D6.4: PoC design document

Revision: v.1.0

Work package	WP 6
Task	Task 6.2
Due date	30/06/2025
Submission date	11/07/2025
Deliverable lead	Thales Alenia Space (TAS-F)
Version	1.1
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Abstract	This deliverable describes the POC bench for the STARDUST demonstrations
Keywords	PoC, NTN, 3GPP, TN, Physical architecture, test bench

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Co-funded by the European Union

Grant Agreement No.: 101096573
Call: HORIZON-JU-SNS-2022

Topic: HORIZON-JU-SNS-2022-STREAM-A-01-02
Type of action: HORIZON-JU-RIA

Document Revision History

Version	Date	Description of change	List of contributor(s)
V1.0	30/06/2025	Partially updated draft from D6.2 v1.3F.	TAS-F, DLR, CTTC, SRS, AW2S, FHG
V1.1	11/07/2025	Final document completion update post Q&A review.	TAS-F, DLR, CTTC, SRS, AW2S, FHG

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5G-STARDUST (*Satellite and Terrestrial Access for Distributed, Ubiquitous, and Smart Telecommunications*) project has received funding from the **Smart Networks and Services Joint Undertaking (SNS JU)** under the European Union's **Horizon Europe research and innovation programme** under Grant Agreement No 101096573.

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

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EXECUTIVE SUMMARY

The present document addresses the definition of the bench associated to the PoC, which is one of the main outputs expected from the 5G-STARDUST project.

As such, this deliverable represents a bridge between the first phase of the project mostly devoted to the definition of the system architecture and the second phase, where the integration of the developed component will provide the building blocks necessary for the realisation of the PoC, which will be then used at the end of the project in key dissemination and promotional activities, aimed at showing the research delta and the added technological value achieved by the project with respect to the existing state of the art.

As such, this document takes as references the main indications drawn in the first phase of the project from an architectural standpoint and breaks down further the system into physical and logical components, constituting the terrestrial and non-terrestrial paths involved in the end-to-end connectivity concept developed in the project. In particular, it is worth noticing that the target TRL for the project is 4-5, so that key elements for the realisation of a fully integrated 5G-NTN system are here considered. In this respect, a key role is being played by the UE and gNB implementing the necessary NTN adaptation.

Then one of the main merits of the architecture developed in the project is the use of a regenerative payload onboard satellite. Last but not the least, one of the objectives to be reached with the planned PoC is also to support the case of multi-connectivity, in order to show how switching from one path to another or even the simultaneous use of both can be beneficial for the overall system performance.

The overall PoC is then aimed at reproducing the performance of a realistic 5G-NTN integrated system with respect to a number of use cases and related possible configurations, hence reaching an important milestone in the demonstration of the capabilities that a unified technology system may offer.

The main findings contained in this document with respect to physical layout and functional architecture will be from the D6.2 document a consolidated description of the bench and the implementation of the functionalities needed for the concept demonstration.

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ABBREVIATIONS

AI	Artificial Intelligence,
CU	Centralised Unit
DU	Distributed Unit
GTP	Generic Tunnelling Protocol
HW	Hardware
IAB,	Integrated Access and Backhaul
IP	Internet Protocol
KPI	Key Performance Indicator,
MC	Multi Connectivity,
MEC	Multi-Access Edge Computing,
ML	Multi Link,
MP	Multi Path,
MPL	Multi-Path Layer, etc.
MPQUIC	Multi-Path QUIC
MPTCP	Multi-Path Transmission Control Protocol
NGAP	NG Application Protocol,
NTN	Non-Terrestrial Network,
PCI	Peripheral Component Interconnect,
PoC	Proof of Concept
PSA	PDU Session Anchor
RF	Radio Frequency,
RU	Radio Unit,
SCTP	Stream Control Transmission Protocol,
SDR	Software Defined Radio,
SLE	Satellite Link Emulator,
SMA	Sub-Miniature version A,
SU	Switching Unit

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SW	Software
TCP	Transmission Control Protocol
TGA	Traffic Generator and Analyse,
TN	Terrestrial Network,
UE	User Equipment**,**

1 INTRODUCTION

1.1 POC CONCEPT AND DEVELOPMENT PHASES

Deliverable D6.4 contains the definition of the PoC bench in the context of WP6 'Integration, testing, and validation' overall aimed at the definition and integration of the PoC according to the system architecture defined in WP3 (Architecture Design) and on the basis of the activities carried out within WP4 (Radio Technologies) and WP5 (Networking Operations), whose main outputs in the form of SW/HW pieces are then the object of the PoC integration. In turn, once the PoC will be fully integrated and operational, the corresponding demonstration campaigns will be carried out, whose results analysis is performed immediately afterwards. A dedicated study-logic illustrating such a process is shown in Figure 1.

