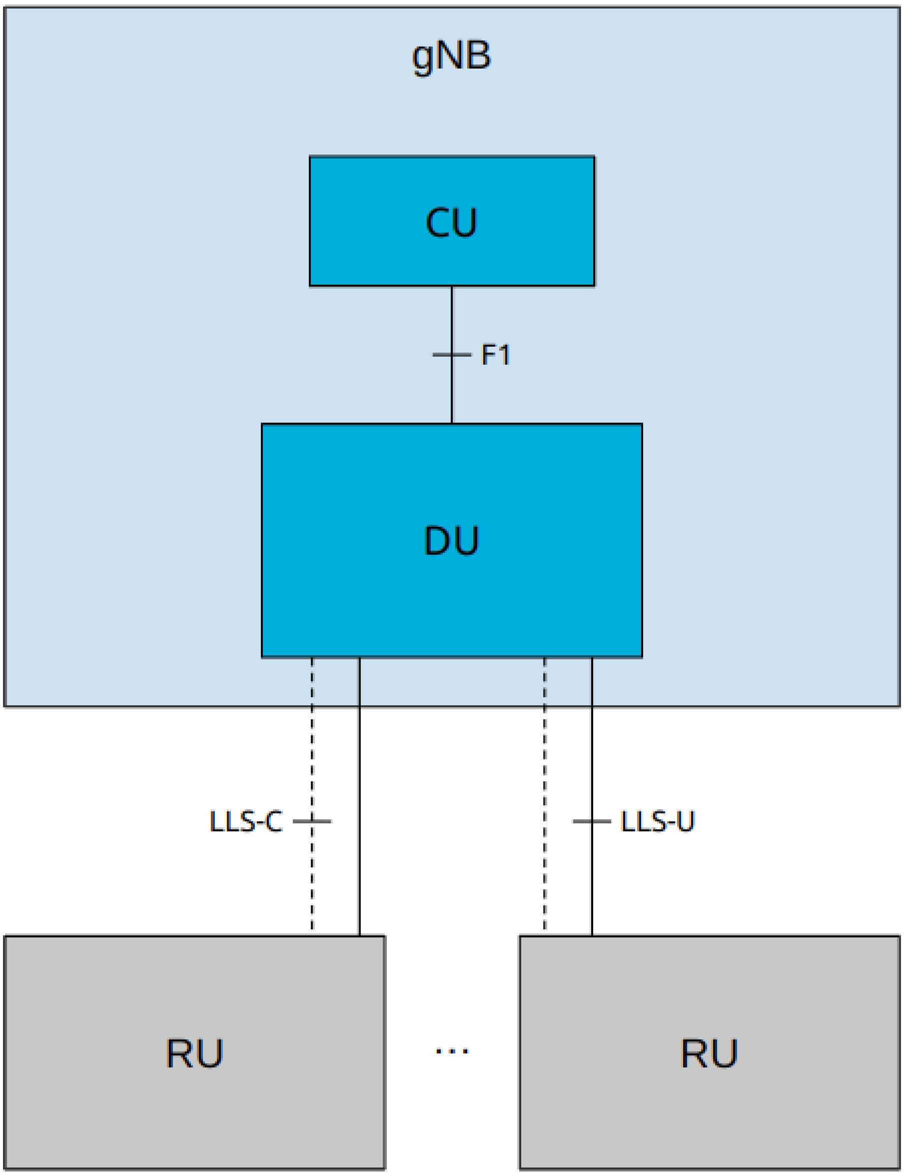
Xn-C

The Xn interface connects CU-CP instances of neighbouring gNBs for inter-gNB signalling. The control plane of the Xn interface (Xn-C) uses the application protocol (XNAP) implemented on top of SCTP using ASN1 messages, as defined by 3GPP TS 38.423. Its main functions are:

- XN Setup (peer-initiated and locally-initiated)
- Inter-gNB mobility and handover signalling

Open FrontHaul

The architecture of a gNB with CU, DU and RUs is shown in the following figure, using split 7.2x. Here, the term Lower Layer Split (LSS) replaces FrontHaul. LLS-C and LLS-U provide the control and user planes over the LLS interface respectively.



The FrontHaul interface is divided into two main planes:

- **CUS plane:** control, user and synchronization
- **M plane:** management

The CUS plane of the FrontHaul interface uses different data flows to exchange data between the DU and the RU. They are:

1. User plane:

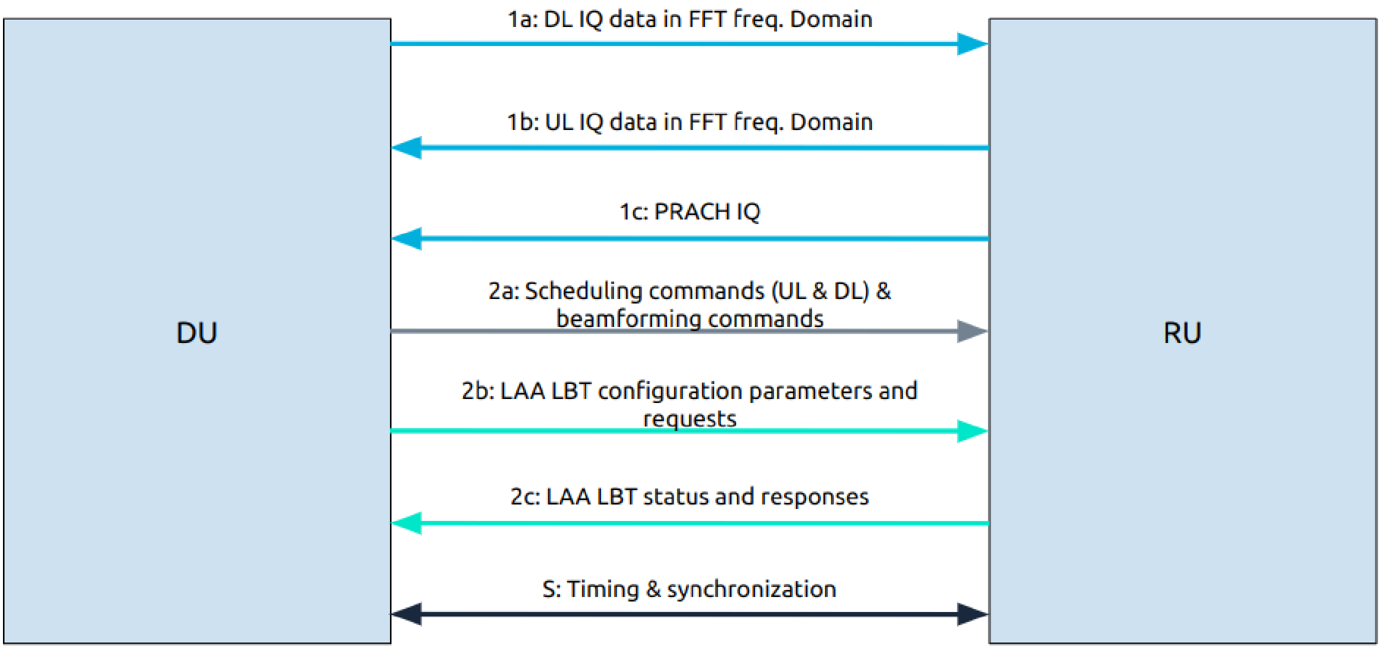
- **1a:** flow of IQ data in FFT frequency domain on DL
- **1b:** flow of IQ data in FFT frequency domain on UL
- **1c:** flow of PRACH IQ data in FFT frequency domain

2. Control plane:

- **2a:** Scheduling commands (DL and UL) & beamforming commands
- **2b:** LAA listen-before-talk (LBT) configuration commands and requests
- **2c:** LAA LBT status and response messages

3. Synchronization plane:

- **S:** timing and synchronization data



The Management plane, not included in the previous figure, uses a similar interface to O1 to set up, configure and perform maintenance tasks on the FrontHaul interface.

