

O-DU High Overview

O-DU High implements the functional blocks of L2 layers of a 5G NR protocol stack in Stand Alone (SA) mode. The L2 layers are NR RLC (Radio Link Control), NR MAC (Medium Access Control) and NR Scheduler. These layers aid in the transmission of traffic from the UE to the 5G Core network.

5G NR RLC layer provides services for transferring the control and data messages between MAC layer and O-CU (via DU App).

5G NR MAC layer uses the services of the NR physical layer (O-DU Low) to send and receive data on the various logical channels using multiplexing and demultiplexing techniques.

5G NR SCH layer allocates resources in UL and DL for cell and UE based procedures.

O-DU High Architecture

O-DU implements the functional blocks of L2 layer of a 5G NR protocol stack in SA (StandAlone) mode. These layers primarily include NR MAC, NR Scheduler and NR RLC layers.

O-DU modules are developed as shown in the below diagram.

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O-DU High Thread Architecture

As shown in the figure above, there are multiple entities within O-DU High. Modules sharing a given color belong to one thread. O-DU architecture can be defined at a thread level as follows:

- Thread 1: O-DU thread
- Thread 2: DU APP inclusive of Config Handler, DU Manager, UE Manager, EGTP Handler and ASN.1 Codecs
- Thread 3: 5G NR RLC DL and MAC (inclusive of 5G NR SCH and Lower MAC)
- Thread 4: 5G NR RLC UL
- Thread 5: SCTP Handler
- Thread 6: Lower MAC Handler

O-DU High Modules

DU APP

This module configures and manages all the operations of O-DU. It interfaces with external entities as follows:

- OAM: DU APP interacts with OAM on the O1 interface for configuration, alarms and performance management.
- O-CU: DU APP interacts with O-CU for RAN functionalities over the F1 interface which is built on SCTP. Control messages are exchanged on the F1-C interface and data messages on the F1-U interface.
- Near RT RIC: DU APP interacts with RIC on E2 interface over SCTP.

DU App submodules are as follows:

- Config Handler manages the configurations received on O1 interfaces and stores them within DU APP context.
- DU Manager handles all cell operations at the DU APP.
- UE Manager handles UE contexts at the DU APP.
- SCTP handler is responsible for establishing SCTP connections with O-CU, RIC on the F1AP and E2AP interfaces respectively.
- EGTP handler is responsible for establishing EGTP connection with O-CU for data message exchange on the F1-U interface.
- ASN.1 Codecs contain ASN.1 encode/decode functions which are used for System information, F1AP and E2AP messages.

5G NR RLC

This module provides services for transferring the control and data messages between MAC layer and O-CU (via DU App).

5G NR RLC UL and 5G NR RLC DL are the sub modules of this module that implement uplink and downlink functionality respectively.

5G NR MAC

This module uses the services of the NR physical layer to send and receive data on the various logical channels. Functions of the 5G NR MAC module are as follows:

- 5G NR MAC is responsible for multiplexing and de-multiplexing of the data on various logical channels.
- 5G NR SCH schedules resources in UL and DL for cell and UE based procedures. 5G NR SCH is completely encapsulated within the 5G NR MAC i.e., all interactions of the 5G NR SCH is via the 5G NR MAC.
- Lower MAC interfaces between the MAC and the O-DU Low. It implements all the messages of FAPI specification. It has a receiver thread to handle messages from L1.

O-DU Utility and Common Functions

These modules contain platform specific files and support O-DU High functionality and message exchanges.

O1 Module

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O1 Architecture

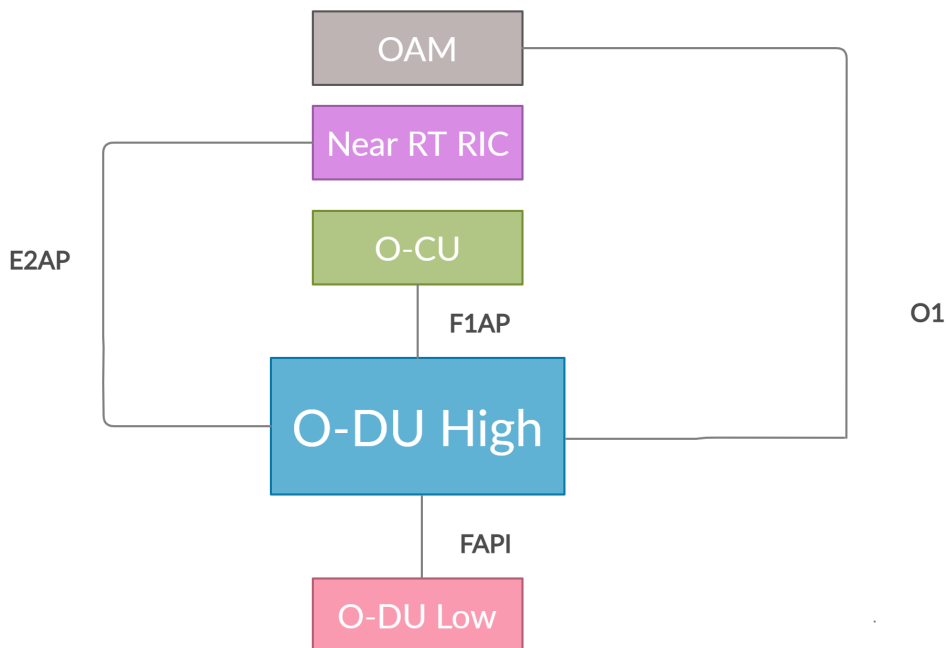
As shown in the figure O1 module runs as a thread in O-DU High. Alarm communication happens over a Unix socket between the O1 and O-DU threads. O1 module uses API calls for interacting with the Netconf server(Netopeer) and datastore(sysrepo) for providing the Netconf interface.