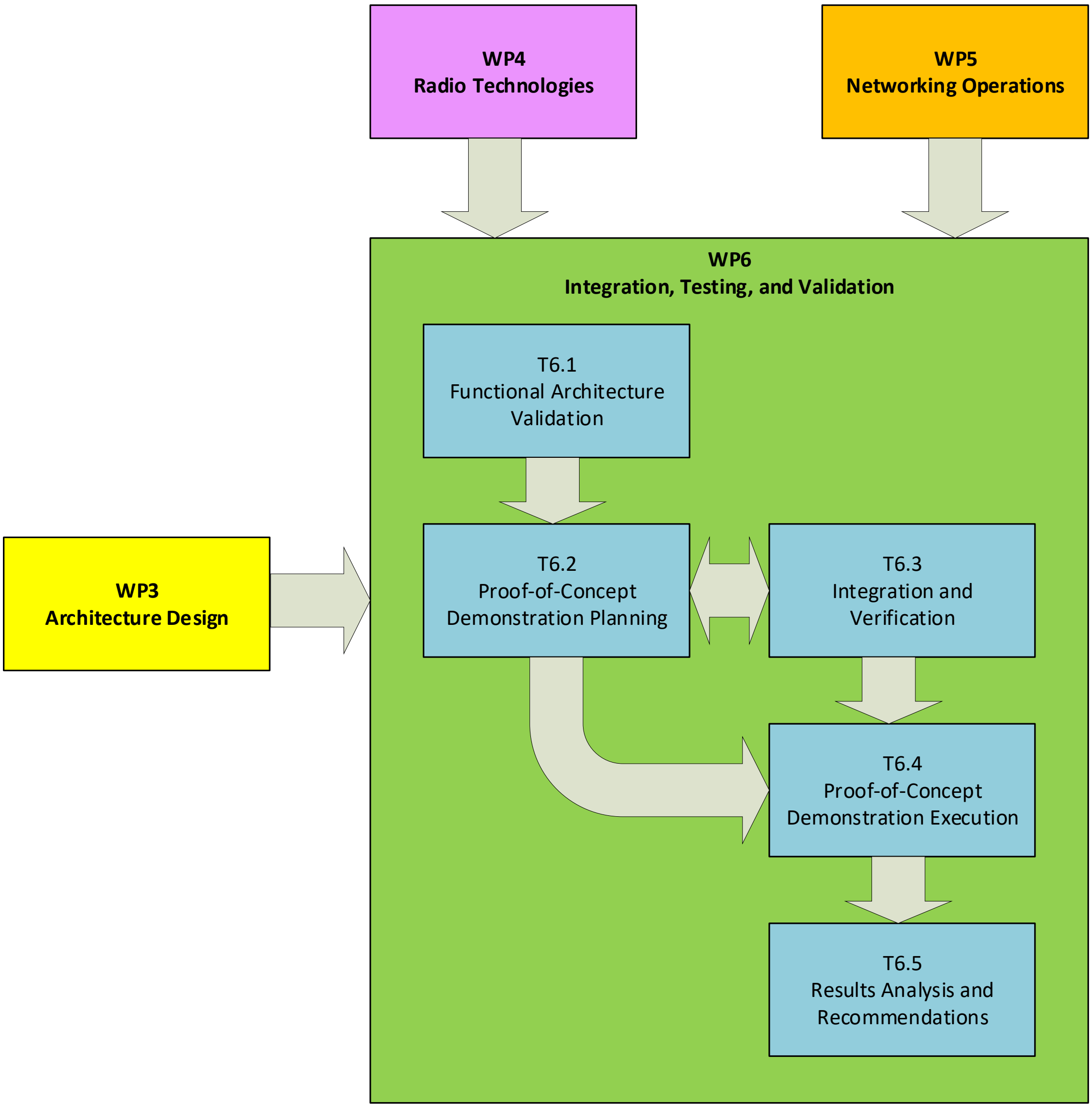


Figure 1 WP 6 interaction with development activities in 5G-STARDUST

From the above picture is then clear the role of this deliverable as output of Task 6.2 in providing the foundation of the PoC, as it elaborates physical architecture and overall component projection on the physical architecture of the PoC. As such, the main indications provided in this document will be later used to plan the actual demonstration and how the different building blocks here defined will be integrated and tested towards the full system verification. In this respect, obviously, a prerequisite for the definition of the functional architecture is the system design as developed in the course of WP3, so that in particular D3.2 [2] is the starting point for the definition of the PoC functional architecture.

In more detail, the discussions and findings summarised at the end of D3.2 [2] allowed to define the macro-architecture (see Figure 2) for the project PoCs so as to address both direct and indirect access, hence offering the possibility to address multiple scenarios.

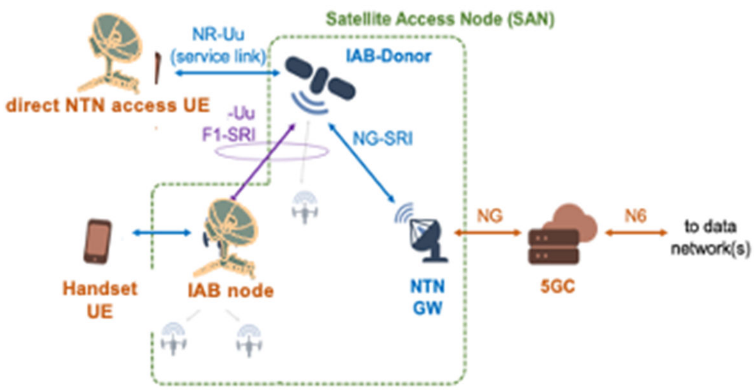


Figure 2 Macro-architecture of the NTN segment for the PoC (TN segment not shown here)

As a matter of fact, the access to the satellite in the indirect configuration will happen through a relay node, hence resembling that of IAB node functionality, although this is not exactly the approach taken in the project. The adopted methodology does not rely on IAB implementation (for which no NTN adaptations have been addressed so far in 3GPP), but on the contrary the idea is to take advantage of an intermediate node responsible for interacting with a UE and extending its connectivity so as to reach the gNB, which will be implemented (either fully or in distributed manner) in the space segment. Further to this, it is expected to have different classes of UE, able to achieve data connectivity in either FR1 or FR2 with different bandwidth availability. Last but not least, the satellite path is then complemented by a terrestrial counterpart in order to show the coexistence of different paths and demonstrate the added value of a unified network architecture, where both TN and NTN segments are available.

In general, the main objective of the PoCs will be that of proving the added value coming from integrated TN and NTN networks implementing a regenerative LEO satellite system. In that respect, first of all it is assumed to consider a transparent LEO setup as actual benchmark. Then in turn, some of the main functions to be considered for the demonstration to prove the value of integrating TN and NTN will be about:

1) Support of FR1 frequency band and some characteristics of the FR2 frequency band (100 MHz bandwidth).

2) End-to-end connectivity through a unified radio interface

3) Multi-link/path achievement towards effective utilisation of the available TN/NTN resources

The demonstration of the FR2 capacities will not be performed on the PoC but with theoretical demonstration. This demonstration is in line with the objective 4 where the measurable results can be performed either by on laboratory test beds and numerical simulation.

To this end, the overall PoC picture will address network disaggregation by considering different functional splitting models aimed at showing performance fluctuations and corresponding configuration adjustment.

Last but not the least, the final version of the demonstrator will be plugging real user applications in order to have impactful demonstrations of the added value of the 5G-STARDUST concept by achieving a close-to-real setup (though still up to max. TRL 5).