The following tables show the protocol architecture for each plane:

Control Plane	**User Plane**	**Sync Plane**	
eCPRI / ROE	eCPRI / ROE		
UDP (optional)	UDP (optional)		
IP (optional)	IP (optional)	PTP	SyncE
Eth L2 + VLAN	Eth L2 + VLAN	ETH L2	
ETH L1	ETH L1	ETH L1	

We can see that for user and control planes we can choose, for transport purposes, between eCPRI or IEEE 1914.3 (Radio over Ethernet).

Supported E2 Metrics

What is E2SM-KPM?

E2SM-KPM (E2 Service Model, Key Performance Measurements) is an O-RAN Alliance service model that lets a near-RT RIC subscribe to performance measurements from an E2 node. It is carried over the E2 interface using E2AP and is defined in O-RAN.WG3.E2SM-KPM-R003-v03.00.

The RIC sends a subscription request specifying which metrics to collect, at what reporting interval, and using which report style. The gNB's E2 agent collects those measurements internally and sends periodic RIC Indication messages back to the RIC with the results.

The three main concepts in an E2SM-KPM subscription are:

- **Report Style:** determines how measurements are aggregated (node-level, per-UE, or conditional).
- **Metric name:** identifies the specific measurement, using names from the 3GPP TS 28.552 or O-RAN specifications.
- **Labels:** optional dimensions attached to a measurement (per-PLMN, per-5QI, per-slice). If no label is requested, the aggregate value is returned.

To enable E2SM-KPM, configure the gNB as described in the Near-RT RIC tutorial.

Metric Coverage

OCUDU implements E2SM-KPM v3.00. The table below shows the current coverage of the full 3GPP and O-RAN metric specifications.

Specification	Defined	Supported
3GPP TS 28.552	278	24
O-RAN WG3	9	3
Total	**287**	**27**

The metric set grows with each release as new internal measurements are exposed through the E2 interface.

Report Service Styles

E2SM-KPM defines six report styles that control how measurements are aggregated and delivered. All six are supported.

Style	Name	Description
1	E2 Node Measurement	Node-level aggregate measurements across all UEs
2	E2 Node Measurement for a single UE	Measurements filtered to one specific UE
3	Condition-based, UE-level E2 Node Measurement	UE-level measurements for UEs matching subscribed conditions
4	Common Condition-based, UE-level Measurement	UE-level measurements across multiple metric types with shared conditions
5	E2 Node Measurement for multiple UEs	Measurements for a named set of UEs
255	Multiple report measurements	Multiple simultaneous subscriptions (Integrated level)

Style 255 is functional but has not been tested against available RICs due to limited xApp support for this mode.

For styles 3 and 4, condition checking is not yet implemented; all active UEs are included in reports regardless of the conditions specified in the subscription request.

Supported Metrics

Each metric is produced by one of three E2 agent instances in the gNB. Each must be enabled separately in the gNB configuration:

- **DU**: the Distributed Unit E2 agent (`enable_du_e2: true`)
- **CU-CP**: the CU Control Plane E2 agent (`enable_cu_cp_e2: true`)
- **CU-UP**: the CU User Plane E2 agent (`enable_cu_up_e2: true`)

Most metrics support the `NO_LABEL` (aggregate) variant only. Where a narrower restriction applies, it is noted in the table.

Throughput and Data Volume

Metric	Source	Unit	Notes
`DRB.UEThpDl`	DU	kbps	DL per-UE throughput; NO_LABEL only
`DRB.UEThpUl`	DU	kbps	UL per-UE throughput; NO_LABEL only
`DRB.RlcSduTransmittedVolumeDL`	DU	kbit	DL RLC transmitted SDU volume (O-RAN); NO_LABEL only
`DRB.RlcSduTransmittedVolumeUL`	DU	kbit	UL RLC transmitted SDU volume (O-RAN); NO_LABEL only

Latency and Delay

Metric	Source	Unit	Notes
`DRB.AirIfDelayUl`	DU	ms	UL air interface delay per DRB; NO_LABEL only
`DRB.RlcDelayUl`	DU	ms	UL RLC delay per DRB; NO_LABEL only
`DRB.PdcpReordDelayUl`	CU-UP	ms	UL PDCP reordering delay; NO_LABEL only
`DRB.RlcSduDelayDl`	DU	0.1 ms	DL RLC SDU delay; NO_LABEL only

Physical Resource Block Utilization

Metric	Source	Unit	Notes
`RRU.PrbTotDl`	DU	%	Total DL PRBs in the scheduling period; NO_LABEL only
`RRU.PrbTotUl`	DU	%	Total UL PRBs in the scheduling period; NO_LABEL only
`RRU.PrbUsedDl`	DU	—	DL PRBs occupied; NO_LABEL only
`RRU.PrbAvailDl`	DU	—	DL PRBs available; NO_LABEL only
`RRU.PrbUsedUl`	DU	—	UL PRBs occupied; NO_LABEL only
`RRU.PrbAvailUl`	DU	—	UL PRBs available; NO_LABEL only

Packet Loss and Success Rates

Metric	Source	Unit	Notes
`DRB.PacketSuccessRateUlgNBUu`	DU	—	UL packet success rate at the Uu interface; NO_LABEL only
`DRB.RlcPacketDropRateDl`	DU	—	DL RLC packet drop rate; NO_LABEL only
`DRB.RlcPacketDropRateDL`	DU	—	DL RLC packet drop rate (O-RAN); spec name is `DRB.RlcPacketDropRateDLDist` — subscribe using `DRB.RlcPacketDropRateDL`; NO_LABEL only

RRC Connections

These metrics are reported at E2 node level only. UE-level granularity and per-PLMN labels are not supported.

Metric	Source	Unit	Notes
`RRC.ConnMean`	CU-CP	—	Mean number of RRC-connected UEs
`RRC.ConnMax`	CU-CP	—	Peak number of RRC-connected UEs
`RRC.ConnEstabAtt`	CU-CP	—	RRC connection setup attempts
`RRC.ConnEstabSucc`	CU-CP	—	RRC connection setup successes
`RRC.ConnEstabFailCause`	CU-CP	—	RRC setup failure cause; only the `NetworkReject` sub-metric is exposed
`RRC.ReEstabAtt`	CU-CP	—	RRC re-establishment attempts
`RRC.ReEstabSuccWithUeContext`	CU-CP	—	RRC re-establishment successes with retained UE context

UE Context

Metric	Source	Unit	Notes
`UECNTX.ConnEstabAtt`	CU-CP	—	UE context setup attempts; node-level, NO_LABEL only
`UECNTX.ConnEstabSucc`	CU-CP	—	UE context setup successes; node-level, NO_LABEL only

RACH

Metric	Source	Unit	Notes
`RACH.PreambleDedCell`	DU	—	Dedicated RACH preambles received at cell level; NO_LABEL only

Extending the Metric Set

Adding support for a new metric involves three steps.

All relevant files are under `lib/e2/e2sm/e2sm_kpm/`.

Step 1: Confirm the internal measurement exists

Each getter reads from the in-memory data that the provider receives from the gNB stack. Before writing any E2 code, confirm the value you need is already being produced by the relevant subsystem:

Provider	Member variables	Source structs
DU	`last_ue_metrics` (scheduler per-slot PRB and PRACH data); `ue_aggr_rlc_metrics` (RLC SDU/PDU byte counts and delays)	`scheduler_cell_metrics`, `rlc_metrics`
CU-CP	`cu_cp_metrics` (RRC connection and UE context counters)	`cu_cp_metrics_report`
CU-UP	`ue_aggr_pdcp_metrics` (PDCP reordering and delay); `ue_aggr_f1u_metrics` (F1-U counters)	`pdcp_metrics_container`, `f1u_metrics_container`

If the value is not present in these structs, it must first be added to the relevant gNB subsystem and plumbed into the provider via its `report_metrics()` entry point.