O1 architecture has following components:

- Netconf Session Handler: Subscribe to Netconf YANG modules and events. Register callback handler methods.
- VES Agent : Sends the VES events to SMO
- Alarm Manager: Stores and manages(add/updated/delete) alarms.
- Alarm Interface : Provides an interface to O-DU High threads for sending the alarm messages to O1 module over Unix socket.
- Config Interface : Interface to handle the configurations sent from SMO to the stack
- Netopeer server: Serves the northbound SMO/OAM Netconf requests.

O-DU-High Interfaces

This section describes the other modules that O-DU High interfaces with, as shown in below diagram.



As shown above, O-DU High interfaces with the following modules:

- O-CU: O-DU High communicates with O-CU on the F1AP interface. The control message exchanges are on F1-C while data message exchanges are on F1-U interfaces. The below F1AP messages on F1-C are implemented, as per 3GPP 38.473-f60 v15.3:
 - Interface Management
 - F1 Setup
 - gNB-DU Configuration Update
 - F1 Reset
 - UE Context Management
 - UE Context Setup

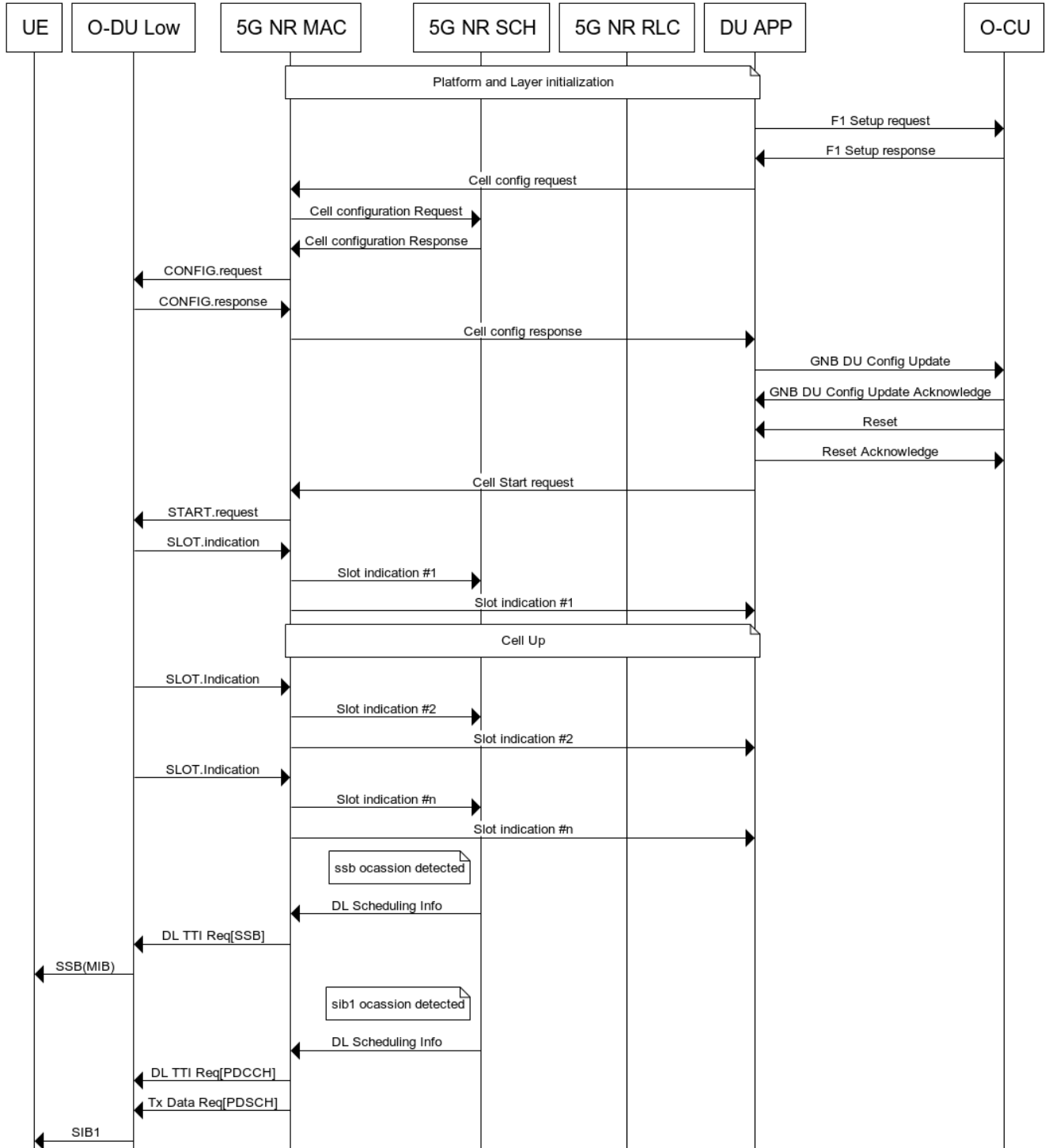
- RRC Message Transfer
 - Initial UL RRC Message Transfer
 - DL RRC Message Transfer
 - UL RRC Message Transfer
 - RRC Delivery Report
- Near RT RIC: O-DU High communicates with Near RT RIC on the E2 interface. The below E2AP messages are implemented, as per ORAN WG3. E2AP v01.00:
 - Global Procedures
 - E2 Setup
 - Near RT RIC Functional Procedures
 - RIC Subscription
 - RIC Indication
- O-DU Low: O-DU High communicates with O-DU Low on the FAPI interface. The below FAPI messages are supported, as per FAPI interface files shared by Intel:
 - P5 messages - PHY mode control interface
 - PARAM.request/PARAM.response
 - CONFIG.request/CONFIG.response
 - START.request
 - STOP.request
 - STOP.indication
 - P7 messages - Main data path interface
 - DL_TTI.request
 - UL_TTI.request
 - SLOT.indication
 - UL_DCI.request
 - TX_Data.request
 - RX_Data.indication
 - CRC.indication
 - UCI.indication
 - RACH.indication
- OAM: O-DU High communicates with OAM on the O1 interface.