1.2 TRL REVIEW

On the basis of the first iteration presented at the end of D3.2 [2], a successive refinement has been conducted to identify the macro-blocks necessary for the definition of the PoC, which are further summarised in Table 1, here below:

Table 1 PoC Macro-blocks and related TRL progression

Technology	Initial TRL	Estimated TRL	Support (full/partial)[1]	Notes
Regenerative payload	2	4	full	Key demonstration objective of the project, also in relation to embark a gNB in space with all necessary functions from physical layer up to PDCP
Unified UE interface	2	4/5	full	Key demonstration objective of the project, with respect to proving the benefits of integrating a UE into TN/NTN segments interchangeably.
ML supported TN/NTN MC on higher layers	2	4	partial	Multi-connectivity supported in terms of multi-path protocols and related integration between core network, RAN, and UEs
AI data driven networking solutions for MC (management)	2	4	partial	Multi-connectivity management carried out in static manner, since AI would not bring much benefit in a PoC of limited size (i.e. few UEs)
AI data driven networking solutions for MC (slicing)	2	4	partial	Network slicing supported in the sense of differentiating QoS classes, through static classes separation.
MEC platform for NTN nodes	2	4	TBC[2]	-
RAN softwarization	2	4	full	Pretty much oriented to the achievement of gNB in space, either in the form of full gNB in

[1] In the case of partial support, not all functionalities as planned within 3GPP will be part of the PoC. Detailed description will be provided in the technical specification, object of D6.2 and D6.3.

[2] WP5 will come up with a dedicated testbed to show the potentials of a MEC agent in space. Its actual integration in the WP6-developed PoC is a nice-to-have feature, but not strictly fundamental to reach the objectives of the project. Such an opportunity will be better assessed in the next phases of WP6, while planning the integration of PoC and the related demonstration execution.

Technology	Initial TRL	Estimated TRL	Support (full/partial)[1]	Notes
				space or in distribute manner (i.e. function CU/DU splitting)
Core Network Functionality	**4**	**5**	**full**	The core network was tested already with gNBs placed at large distance, however not with gNBs at continuous variable delays. However, we do not expect to be a major issue

1.3 OBJECTIVE AND ORGANISATION OF THE DOCUMENT

The document is organised in four main parts:

- A recall of the expectation of the bench for covering the demonstration in chapter 2.1.
- An overview of the physical architecture regarding the three main functional prerequisites, architecture implementation, time synchronization and remote-control capabilities, needed to perform the demonstration on chapter 2.2, 2.3 and 2.4.
- A description of all the hardware component for the PoC bench manufacturing.
- A description of all identified software component.

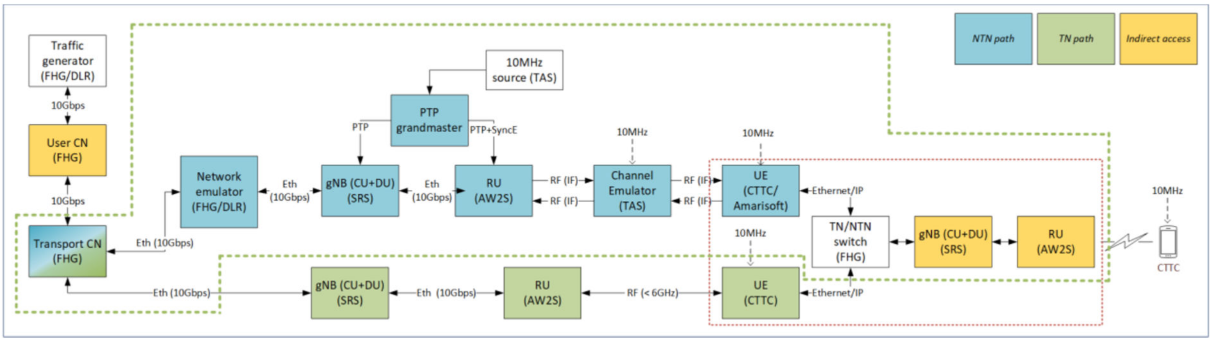
2 BENCH DESCRIPTION

2.1 RECAP OF OBJECTIVES AND PRELIMINARY DEFINITION

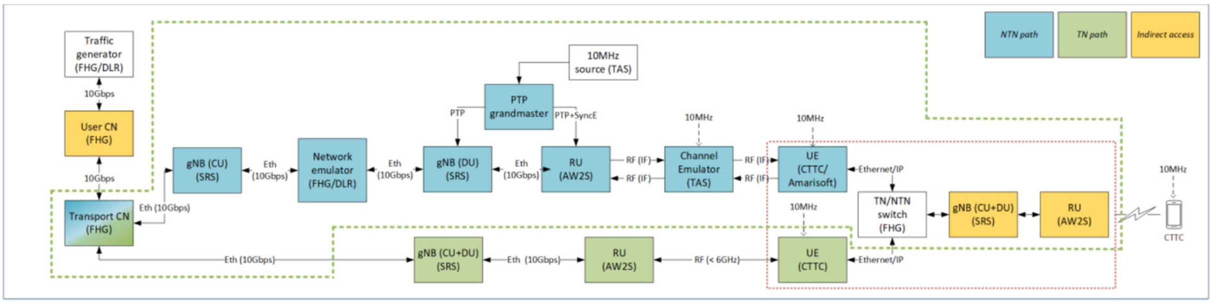
The PoC bench shall be able to demonstrate the Use Cases identified in the D2.1 [1] in line with the different splitting defined in the D6.1 [4] PoC functional architecture document.

The different splits are reminded here after:

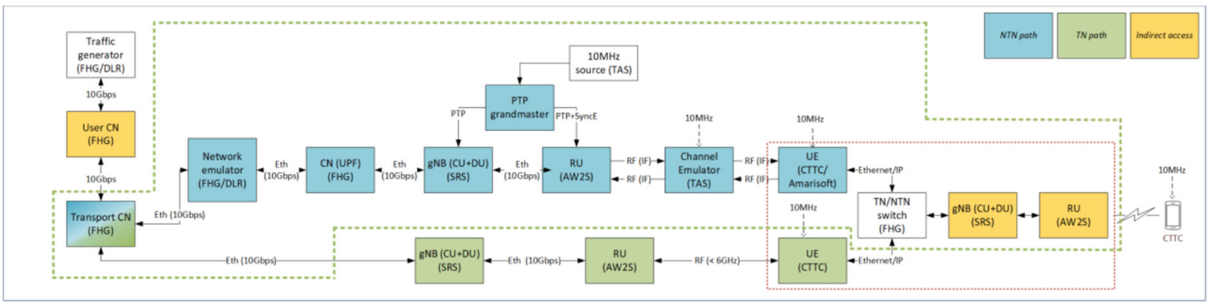
- Split #1 -Full GNB On Board:



- Split #2 - CU/DU splitting



- Split #2 - Full gNB on board with 5GC functions



The splits defined introduce some constrains on the design and the logical architecture. The three splits imposed to separate the gNB in a minimum of two logical partition, one for the CU, one for DU/RU, and to separate the Core Network in two logical partitions (one for the UPF function, one for the rest of the Core Network).