Step 2: Implement the getter function

Add a getter method to the provider class that corresponds to where the data lives. All getters share the same signature:

```
bool get_my_metric(
const asn1::e2sm::label_info_list_l          label_info_list,
const std::vector<asn1::e2sm::ue_id_c>&      ues,
const std::optional<asn1::e2sm::cgi_c>       cell_global_id,
std::vector<asn1::e2sm::meas_record_item_c>& items);
```

The body follows the same pattern in every getter:

1. If `ues` is empty, compute one aggregate (node-level) value and push it into `items`.
2. If `ues` is non-empty, iterate over them and push one record per UE from the stored per-UE data.
3. Return `true` if at least one record was added, `false` if no data was available yet.

Existing getters such as `get_prb_avail_dl` (DU, node-level) and `get_drb_dl_mean_throughput` (DU, per-UE) are good templates. Declare the new method in the corresponding header file alongside the existing getter declarations:

Provider class	Header	Implementation
`e2sm_kpm_du_meas_provider_impl`	`e2sm_kpm_du_meas_provider_impl.h`	`e2sm_kpm_du_meas_provider_impl.cpp`
`e2sm_kpm_cu_cp_meas_provider_impl`	`e2sm_kpm_cu_meas_provider_impl.h`	`e2sm_kpm_cu_meas_provider_impl.cpp`
`e2sm_kpm_cu_up_meas_provider_impl`	`e2sm_kpm_cu_meas_provider_impl.h`	`e2sm_kpm_cu_meas_provider_impl.cpp`

Step 3: Register the metric

In the constructor of the provider class, add a call to `supported_metrics.emplace()`:

```
supported_metrics.emplace(
"Metric.Name",
e2sm_kpm_supported_metric_t{
NO_LABEL,                    // supported label flags (e.g. NO_LABEL, PLMN_ID_LABEL,
FIVE_QI_LABEL)
E2_NODE_LEVEL | UE_LEVEL,    // supported granularity levels
false,                       // cell-scope granularity supported
&e2sm_kpm_du_meas_provider_impl::get_my_metric});
```

Replace `e2sm_kpm_du_meas_provider_impl` with the actual provider class name from the table above.

The declared labels and levels control which RIC subscription parameters the E2 agent accepts, and they are also advertised to the RIC in the RAN Function Definition at E2 setup. They must not exceed what `e2sm_kpm_metric_defs.h` defines for this metric name. The constraint is validated by `check_e2sm_kpm_metrics_definitions()` at startup, which will log an error if a violation is detected.

For contributions that add new metrics, see the Contributing Guide.

COTS UEs

This section of our knowledge base aims to list COTS UEs known to be working with OCUDU including tested bands and configurations. It's not an exhaustive list and many more UEs will work out of the box even though they are not listed in this document.

However, if you have done extensive testing with a particular phone and want to contribute your findings please don't hesitate to submit a merge request.

Tested COTS UEs

This is a list of COTS UEs that have been confirmed to be working with OCUDU tested by the OCUDU developer team.

OCUDU developer tested COTS UEs

Make	Model	Codename	Baseband	FDD	TDD	Configuration	SDR
Google	Pixel 6	GB7N6		n71: 10 MHz		IMSI: 00101, gNB PLMN: 00101	USRP
Motorola	Edge 30 Pro	XT2201-1	SM8450 Snapdragon 8 Gen 1	n3: 5, 10, 20 MHz	n78: 10, 20, 40 MHz		USRP B200 GPSD
OnePlus	Nord 5G	A2003	SM7250 Snapdragon 765G	n3: 5, 10, 20 MHz	n78: 20, 40, 80, 100 MHz	IMSI: 00101, gNB PLMN: 90170	B210 Bodn GPSD N310 Exter
OnePlus	8T	KB2003	SM8250 Snapdragon 865 5G		n78: 20 MHz	IMSI: 00101, gNB PLMN 90170	B210 Bodn GPSD

Make	Model	Codename	Baseband	FDD	TDD	Configuration	SDR
OnePlus	9 Pro	LE2123	Snapdragon 888 Octa-core	n3: 10 MHz	n78: 20 MHz	IMSI: 00101, gNB PLMN: 00101, 99970, 46007	
Quectel	RM500q		Snapdragon X55				
Simcom	SIM8262E-M2		Snapdragon X62		n78: 20 MHz		
Telit	FN990A28		Snapdragon X62	n7: 5, 10, 20 MHz, n71: 5, 10, 20 MH, n78: 20, 30 MHz	IMSI: 00101, 99970, gNB PLMN: 00101, 99970	USRP B210 [1]	Test S Sysm SJS1 (must servic For Sysm Break Board requi SIMIN “Activ MS op mode or type_ (both
Xiaomi	11 Lite 5G NE		SM7325 Snapdragon	n3: 10,	n78: 20	gNB PLMN: 00101	B210 Bodn

Make	Model	Codename	Baseband	FDD	TDD	Configuration	SDR
			778G 5G	20 MHz	MHz		GPSD
Xiaomi	12		SM8450 Snapdragon 8 Gen 1	n3: 20 MHz	n78: 20 MHz	gNB PLMN: 00101	B210 Bodn GPSD
iPhone	13 Pro		A15 Bionic		n78: 30 MHz	gNB PLMN: 00101	B210 Bodn GPSD

User reported working UEs

This is a list of COTS UEs that have been reported to be working with OCUDU by users.

User reported COTS UEs

Make	Model	Codename	Baseband	FDD	TDD	Configuratio
OnePlus	8	IN2013				
OnePlus	Nord N10	BE2029	Snapdragon 690			
OnePlus	Nord CE 5G	EB2103	Snapdragon 750G 5G	n3	n78 - 20 MHz	
OnePlus	10 Pro		SM8450 Snapdragon 8 Gen 1	n3	n78 - 100 MHz	
Quectel	RM510Q-GL					
Sierra	EM9191		Snapdragon X55		n78 - 40 MHz	
Xiaomi	Redmi Note 10 5G		Mediatek MT6833 Dimensity 700	n28	N77 and 78	
ZTE	MU5002/MU5001		SDX55+QCA6391			
OnePlus	Nord CE 2 Lite 5G				n78 - 20 MHz and 40 MHz	
OnePlus	Nord CE 3 Lite 5G				n78 - 20 MHz and 40 MHz	
Asus	Zenfone 8				n78 - 20 MHz	

Make	Model	Codename	Baseband	FDD	TDD	Configuratio
					and 40 MHz	
Crosscall	Core Z5				n78 - 20MHz	
Google	Pixel 7 Pro				n78 - 40 MHz to 60 MHz	
Realme	9				n78	
Xiaomi	Redmi Note 12 5G				n78	
Motorola	Moto G54				n78	
Nokia	G42 5G				n78	
Oppo	A78 5G				n78	
Samsung	A15 5G				n78	

Make	Model	Codename	Baseband	FDD	TDD	Configuratio
Samsung	A23 5G				n78	
Google	Pixel 7 Pro				n28	
Samsung	S23 Ultra	SM-S91B/DS			n28	
Samsung	S22 Ultra	SM-S908B/DS			n28	
Samsung	Z Flip 4	SM-F721B			n28	

UE Capability Messages

This is a list of PCAP messages containing COTS UE capability messages. Information on viewing PCAP files can be found in the user manual.