O-DU High functionality

Cell Up and Broadcast Procedure

This section describes the cell-up procedure within O-DU High.

O-DU High Cell Up and Broadcast Procedure



As seen in the above Figure, - The DU APP module of O-DU High sends F1 Setup Request to O-CU. This message contains a list of cells that the O-DU High has been configured with.

- The O-CU responds with F1 Setup Response. This message contains a list of cells which must be activated.
- The O-DU High scans the list of cells received and sends corresponding cell configurations to 5G NR MAC.
- 5G NR MAC, in-turn configures the 5G NR SCH. It also configures the O-DU Low via the Lower MAC module.
- On receiving the cell config response, DU APP sends a gNB DU Config Update towards the O-CU. The O-CU responds with gNB DU Config Update ACK towards the O-DU High.

- The DU APP now exchanges F1 Reset message with the O-CU to initialize the UE contexts.
- DU APP sends Cell Start Req towards 5G NR MAC. This message is translated by the Lower MAC into the FAPI message START.request towards the O-DU Low.
- On receiving START.request, O-DU Low begins to send slot indications towards 5G NR MAC via the lower MAC. The frequency of these slot indications is determined by the numerology(Mu) supported. 5G NR MAC forwards these slot indications to the 5G NR SCH and DU APP modules.
- When the first slot indication reaches the DU APP, cell is marked as up.
- The 5G NR SCH, keeps tracking the SSB and SIB1 occasions on receiving regular slot indications. On detecting the relevant occasion, 5G NR SCH schedules SSB/SIB1 and forwards the DL Scheduling Information to 5G NR MAC.
- The 5G NR MAC multiplexes the PDU and sends SSB/SIB1 packets towards the O-DU Low through the Lower MAC.

UE Related Procedure

The O-DU High supports

- All physical channels - PBCH, PRACH, PDCCH, PDSCH, PUSCH, PUCCH
- All control logical channels - UL CCCH, DL CCCH, UL DCCH, DL DCCH
- All control transport channels - BCH, UL-SCH, DL-SCH, RACH

The above channels are used to achieve the below messages:

- Cell broadcast of System Information which includes SSB and SIB1.
- RACH Procedure
 - RACH Indication
 - Random Access Response
 - RRC Setup Request
 - RRC Setup
- UE attach signalling flow
 - RRC Setup Complete
 - Registraton Request
 - Security Mode Command
 - Security Mode Complete
 - Registraton Accept
 - Registraton Complete
 - Several NAS Message Exchanges
 - RRC Reconfiguration
 - RRC Reconfiguration Complete

Below figure depicts the above call flow, inclusive of all interfaces:

UE Attach