Considering the feeder link for the NTN, the technology usually used for the link is well none and presents no major point to be de-risked, based on this assumption, only time delay is taken into account for the feeder link. The PoC will use an Ethernet link to simulate the feeder RF link, limited currently to the traffic delay (propagation time) without other type of interferences (weather, location discrepancies …).

Considering the NTN “user” link, the complexity and specificity of the RF parts (OFDM wave form, Doppler effects, losses …), the satellite to user link will be emulated with a two-way RF satellite link emulator connected through RF wire (coaxial).

For the TN link, the connection will be also performed with coaxial wires despite over the air link. The aim of the demonstrator is not to verify the TN capacities that are already demonstrated in many ways but ensure that the commutation between the TN and the NTN is feasible.

The link between the final end user device and the IAB is performed by wire. This link is well known and only the access principle shall be demonstrated.

2.2 TN AND NTN ARCHITECTURE OVERVIEW

2.2.1 Principle

The PoC bench will be able to sustain the TN and NTN demonstrations. The physical architecture is based on several servers, one dedicated simulator (i.e., SLE) and further Software Define Radio devices representing the RF emulation (i.e., RU cards and associated software).

There are two foundational principles for the system's setup. Each functional component requiring dedicated processing will be assigned its own computer. Then, unless specific requirements dictate otherwise, functional components will be deployed using either containers or VMs, based on the provider's specifications. This approach also entails the virtualization of Ethernet links for each hardware component. Optionally, resources can be further partitioned based on application needs, allowing for optimized allocation of core processing and Ethernet interfaces, especially when multiple interfaces are available on the server.

The network capacity is based on the maximum traffic load to avoid any overloading or discrepancies.

2.2.2 Description

The TN and NTN network is based on the following equipment:

- One server for the “Core Networks”. It will host the following functionalities:
    - Traffic Generator
    - 5G Core Network system
    - 5G Core Network TN/NTN without NTN UPF functions
    - 5G Core Network NTN UPF functions
    - Feeder link channel Network Emulator (in case of split #3)
- One server for gNB TN/NTN. It will host the following functionalities:

- DU NTN
- CU NTN
- DU TN
- CU TN
- Feeder link channel Network Emulator (in case of splits #1 & #2)

- Final UE server
- One IAB server. It will host the following functionalities:
  - gNB (CU+DU systems) final end user UE bridge
  - IAB switching function
- The RU modules to perform the conversion from the frames issued of the DU to generate the RF signal and its reverse link:
  - RU NTN
  - RU TN
  - RU IAB/NTN
  - RU IAB/TN
  - RU final end user UE bridge
  - RU final end user UE
- The Satellite Link Emulator.
- The Ethernet switch with the capacity of a 10 Gbit/s network and RJ-45/SFP+ cables to ensure the data transfers between each server.

The overview of this network is presented in Figure 3.

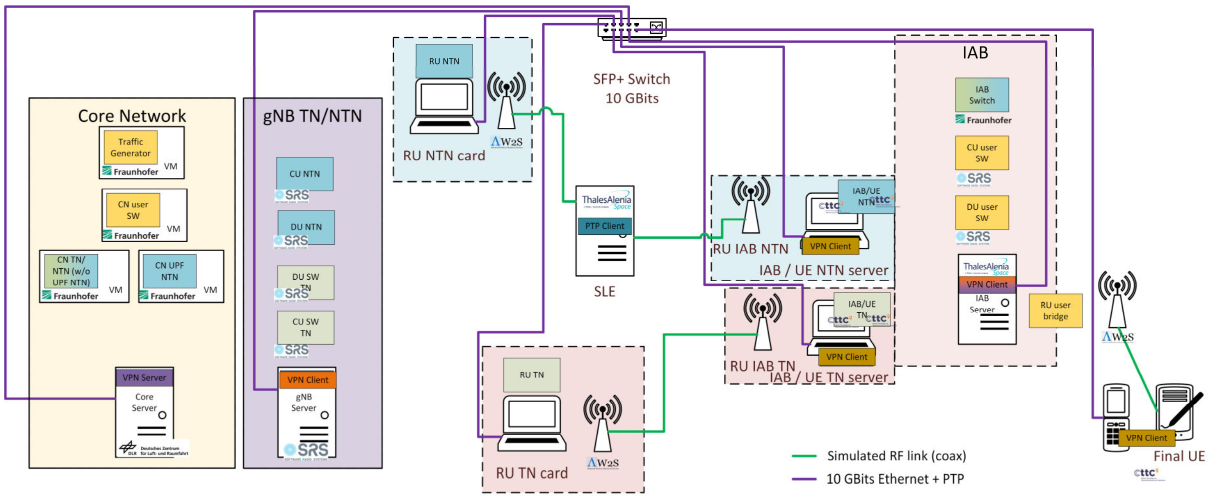


Figure 3: Bench TN/NTN backhaul & indirect user access architecture

All the equipment presented in this architecture are located in the TAS-F facilities.

For the NTN simulation, only a part of the presented architecture will be used. Figure 4 presents the components used for the part of the simulation.