UE Capability PCAP

Make	Model	UE Capability PCAP
Simcom	SIM8262E-M2	pcap
Motorola	Edge 30 Pro	pcap
Google	Pixel 6a	pcap

Footnotes

1. https://www.ettus.com/all-products/ub210-kit/ ↩ ↩[2] ↩[3]

2. https://osmocom.org/projects/cellular-infrastructure/wiki/SysmoUSIM-SJS1 ↩ ↩[2] ↩[3]

3. https://osmocom.org/projects/cellular-infrastructure/wiki/SysmoISIM-SJA2 ↩ ↩[2] ↩[3] ↩[4] ↩[5]

4. https://docs.srsran.com/projects/4g/en/latest/app_notes/source/5g_sa_COTS/source/index.html?highlight=cots#g-sim ↩ ↩[2] ↩[3]

5. https://www.ettus.com/all-products/usrp-b200mini/ ↩

6. https://www.ettus.com/all-products/usrp-n310/ ↩

7. https://docs.srsran.com/projects/4g/en/latest/app_notes/source/5g_sa_COTS/source/index.html?highlight=cots#rooting-cots-ue ↩

8. https://docs.srsran.com/projects/4g/en/latest/app_notes/source/5g_sa_COTS/source/index.html?highlight=cots#network-signal-guru ↩

9. https://www.ettus.com/all-products/usrp-x410/ ↩

Glossary

Terms and abbreviations used in the OCUDU documentation, covering O-RAN architecture, 5G NR air interface, core network functions, and key identifiers.

A B C D E F G H I K L M N O P Q R S T U V X Z

3

3GPP: 3rd Generation Partnership Project

The international standards body that produces technical specifications for mobile communication systems, including LTE (4G) and NR (5G). OCUDU is implemented to 3GPP Release 17/18 specifications. Each specification is identified by a TS number (e.g., TS 38.212 for NR channel coding).

5G: 5th Generation Cellular Network Technology

The fifth generation of mobile network technology, standardized by 3GPP from Release 15 onward. 5G introduces NR as the radio access technology and the 5G Core as the network architecture, offering higher throughput, lower latency, and support for network slicing and massive IoT.

A

A1: A1 Interface

The interface between the Non-RT RIC (inside the SMO) and the Near-RT RIC. It carries policy guidance from rApps to xApps, enrichment information, and ML model management messages. This is the channel through which long-term optimization decisions (greater than 1 second) influence the real-time RAN controller.

AMF: Access and Mobility Management Function

The 5G Core network function that handles UE registration, authentication coordination, paging, and handover signaling. The AMF terminates the N2 interface toward the gNB and the N1 NAS signaling interface toward the UE, and connects to the SMF via N11.

ARFCN: Absolute Radio Frequency Channel Number

A channel numbering scheme that maps a carrier frequency to an integer. In 5G NR, the variant is called NR-ARFCN and covers the full frequency range in 5 kHz steps. Used in configuration files to specify downlink and uplink carrier frequencies.

AVX: Advanced Vector Extensions

Intel SIMD instruction set extensions operating on 256-bit registers, introduced with Sandy Bridge processors. OCUDU uses AVX2 and AVX512 intrinsics for accelerated PHY processing including LDPC encoding and decoding, FFT, and channel estimation.

AWGN: Additive White Gaussian Noise

A channel model that adds white Gaussian noise uniformly across all frequencies. Used as the standard noise model in 5G NR link-level simulations and PHY unit tests.

B

Beamforming

A signal processing technique that focuses transmitted or received radio energy in a specific direction by controlling the phase and amplitude across an antenna array. In O-RAN, the O-DU sends beamforming commands to the O-RU via C-plane messages on the Open Fronthaul.

BFP: Block Floating Point

A lossy compression scheme used in the Open Fronthaul to reduce IQ sample bandwidth. Each block of samples shares a common exponent, and the mantissas are stored at a reduced bit width (typically 9 bits). BFP is the most common compression method used in Split 7.2 deployments with OCUDU.

BG: Base Graph

One of two LDPC base graphs defined in 3GPP NR (BG1 and BG2). BG1 is used for large transport blocks and high code rates; BG2 is used for small transport blocks and low code rates. The base graph is lifted by a lifting factor Z to produce the full parity-check matrix.

BLER: Block Error Rate

The fraction of transport blocks that fail CRC verification after decoding. The 5G NR scheduler targets approximately 10% BLER for initial transmissions when selecting an MCS, relying on HARQ retransmissions to correct residual errors.

BSR: Buffer Status Report

A MAC control element sent by the UE to tell the gNB scheduler how much uplink data is queued in its logical channel buffers. The scheduler uses BSR reports to allocate appropriate UL resources in subsequent slots.

BWP: Bandwidth Part

A contiguous set of physical resource blocks within a carrier, configured by the gNB with a specific numerology. A UE can have up to four DL and four UL BWPs configured, with one active at a time. BWP switching enables power saving and the coexistence of different numerologies on a single carrier.

C

Cell

The basic unit of radio coverage served by a gNB. Each cell has a Physical Cell Identity (PCI), broadcasts system information (MIB, SIB1) on its Synchronization Signal Block, and manages UE connections via RRC.

CORESET: Control Resource Set

A configured time-frequency region within which the UE monitors PDCCH candidates. A CORESET is defined by a bitmap of 6-PRB groups in frequency and 1–3 symbols in time. CORESET 0 is configured via the MIB and used for initial access before full RRC connection.

COTS UE: Commercial Off-The-Shelf User Equipment

A standard consumer device (smartphone, tablet, or data modem) used to test a 5G network without custom firmware. COTS UEs require a correctly provisioned test SIM and a gNB configuration that matches the device's supported bands and PLMN.

CFO: Carrier Frequency Offset

A frequency mismatch between the transmitter and receiver local oscillators, causing a phase ramp in the received signal that degrades demodulation performance. CFO estimation and compensation is performed during time-frequency synchronization in the receiver.

CQI: Channel Quality Indicator

A 4-bit value reported by the UE indicating the downlink channel quality observed during a measurement period. The gNB scheduler uses the CQI to select a Modulation and Coding Scheme that the UE can receive with at most 10% block error rate.

CRC: Cyclic Redundancy Check

An error-detection code appended to each transport block. The receiver recomputes the CRC and compares it to the received value; a mismatch (CRC KO) triggers a HARQ retransmission. CRC pass and fail counts are reported in scheduler UE metrics as `ul_nof_ok` and `ul_nof_nok`.

CSI: Channel State Information

The collection of measurements describing the radio channel from the UE's perspective, including CQI, PMI, and RI. The UE measures and reports CSI to enable the gNB to apply adaptive modulation, rank selection, and beamforming.

CSI-RS: Channel State Information Reference Signal

A downlink reference signal transmitted by the gNB that the UE uses for channel estimation, CSI reporting, and radio link monitoring. CSI-RS resources are configured per cell and can be used for beam management and mobility measurements.

C-RNTI: Cell Radio Network Temporary Identifier

A cell-specific 16-bit identifier assigned to a UE after successful random access contention resolution. It is used to address the UE in PDCCH scheduling assignments, HARQ feedback, and MAC control signaling.

D

DCI: Downlink Control Information

The control message carried on PDCCH that schedules a UE for downlink or uplink transmission. A DCI format specifies resource allocation, MCS, HARQ process number, redundancy version, and other scheduling parameters.

DMRS: Demodulation Reference Signal

A reference signal embedded within PDSCH, PUSCH, PUCCH, and PBCH transmissions that the receiver uses for channel estimation and coherent demodulation. DMRS patterns are configurable, and additional DMRS positions can be enabled for high-Doppler channels.

DPDK: Data Plane Development Kit

A set of software libraries and kernel-bypass drivers that moves packet processing from the OS kernel into userspace, reducing latency and CPU overhead. In OCUDU, DPDK is used to achieve high-throughput, low-jitter Open Fronthaul packet processing, particularly for 4x4 MIMO and wide-bandwidth configurations.