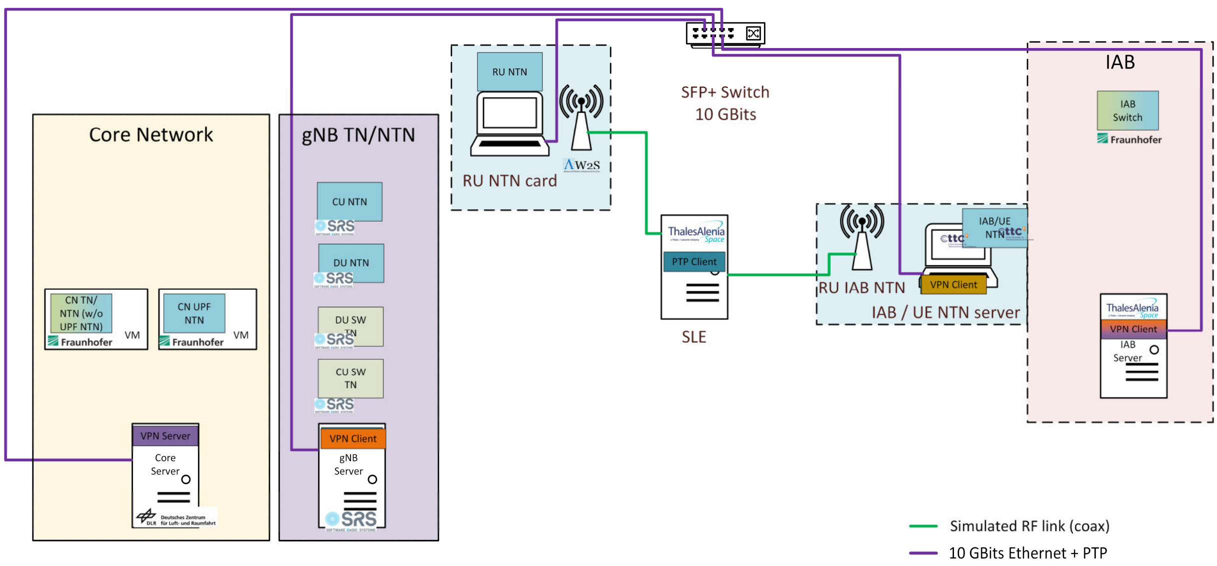


Figure 4: Bench NTN backhaul components

In the same way, the TN network is simulated with the components presented in Figure 5.

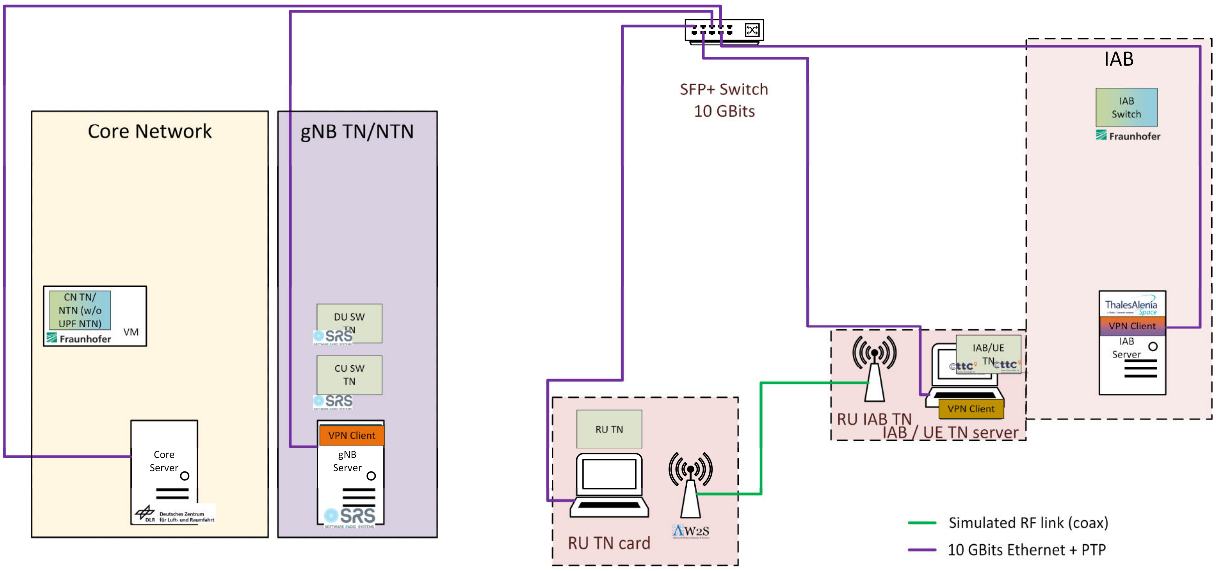


Figure 5: Bench TN backhaul components

For the TN and NTN network, the TN Core Network and IAB switching components are common to those two networks and represented with two colours box.

The encapsulated network constitution is summarised in Figure 6.

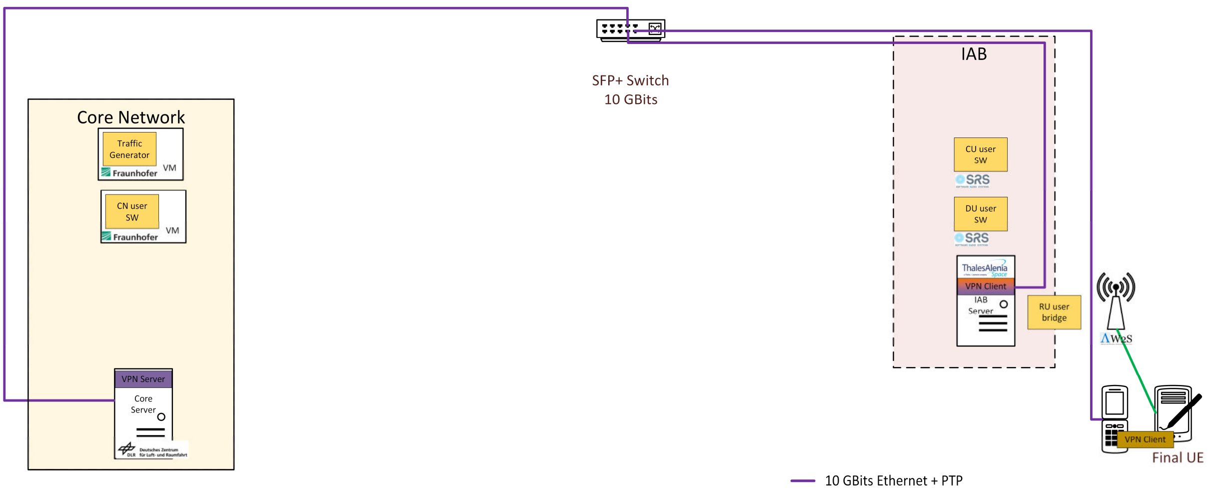


Figure 6: Encapsulated indirect user access network

This last configuration also contents the traffic generator that will be used to simulate the inputs for the different use cases that will be demonstrated.

2.3 TIME SYNCHRONISATION

2.3.1 Principle

The time synchronisation is critically important for both NTN and TN. Depending on the functionality, the synchronisation shall be performed as absolute of relative time. This is done at different level regarding the component. As specified in the 3GPP NR (TS 29.565), a

Precision Time Protocol synchronisation shall be distributed to all components for synchronisation purpose. The PTP is defined in the IEEE 1588. For telecommunication purpose, it is defined under the ITU specification G.8265.1, G8275.1 and G.8275.2. The principle of the PTP is based on time stamp exchange between the master and the slaves. It's a "four steps" as shown in Figure 7.

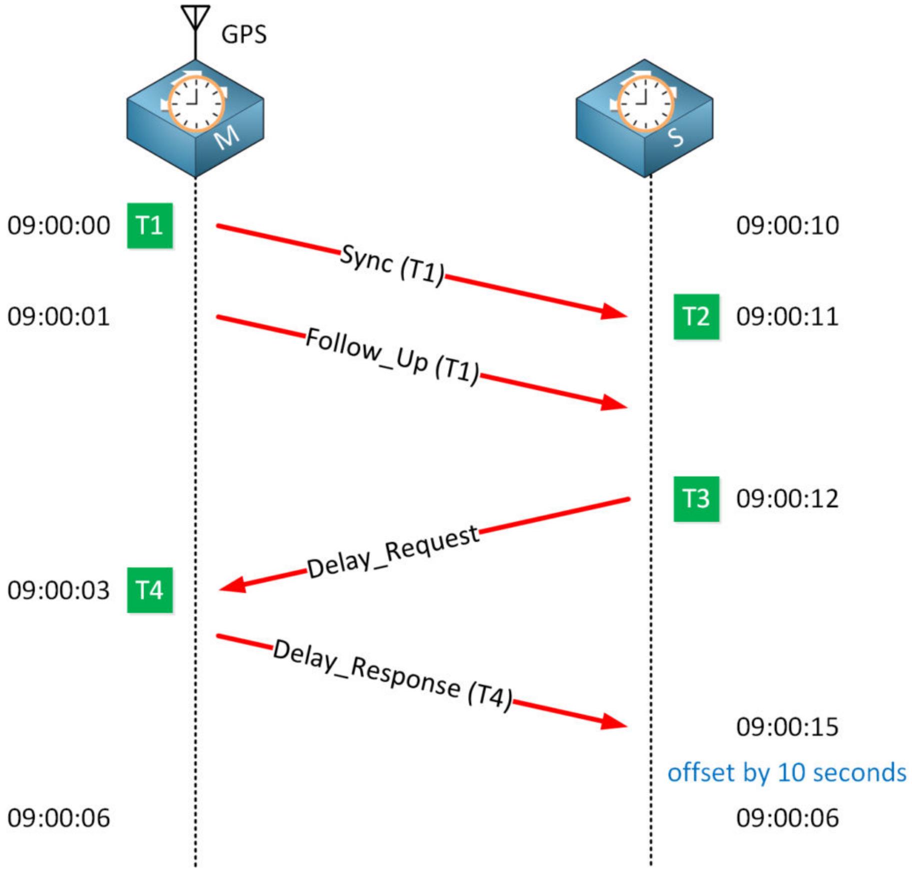


Figure 7: PTP message principle

The process involves the master sending a Sync (T1) message, followed by a Follow_Up (T1) message containing a timestamp, then the slave sending a Delay_Req message, and finally, the master responding with a Delay_Resp (T4) message. This exchange allows the slave to calculate the offset and propagation delay from the master, enabling accurate time synchronization

The computation of the transmission time and offset time between messages allows the synchronisation of the client clock (slave clock) to the Grandmaster clock (master clock). Regarding PoC bench implementation, the time will be provided by Ethernet link. Each device will be connected through an Ethernet link to the timing reference & data network switch unit (refer to section 2.5.1) to get the PTP service. A 10 MHz reference signal is also delivered by the Falcon-RX to ensure an external synchronisation.

2.3.2 Description

The architecture used for the time synchronisation is based on a Falcon-RX (refer to section 2.5.1). It is used as Grandmaster clock and connected to a GNSS antenna. The GNSS system is used as the global high accuracy and stability reference clock.

In each component, a hardware or software PTP is implemented to synchronise the time to the Grandmaster one.

The overall time and frequency reference distribution architecture is represented in Figure 8.

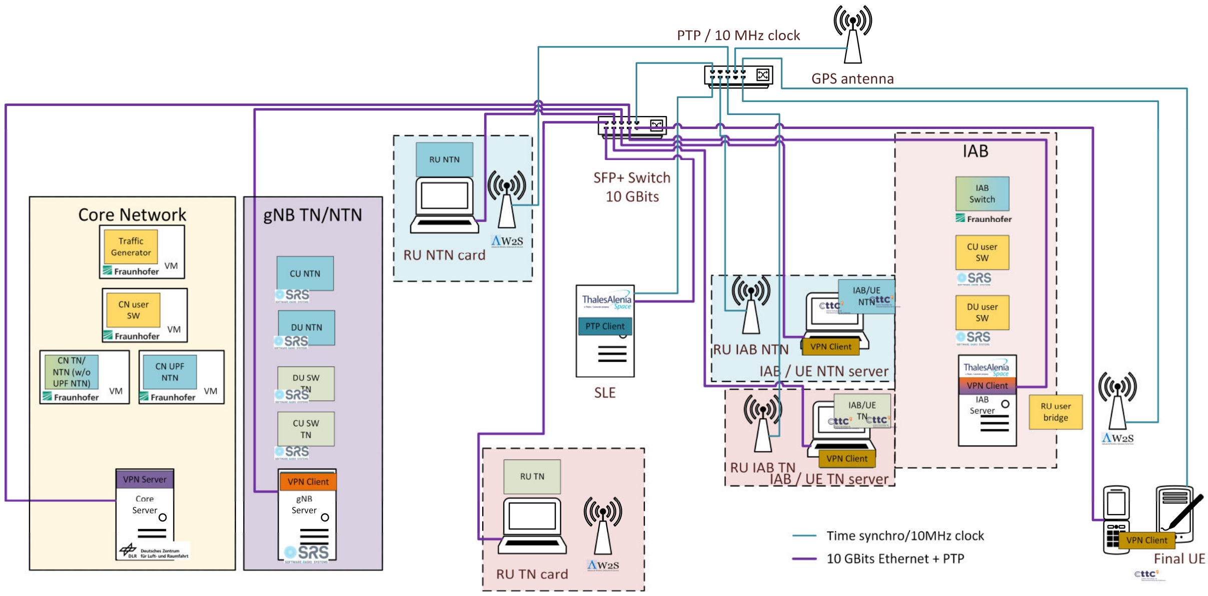


Figure 8: Time and Reference oscillator sharing architecture

The server OS can be:

- Linux distribution
- Windows

For each OS, there is a software client that synchronise the local clock.

The precision that can be reached is lower than the µs. This precision needs to be shared to ensure that the NTN and TN are based on the same time synchronisation (TDD OFDM synchronisation and delay accuracy computation). It is also used for standalone device to monitor the LO frequency (ensuring stability).

All the equipment presented in this architecture are located in the TAS facilities.

2.4 REMOTE CONTROL ARCHITECTURE OVERVIEW

2.4.1 Principle

The aim of the remote-control system is to ensure that every partner could access their component in the bench located in TAS facilities and also be able to demonstrate some use cases remotely from their own location.

The principle is to use, for each partner, a secure VPN service connection between the partner facilities and the bench resources:

- The partner could install as much as needed VPN client (up to one per VM)
- No visibility of the bench on internet (no open port on the firewall).

The VPN client can be defined at the OS level or at the VM level, depending of the customer needs and interaction.

2.4.2 Description

The remote-control set-up is presented as per architecture in Figure 9.

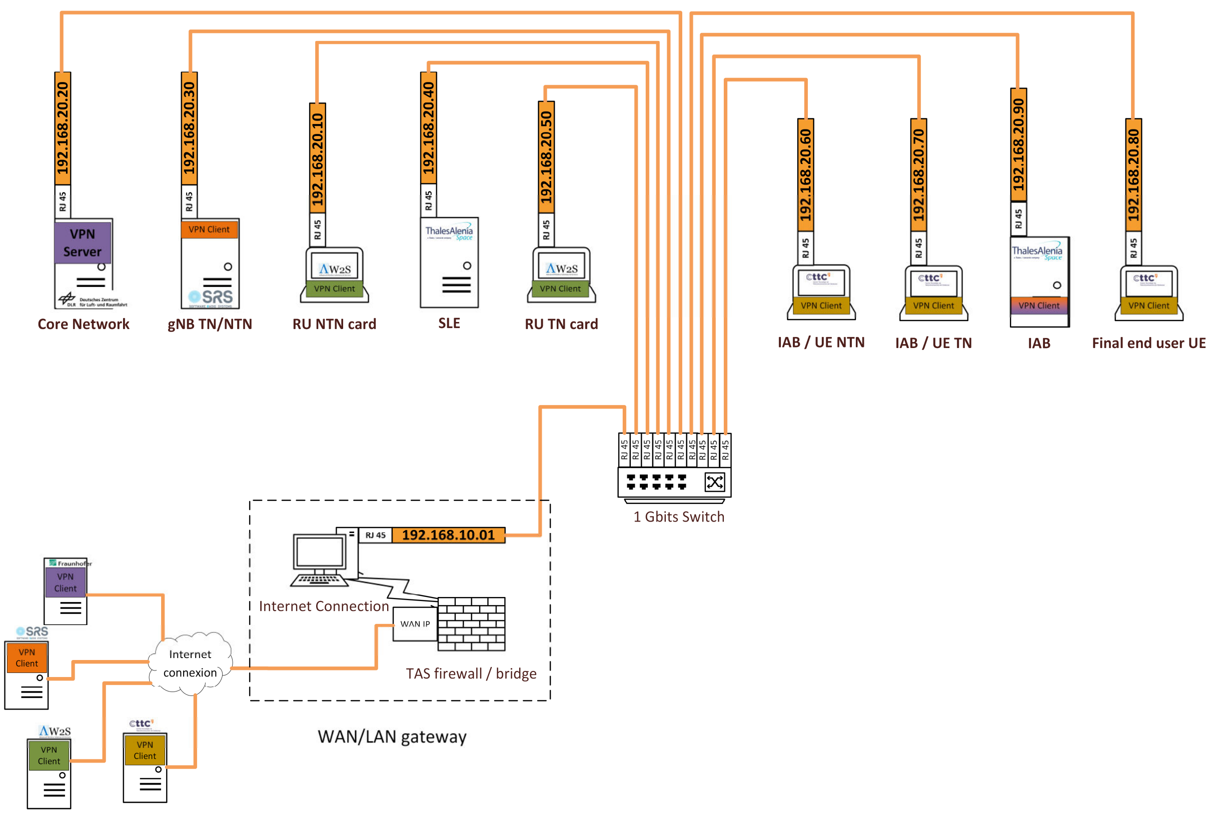


Figure 9: Remote control architecture

As described in Figure 9, a WAN/LAN gateway has been implemented by an internet WAN routing access point (DHCP) with some routing and firewall features that is then associated with a dedicated LAN where the bench equipment connects through a fixed IP addressing. Its physical infrastructure relies on a router device, a 1 Gbit/s switch, and SFTP-category 6 cabling equipped with RJ-45 or SFP+ interfaces. The VPN service uses the WireGuard protocol with a local server software hosts by the CN server PoC bench equipment to then establish an individual tunneling between client applications respectively running on bench components and at partners side.

2.5 HARWARE COMPONENTS

2.5.1 Time PTP & Frequency reference unit

2.5.1.1 Description

The PTP server is the equipment needed to distribute the Time reference through Ethernet link to all connected equipment over the PoC bench data network.

The current installed reference is the Fibrolan FALCON-RX which combines network, time and frequency distribution capabilities.