DRB: Data Radio Bearer

A radio bearer carrying user-plane data. Each DRB is associated with one or more QoS flows via SDAP mapping. DRB configuration (PDCP, RLC, and MAC parameters) is delivered by RRC in RRCSetup or RRCReconfiguration messages.

E

E1 Interface

The interface between O-CU-CP and O-CU-UP within a disaggregated O-CU. It carries E1AP messages for bearer context management: setup, modification, and release of data radio bearers. E1 enables independent scaling of the control-plane and user-plane CU functions.

E2 Interface

The O-RAN interface between the Near-RT RIC and E2 Nodes (O-CU-CP, O-CU-UP, O-DU). xApps use E2 to subscribe to RAN telemetry and issue control actions. Messages are carried via E2AP over SCTP.

eCPRI: Enhanced Common Public Radio Interface

An Ethernet-based fronthaul transport protocol used in O-RAN between the O-DU and O-RU. It carries C-plane, U-plane, and S-plane data over standard Ethernet infrastructure, enabling lower-cost fronthaul than legacy CPRI while supporting functional splits at higher points.

EPC: Evolved Packet Core

The 4G LTE core network, consisting of the MME, S-GW, P-GW, and HSS. Referenced in OCUDU documentation in the context of Open5GS, which implements both the EPC and the 5G Core. Not directly used by OCUDU, which connects to a 5G Core via the NG interface.

F

F1 Interface

The interface between the O-CU and one or more O-DUs. It splits into F1-C (control plane, carrying F1AP for UE context management) and F1-U (user plane, carrying GTP-U tunnels for data radio bearer traffic). F1 traffic traverses the midhaul transport.

F1-C: F1 Control Plane Interface

The control-plane portion of F1. Carries F1AP messages for F1 setup, gNB-DU configuration updates, UE context management, and paging distribution. Terminated by the O-CU-CP.

F1-U: F1 User Plane Interface

The user-plane portion of F1. Carries GTP-U tunnels for DRB user data between the O-CU-UP and O-DU. Part of the midhaul transport.

FAPI: Functional Application Platform Interface

A Small Cell Forum interface specification defining the API between the MAC scheduler and the PHY layer inside an O-DU. FAPI decouples the scheduler software from PHY hardware or firmware, enabling multi-vendor MAC and lower PHY integration.

FDD: Frequency Division Duplex

A duplex scheme that uses separate paired frequency bands for uplink and downlink transmissions simultaneously. Used in FR1 paired spectrum bands. Compare with TDD.

FEC: Forward Error Correction

A class of error-correction techniques that add redundancy to transmitted data so the receiver can detect and correct errors without retransmission. In 5G NR, LDPC codes are used for FEC on data channels

(PDSCH, PUSCH) and polar codes on control channels (PDCCH, PBCH).

FFT: Fast Fourier Transform

The algorithm used in OFDM receivers to convert a time-domain signal into the frequency domain, separating subcarriers. In 5G NR, the FFT is performed in the O-RU (Split 7.2) or in the DU-low (Split 8). OCUDU supports multiple FFT library backends including libfftw, oneMKL, AOCL-FFTZ, and Arm Performance Libraries.

FR1: Frequency Range 1

The sub-6 GHz frequency range for 5G NR, covering 410 MHz to 7125 MHz. Supports subcarrier spacings of 15, 30, and 60 kHz and channel bandwidths up to 100 MHz. FR1 provides better coverage and building penetration than FR2.

FR2: Frequency Range 2

The millimetre-wave frequency range for 5G NR, covering 24.25 GHz to 52.6 GHz. Supports subcarrier spacings of 60 and 120 kHz and channel bandwidths up to 400 MHz. FR2 offers very high throughput but shorter range and limited building penetration compared to FR1.

G

gNB: Next Generation Node B

The 5G base station providing NR radio access. A gNB connects to UEs via the Uu air interface and to the 5G Core via NG (N2 control, N3 user plane). It can be deployed as a monolithic unit or disaggregated into O-CU and O-DU components.

GPSDO: GPS-Disciplined Oscillator

A precision frequency reference that locks a local oscillator to GPS timing signals, producing a highly accurate 10 MHz clock and 1PPS output. In OCUDU Split 8 deployments, a GPSDO connected to the USRP ensures the RF carrier frequency is accurate enough for COTS UEs to lock onto the cell.

GPP: General Purpose Processor

A standard CPU (x86 or ARM) as opposed to dedicated hardware accelerators. OCUDU is designed to run the full gNB stack on a GPP, using SIMD acceleration (AVX2, AVX512, ARM Neon) and optionally DPDK for high-performance deployments.

GTP-U: GPRS Tunnelling Protocol - User Plane

A UDP-based tunneling protocol used to carry user-plane PDU session data between 5G nodes. GTP-U tunnels are used on N3 (O-CU-UP to UPF), F1-U (O-CU-UP to O-DU), and N9 (UPF to UPF).

H

HARQ: Hybrid Automatic Repeat Request

A PHY/MAC-layer retransmission mechanism combining forward error correction with ARQ. When a transport block fails its CRC check, the receiver sends a NACK and the transmitter retransmits. The new transmission is chase-combined or incrementally combined with prior attempts before decoding.

I

IMSI: International Mobile Subscriber Identity

A globally unique identifier for a mobile subscriber, stored on the USIM. In 5G, the IMSI is the primary form of SUPI. It is sent in the gNB configuration to match the PLMN and is used in test SIM provisioning when connecting COTS UEs.

IQ Data

The in-phase and quadrature components of a complex baseband signal representing the amplitude and phase of a radio waveform. In Split 7.2 deployments, compressed IQ data is exchanged between the O-DU and O-RU over the Open Fronthaul using eCPRI.

K

KPM: Key Performance Measurement

An O-RAN E2 service model that defines a set of standardized RAN metrics exposed to the Near-RT RIC via the E2 interface. KPM allows xApps to subscribe to performance indicators such as DL/UL PRB usage, number of active UEs, and PDCP throughput.

L

LDPC: Low-Density Parity-Check

The channel coding scheme used for data channels (PDSCH and PUSCH) in 5G NR from Release 15 onward. OCUDU includes optimized LDPC encoder and decoder implementations for x86 (AVX2/AVX512) and ARM (Neon) processors to maximize throughput.

LLS: Lower Layer Split

The O-RAN WG4 term for the functional split between the O-DU and O-RU, equivalent to Split 7.2x. LLS-C refers to the synchronization topology between the DU and RU: LLS-C1 uses the DU as a PTP grandmaster, while LLS-C3 uses an external grandmaster with both DU and RU as clients.

LLR: Log-Likelihood Ratio

A soft-decision metric output by the demodulator for each received bit, representing the log ratio of the probability the bit is 0 to the probability it is 1. LDPC decoders operate on LLRs from the channel for iterative belief-propagation decoding.

LTE: Long Term Evolution

The 4G radio access technology standardized by 3GPP from Release 8. LTE introduced OFDMA, MIMO, and an all-IP architecture. Referenced in OCUDU documentation as context for srsRAN migration and NSA versus SA deployment comparisons.

M

MAC: Medium Access Control

The Layer-2 sublayer responsible for scheduling (via DCI), HARQ operation, random access, logical channel multiplexing, and DRX. The MAC runs between the UE and O-DU over the Uu interface.

MCC: Mobile Country Code

A three-digit code identifying the country of a mobile network. Together with the MNC, it forms the PLMN identifier that the UE reads from SIB1 during cell selection and includes in NAS Registration Requests.

MCS: Modulation and Coding Scheme

A combined index specifying the modulation order (QPSK, 16QAM, 64QAM, 256QAM) and channel coding rate for PDSCH and PUSCH. Selected by the gNB scheduler based on reported CQI. The transport block size is computed from the MCS, the number of PRBs, and the number of MIMO layers.

MIMO: Multiple-Input Multiple-Output

An antenna technique that uses multiple transmit and receive antennas to increase throughput, coverage, or reliability. In OCUDU, MIMO is configured through the `nof_antennas_dl` and `nof_antennas_ul` parameters; 4x4 MIMO is supported in the current release.

MNC: Mobile Network Code

A two- or three-digit code that, together with the MCC, uniquely identifies a mobile network. The MCC plus MNC forms the PLMN ID used throughout 5G NAS and RRC signaling.

N

NAS: Non-Access Stratum

The protocol layer between the UE and the 5G Core (AMF and SMF) that is transparent to the RAN. NAS carries mobility management (registration, authentication, paging) and session management (PDU session establishment, modification, release) procedures.

Near-RT RIC: Near Real-Time RAN Intelligent Controller

An O-RAN platform that hosts xApps and performs RAN control functions with a 10 ms to 1 second control loop. It connects to E2 Nodes (O-CU-CP, O-CU-UP, O-DU) via the E2 interface and receives policy guidance from the Non-RT RIC via A1.

NG Interface

The interface between the gNB (O-CU) and the 5G Core. It splits into NG-C (N2, control plane toward AMF, carrying NGAP) and NG-U (N3, user plane toward UPF, carrying GTP-U). NG traffic traverses the backhaul.

NGAP: Next Generation Application Protocol

The control-plane protocol on the N2 interface between the O-CU-CP and the AMF. Handles NG setup, initial UE message forwarding, NAS transport, UE context setup and release, paging, and handover signaling.

NR: New Radio

The 5G radio access technology standardized by 3GPP from Release 15 onward. NR supports flexible numerology, massive MIMO, mmWave (FR2), and sub-6 GHz (FR1) operation.

NRF: NF Repository Function

A 5G Core function that maintains a registry of all active network function instances and their capabilities. NFs register with the NRF at startup and discover other NFs via NRF queries, enabling service-based discovery.

NSSAI: Network Slice Selection Assistance Information

A set of S-NSSAIs identifying the network slices requested by a UE or allowed by the network. The UE includes the Requested NSSAI in its Registration Request; the AMF responds with an Allowed NSSAI.

NTN: Non-Terrestrial Network

A 5G network deployment in which the radio link between the gNB and UE is relayed via a non-terrestrial node, typically a low-Earth orbit (LEO) or geostationary (GEO) satellite. NTN introduces unique propagation delays and Doppler effects that require 3GPP Release 17 enhancements. OCUDU supports NTN GEO deployments in the current release.

NZP: NonZero Power

A CSI-RS resource type in which the gNB actively transmits on the configured resource elements. NZP-CSI-RS resources are used by the UE for channel estimation, CSI reporting, and beam management. Contrasted with ZP (Zero Power) CSI-RS used for interference measurement.

Numerology (μ)

The set of OFDM parameters determined by the subcarrier spacing: SCS = 15 × 2^μ kHz where μ runs from 0 to 4. Higher μ gives wider subcarrier spacing, shorter symbol duration, and more slots per subframe, suitable for higher frequencies and lower-latency applications. Numerology is configured per BWP.

O

O-CU: O-RAN Central Unit

The O-RAN equivalent of the 3GPP gNB-CU. It hosts RRC and PDCP protocol layers and can be further split into O-CU-CP (control plane) and O-CU-UP (user plane). The O-CU connects to O-DUs via F1, to the 5G Core via NG, and to peer O-CUs via Xn.

O-CU-CP: O-RAN Central Unit - Control Plane

The control-plane portion of the O-CU. It hosts RRC and control-plane PDCP, terminates F1-C toward O-DU, E1 toward O-CU-UP, and N2 (NGAP) toward the AMF. The O-CU-CP is an E2 Node and connects to the Near-RT RIC via E2.

O-CU-UP: O-RAN Central Unit - User Plane

The user-plane portion of the O-CU. It hosts SDAP and user-plane PDCP (ciphering, header compression), terminates F1-U toward O-DU, E1 toward O-CU-CP, and N3 toward the UPF. The O-CU-UP is also an E2 Node.

O-DU: O-RAN Distributed Unit

The O-RAN equivalent of the 3GPP gNB-DU. It hosts RLC, MAC, and upper PHY layers, connects to the O-CU via F1 (midhaul), and connects to the O-RU via the Open Fronthaul (eCPRI). The O-DU is an E2 Node managed via O1.

O1 Interface

The O-RAN management interface between the SMO and O-RAN managed elements (O-CU-CP, O-CU-UP, O-DU, Near-RT RIC). It carries NETCONF/YANG configuration, VES performance and fault notifications, and software management.

OFH: Open Fronthaul

See Open Fronthaul. OFH is the abbreviation used in OCUDU configuration files, metrics output, and log messages to refer to the Open Fronthaul library and interface.

Open Fronthaul

The O-RAN WG4 standardized interface between O-DU and O-RU, transported over eCPRI on Ethernet. It defines the CUS plane (Control, User, Synchronization) for real-time IQ data and scheduling, and the M-plane (Management) using NETCONF/YANG for O-RU configuration. Supports the Split 7.2x functional split.

O-RAN

The Open Radio Access Network initiative (O-RAN Alliance) defining open, interoperable interfaces for disaggregated RAN. Key interfaces include the Open Fronthaul (O-DU to O-RU), E2 (Near-RT RIC to E2 Nodes), O1 (management), A1 (Non-RT RIC policy), and O2 (O-Cloud management).

O-RU: O-RAN Radio Unit

The O-RAN radio unit implementing lower PHY (IFFT/FFT, CP addition, precoding) and RF functions. It connects to the O-DU via the Open Fronthaul for CUS-plane and M-plane communication, and may implement AAS or mMIMO capabilities.

P

PCI: Physical Cell Identity

A numeric identifier (0–1007) for a 5G NR cell, derived from PSS and SSS within the Synchronization Signal Block. UEs detect the PCI during cell search. The PCI is also used for DMRS sequence generation and neighbor cell differentiation.

PBCH: Physical Broadcast Channel

The physical channel carrying the Master Information Block (MIB). Transmitted within each SSB alongside PSS and SSS. After detecting the SSB and reading the PBCH, the UE obtains the SFN, PDCCH configuration for SIB1, and other parameters needed to access the cell.

PCAP: Packet Capture

A file format (and the act of capturing) network traffic at a specific protocol layer. OCUDU can generate PCAPs at the MAC, RLC, NGAP, N3, E1AP, F1AP, and E2AP layers. PCAP files can be analyzed with Wireshark to debug protocol messages and trace call flows.

PDCCH: Physical Downlink Control Channel

The physical channel carrying Downlink Control Information (DCI). Transmitted in CORESETs within configured Search Spaces. The UE blindly decodes PDCCH candidates to find scheduling assignments, UL grants, and TPC commands addressed to its C-RNTI.

PDCP: Packet Data Convergence Protocol

A Layer-2 sublayer above RLC providing header compression (ROHC), ciphering, integrity protection, sequence number management, in-order delivery, and duplicate detection. Control-plane PDCP (SRBs) terminates on the O-CU-CP; user-plane PDCP (DRBs) terminates on the O-CU-UP.

PDSCH: Physical Downlink Shared Channel

The primary downlink data channel, used to carry DRB user data, SIBs, RRC messages, and paging. Scheduled dynamically per slot by the gNB scheduler via DCI on PDCCH.

PDU Session

An end-to-end association between the UE and a Data Network identified by a DNN. A PDU session provides IP connectivity and may contain one or more QoS flows mapped to DRBs. It is established and released via NAS 5GSM procedures, managed by the SMF, with the UPF anchoring the user plane.

PHY: Physical Layer

The lowest 5G NR protocol layer, responsible for modulation, channel coding, resource mapping, OFDM waveform generation, beamforming, and frame timing. Communicates with MAC via transport channels and with RF hardware via physical channels.

PHR: Power Headroom Report

A MAC control element sent by the UE reporting the difference between the configured maximum transmit power and the estimated power needed for the current PUSCH transmission. The gNB uses PHR to avoid over-scheduling uplink resources when the UE is power-limited.

PLMN: Public Land Mobile Network

A mobile network uniquely identified by a Mobile Country Code (MCC) and Mobile Network Code (MNC). UEs read the PLMN list from SIB1 during cell selection and include the selected PLMN in NAS Registration Requests.

PRACH: Physical Random Access Channel

The uplink physical channel on which UEs transmit random access preambles (Msg1 in the RACH procedure). PRACH resources and preamble sequences are configured via SIB1 for initial access, or via RRCReconfiguration for handover and dedicated RACH.

PRB: Physical Resource Block

The basic frequency-domain resource allocation unit: 12 consecutive subcarriers. The number of PRBs per BWP depends on the channel bandwidth and numerology. For example, a 20 MHz channel at 15 kHz subcarrier spacing contains 106 PRBs.

PTP: Precision Time Protocol

An IEEE 1588 standard for sub-microsecond time synchronization across an Ethernet network. In Split 7.2 deployments, PTP is used to synchronize the O-DU and O-RU to a common timing reference (grandmaster), ensuring correct fronthaul slot timing. O-RAN WG4 defines LLS-C1 and LLS-C3 synchronization topologies using PTP.

PUCCH: Physical Uplink Control Channel

The uplink physical channel carrying uplink control information: HARQ ACK/NACK feedback, CSI reports (CQI, PMI, RI), and Scheduling Requests. Multiple PUCCH formats cover different payload sizes and time durations.

PUSCH: Physical Uplink Shared Channel

The primary uplink data channel carrying DRB user data and, when scheduled, multiplexed CSI reports and scheduling requests. Allocated by the gNB scheduler via UL DCI grants; supports HARQ retransmissions.

Q

QoS: Quality of Service

The framework for differentiating data flows by traffic class. Each QoS flow has a 5QI that maps to a packet delay budget, packet error rate, priority, and resource type (GBR or non-GBR). The SMF provisions QoS rules on the UPF and delivers QoS configuration to the gNB and UE for DRB setup.

5QI: 5G QoS Identifier

A scalar value mapping to a standardized set of QoS characteristics. Pre-defined 5QI values cover GBR flows (e.g., 1 for voice, 2 for video) and non-GBR flows (e.g., 9 for best-effort data). Configured by the SMF and enforced end-to-end.

QPSK: Quadrature Phase Shift Keying

A modulation scheme that encodes 2 bits per symbol using four phase states. Used in 5G NR for control channels (PDCCH, PUCCH) and as the lowest modulation order for data channels under poor channel conditions. Higher modulation orders (16QAM, 64QAM, 256QAM) are selected as channel quality improves.

R

RB: Resource Block

A group of 12 consecutive subcarriers in the frequency domain. Used interchangeably with PRB (Physical Resource Block) in most contexts. The number of RBs in a carrier depends on the channel bandwidth and subcarrier spacing.

RE: Resource Element

The smallest unit of the 5G NR time-frequency resource grid: one subcarrier in frequency and one OFDM symbol in time. Transport block data, reference signals, and control information are all mapped to specific REs.

RS: Reference Signal

A known signal sequence transmitted at defined time-frequency locations for channel estimation, synchronization, or measurement. In 5G NR, reference signals include PSS/SSS (cell search), DMRS (demodulation), CSI-RS (channel state measurement), and SRS (uplink sounding).

RI: Rank Indicator

A CSI report value indicating the number of independent data streams (transmission rank) the channel can support. RI=1 is single-layer; RI greater than 1 enables spatial multiplexing. The gNB uses RI for MIMO rank adaptation.

RIC: RAN Intelligent Controller

The O-RAN platform that hosts applications for RAN optimization and control. The Near-RT RIC (10 ms to 1 s control loop) hosts xApps and connects to E2 Nodes via the E2 interface. The Non-RT RIC (greater than 1 s) hosts rApps within the SMO and provides A1 policy guidance.

RLC: Radio Link Control

A Layer-2 sublayer between MAC and PDCP. Supports three modes: TM (Transparent Mode, for broadcast channels), UM (Unacknowledged Mode, for delay-sensitive flows), and AM (Acknowledged Mode, with ARQ retransmission for reliable delivery). The RLC runs between UE and O-DU.

RNTI: Radio Network Temporary Identifier

A 16-bit identifier used to address UEs or broadcast channels on the air interface. Key types include: C-RNTI (UE-specific scheduling), RA-RNTI (random access response), P-RNTI (paging), and SI-RNTI (system information broadcast).

RoHC: Robust Header Compression

An IETF header compression framework applied at the PDCP layer to reduce the overhead of IP, UDP, and RTP headers on radio bearers. RoHC is particularly beneficial for voice-over-IP traffic, reducing headers from tens of bytes to as few as 1–3 bytes.

RSRP: Reference Signal Received Power

A measurement of the average received power of a single resource element carrying a reference signal (SSB or CSI-RS). Reported by the UE and used by the gNB scheduler and mobility algorithms to assess downlink signal strength. RSRP is visible in the OCUDU console trace and in scheduler UE metrics.

RRC: Radio Resource Control

The control-plane protocol between UE and O-CU-CP. Manages RRC connection establishment and release, bearer configuration, measurement control and reporting, system information broadcast, and paging. RRC terminates on the O-CU-CP.

RRC_INACTIVE

A 5G NR state (not present in LTE) in which the UE AS context is suspended but retained in both the UE and the last serving gNB. The UE performs cell reselection and can resume quickly without full RRC re-establishment, saving UE battery and reducing signaling overhead.

S

SA: Standalone

A 5G deployment mode in which the gNB connects directly to a 5G Core (via NG) without relying on an LTE anchor. OCUDU operates exclusively in SA mode. Contrasted with NSA (Non-Standalone), where a 5G NR carrier is used as an additional carrier alongside an LTE anchor.

S-NSSAI: Single Network Slice Selection Assistance Information

A single network slice descriptor composed of a Slice/Service Type (SST) and an optional Slice Differentiator (SD). Used to identify and request a specific network slice. The UE includes S-NSSAIs in its NSSAI during registration.

SCS: Subcarrier Spacing

The frequency separation between adjacent OFDM subcarriers, defined by the numerology: 15 kHz (μ=0), 30 kHz (μ=1), 60 kHz (μ=2), 120 kHz (μ=3). Wider SCS gives shorter symbol duration, which helps mitigate phase noise at higher frequencies and reduces latency.

SDAP: Service Data Adaptation Protocol

A 5G NR-specific user-plane layer above PDCP. SDAP maps QoS flows to DRBs and adds a 1-byte header containing the QFI and reflective QoS indication bits. It terminates on the O-CU-UP and is absent in LTE.

SDR: Software-Defined Radio

A radio communication system in which components traditionally implemented in hardware (mixers, filters, modulators) are implemented in software. In OCUDU Split 8 deployments, an SDR device such as a USRP acts as the RF front-end, with the digital baseband processed on the host CPU.

SCTP: Stream Control Transmission Protocol

A reliable transport protocol used to carry 5G signaling protocols including NGAP, F1AP, E1AP, XnAP, and E2AP. SCTP provides multi-homing, multi-streaming, and message boundary preservation, making it more suitable for RAN signaling than TCP.

SIB: System Information Block

A container carrying specific categories of cell configuration broadcast by the gNB. SIB1 is always broadcast and contains PLMN identity, cell access restriction, TAC, and RACH configuration. Further SIBs (SIB2 onwards) carry idle-mode parameters, reselection configuration, and neighbor cell lists.

SINR: Signal-to-Interference-plus-Noise Ratio

The ratio of received signal power to the sum of interference and noise power, measured in dB. In OCUDU console output, PUSCH SINR is reported per UE as the `pusch` metric and indicates uplink link quality.

SMF: Session Management Function

A 5G Core function managing PDU session lifecycle: selecting a UPF, allocating a UE IP address, provisioning QoS and charging rules, and coordinating session setup with the AMF and PCF. The SMF communicates with the UPF via the N4 interface using PFCP.

SMO: Service Management and Orchestration

The top-level management and orchestration framework in O-RAN. The SMO houses the Non-RT RIC, manages O-RAN NFs via O1, manages O-Cloud infrastructure via O2, and provides the A1 interface toward the Near-RT RIC.

Split 7.2 (Lower Layer Split)

The O-RAN functional split between O-DU and O-RU. The O-DU handles upper PHY (channel coding, scrambling, modulation mapping) while the O-RU handles lower PHY (IFFT, CP addition, precoding) and RF. Data is transported over eCPRI on Ethernet. Also called LLS (Lower Layer Split).

Split 8

A functional split in which the entire PHY layer (both upper and lower) is co-located in the DU, with the O-RU acting as a simple RF front-end. In OCUDU, Split 8 deployments use an SDR device (USRP via UHD, or virtual radio via ZMQ) as the RF interface.

SRB: Signaling Radio Bearer

A radio bearer carrying RRC and NAS control messages. SRB0 uses RLC TM and carries the initial RRCSetupRequest. SRB1 carries RRC messages before AS security is active. SRB2 carries NAS messages after security is established. SRBs use PDCP AM mode.

SRS: Sounding Reference Signal

An uplink reference signal transmitted by the UE on PUSCH or dedicated SRS resources, allowing the gNB to estimate the uplink channel. SRS measurements are used for uplink-based beamforming, timing advance estimation, and NR positioning.

SC: Successive Cancellation

A decoding algorithm for polar codes in which bits are decoded sequentially from most reliable to least reliable, with each decoded bit cancelling its contribution from subsequent decisions. Used in 3GPP NR for decoding polar-coded control channels including PDCCH and PBCH.

SIMD: Single Instruction, Multiple Data

A parallel processing technique where a single instruction operates simultaneously on multiple data elements using wide registers. OCUDU uses SIMD extensions (SSE, AVX2, AVX512, ARM Neon) to accelerate PHY processing including LDPC decoding, FFT, and channel estimation.

SNR: Signal-to-Noise Ratio

The ratio of signal power to noise power in dB. Higher SNR allows higher modulation orders and coding rates (higher MCS), increasing throughput. Visible in OCUDU console output as a per-UE link quality indicator.

SSE: Streaming SIMD Extensions

Intel SIMD instruction set extensions operating on 128-bit registers, introduced with the Pentium III. SSE provides a baseline SIMD capability on x86 platforms that do not support AVX2 or AVX512.

SSB: Synchronization Signal Block

A periodic transmission containing PSS, SSS, and PBCH. The UE detects SSBs during cell search to synchronize, identify the cell (PCI), and read the MIB. In multi-beam deployments, the gNB sweeps the SSB across different beams in a half-frame burst.

T

TA: Tracking Area

A geographic area composed of one or more cells with a common Tracking Area Code (TAC). When a registered UE moves to a new TA not in its Allowed TA list, it initiates a Mobility Registration Update. TAs balance paging overhead against registration signaling load.

TAC: Tracking Area Code

A 24-bit code identifying a Tracking Area within a PLMN. Broadcast in SIB1. Included in the Tracking Area Identity (TAI) together with the PLMN ID.

TAI: Tracking Area Identity

The globally unique identifier for a Tracking Area, composed of PLMN ID and TAC. Used in NGAP and NAS signaling for mobility management.

TDD: Time Division Duplex

A duplex scheme that uses the same frequency band for both uplink and downlink, separated in time by a configurable pattern of DL, UL, and flexible symbols. Used in FR1 unpaired spectrum (e.g., n78 at 3.5 GHz). TDD allows asymmetric UL/DL ratios suited to data-heavy traffic. Compare with FDD.

TS: Technical Specification

A formal standards document published by 3GPP. Each TS number corresponds to a specific topic (e.g., TS 38.212 covers NR multiplexing and channel coding; TS 38.214 covers physical layer procedures for data). Definitions throughout the OCUDU documentation reference 3GPP TS numbers.

TTI: Transmission Time Interval

The basic unit of scheduling in the radio access network. In 5G NR, one slot (14 OFDM symbols) is the standard TTI, with mini-slot scheduling (2, 4, or 7 symbols) supported for latency-sensitive applications. TTI duration depends on the numerology.

U

UCI: Uplink Control Information

Control data transmitted by the UE in the uplink, including HARQ ACK/NACK feedback, CSI reports (CQI, RI, PMI), and Scheduling Requests. UCI is carried on PUCCH, or multiplexed onto PUSCH when uplink data is simultaneously scheduled.

UDM: Unified Data Management

A 5G Core function providing subscriber data management and authentication credential generation. The UDM stores long-term keys and generates authentication vectors for the AUSF. It also handles subscription data retrieval requested by the AMF and SMF.

UE: User Equipment

The terminal device connecting to the 5G network via the air interface (Uu). Examples include smartphones, tablets, and IoT modules. The UE consists of mobile equipment (hardware) and a USIM (subscriber identity module).

UHD: USRP Hardware Driver

The open-source driver library developed by Ettus Research for interfacing with USRP devices. In OCUDU Split 8 deployments, UHD provides the RF front-end abstraction layer for sample streaming between the host CPU and the USRP hardware.

UPF: User Plane Function

The 5G Core network function anchoring the user-plane data path. The UPF receives downlink traffic from the Data Network via N6, tunnels it to the O-CU-UP via N3, enforces QoS and charging rules, and performs traffic steering. Controlled by the SMF via N4/PFCP.

USIM: Universal Subscriber Identity Module

The application on a UICC (SIM card) that stores subscriber credentials including the IMSI, long-term key, and authentication algorithms. The USIM performs the 5G-AKA or EAP-AKA' authentication procedure and generates session keys. Test USIMs (e.g., Sysmocom SJS1, SJA2) are commonly used in OCUDU lab deployments.

USRP: Universal Software Radio Peripheral

A family of SDR hardware devices manufactured by Ettus Research. In OCUDU Split 8 deployments, a USRP (B200, B210, N310, X410, etc.) serves as the RF front-end, converting between digital baseband samples processed by the gNB software and the over-the-air 5G NR signal.

V

VLAN: Virtual Local Area Network

A logical segmentation of an Ethernet network that allows traffic from different services or nodes to be isolated on the same physical infrastructure using VLAN tags (IEEE 802.1Q). In Split 7.2 deployments, VLANs are commonly used to separate Open Fronthaul traffic from management traffic on the fronthaul switch.

X

xApp: Near-RT RIC Application

A modular application running on the Near-RT RIC platform with a 10 ms to 1 second control loop. xApps subscribe to E2 telemetry from E2 Nodes (KPM, RAN state) and issue E2 control actions for functions such as traffic steering, handover optimization, and load balancing.

Xn Interface

The interface between peer gNB instances (O-CU to O-CU). It splits into Xn-C (XnAP, control plane for handover coordination and dual connectivity) and Xn-U (GTP-U, user plane for data forwarding during handover). Xn-based handover is faster than N2-based handover because it does not require AMF involvement in the preparation phase.

Z

ZMQ: ZeroMQ

A high-performance asynchronous messaging library used in OCUDU to implement a virtual RF interface. When ZMQ is enabled, the gNB or DU sends and receives baseband IQ samples over ZMQ sockets rather than real hardware, enabling purely software-based testing without a USRP.