2.5.1.2 Interface

Figure 10: Fibrolan Falcon RX interface view

The Falcon-RX has:

- A GPS antenna input compatible with GPS, Galileo, GLOSNASS and Beidou constellation with 32 channels,
- Ethernet switch:
    - 12 SFP+ ports @ 10 GbE
    - 8 SFP+ port @ 25 GbE
- 3 sync clock coaxial SMA port @ 10MHz

2.5.1.3 Form factor

The form factor is equivalent to a 1U - 19 inches rack module.

2.5.2 Network TN/NTN switch

2.5.2.1 Description

The Ethernet switch feature of the T&F interconnects bench equipment to network NTN/TN data traffic.

2.5.2.2 Interface

The 8 x SFP28 ports (10/25 GbE) cover the required capacity to support the architecture.

2.5.2.3 Form factor

The form factor is the same as the T&F unit due to the fact the switch is included in the T&F unit equipment.

2.5.3 Traffic generator

The traffic generator application is hosted on the Core Network Server (refer to section 2.5.4).

2.5.4 Core Network server

2.5.4.1 Description

The server will be capable of running the 5G core used for PoC. It will also be able to execute AI/ML operations to assist in decision making tasks (e.g., for multi-connectivity), if needed.

The hardware intended to host the server has the following specifications:

- CPU: Intel i9
- RAM: 32 GB
- GPU: NVIDIA GeForce RTX 4070
- Storage: 1 TB SSD

2.5.4.2 Interface

The machine will have an Ethernet interface with two SFP+ adapters. An interface considered as reference is Intel X710 Quad Port 10GbE SFP+ Adapter, PCIe Full Height, V2.

2.5.4.3 Form factor

The dimensions of the machine will be equivalent to be placed in a 2U - 19-inches rack.

2.5.5 gNB server

2.5.5.1 Description

The gNB server is responsible for hosting both the CU and the DU of the NTN enabled gNodeB from SRS.

The gNodeB consists of L1 to L3 layers of 5G New Radio interface and is compliant to release 17 with the 3GPP features to support NTN.

The server is capable of running the srsRAN 5G Project gNB (with and without NTN extension) used for PoC. The hardware intended to host the server has the following specifications:

- CPU: AMD Ryzen 7 5700G, 16 cores
- RAM: 16 GB
- Storage: 512 GB SSD

2.5.5.2 Interface

The gNB server TN/NTN is interconnected with Core Network, RU TN and RU NTN equipment of PoC bench as described in the next figure:

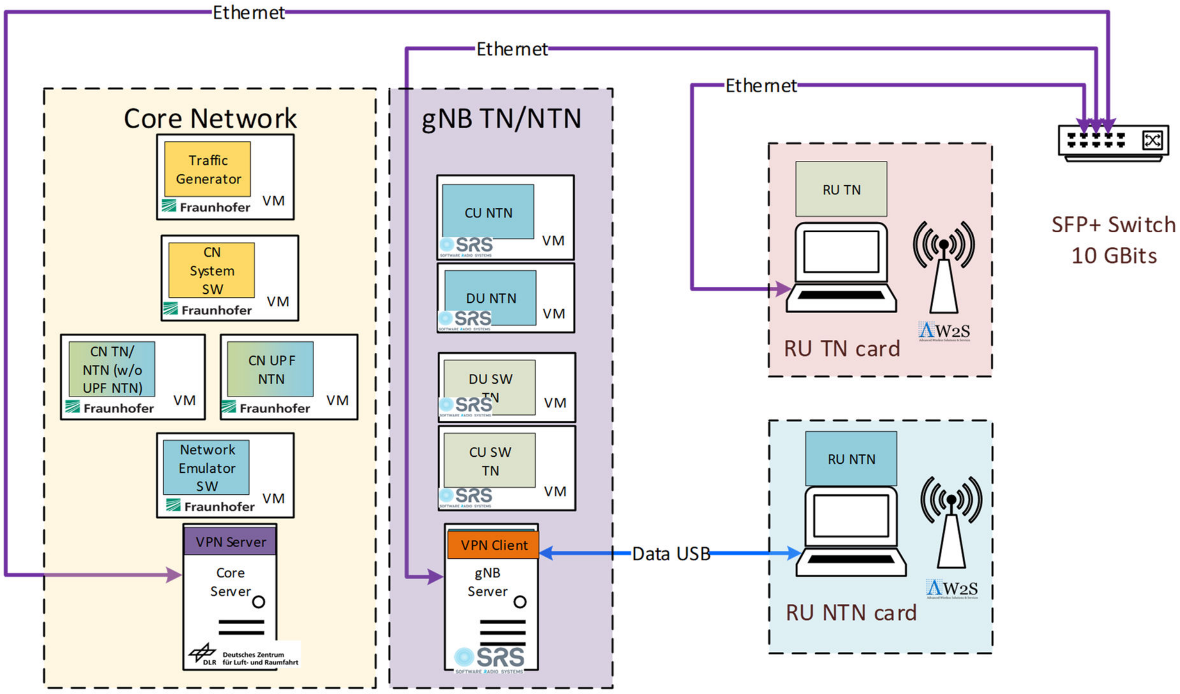


Figure 11: gNB server interfaces

Following interfaces are available to cover this installation:

- Ethernet interface used for remote control (using ssh protocol).
- Two 10G Ethernet ports used between gNB and the Core Network (Intel Corporation 82599ES 10-Gigabit SFI/SFP+)
- Two USB 3.0 ports to connect two Ettus USRP B210 Software Define Radios.

2.5.5.3 Form factor

The gNB server material platform is a standard compact tower casing:

Figure 12: gNB server overall enclosure

Its volume is less than 8 liters.

2.5.6 RU TN

2.5.6.1 Description

The RU TN component is a Software Define Radio module that carries conversion between gNB digital carrier physical layer frames and RF signal on terrestrial backhaul user access link.

The equipment installed on the bench is relied on a COTS Ettus Research USRP B210 reference according to these following main specifications:

- Compute processing chipset Xilinx Spartan 6 XC6SLX150 FPGA.
- RF frequency input/ouput range from 70 MHz to 6 GHz.
- Instantaneous bandwidth up to 56 MHz.
- USB-3.0 SuperSpeed bus.

A proper IP software is implemented to cover PoC bench application.

2.5.6.2 Interface

The RU TN interfaces are depicted in Figure 13.

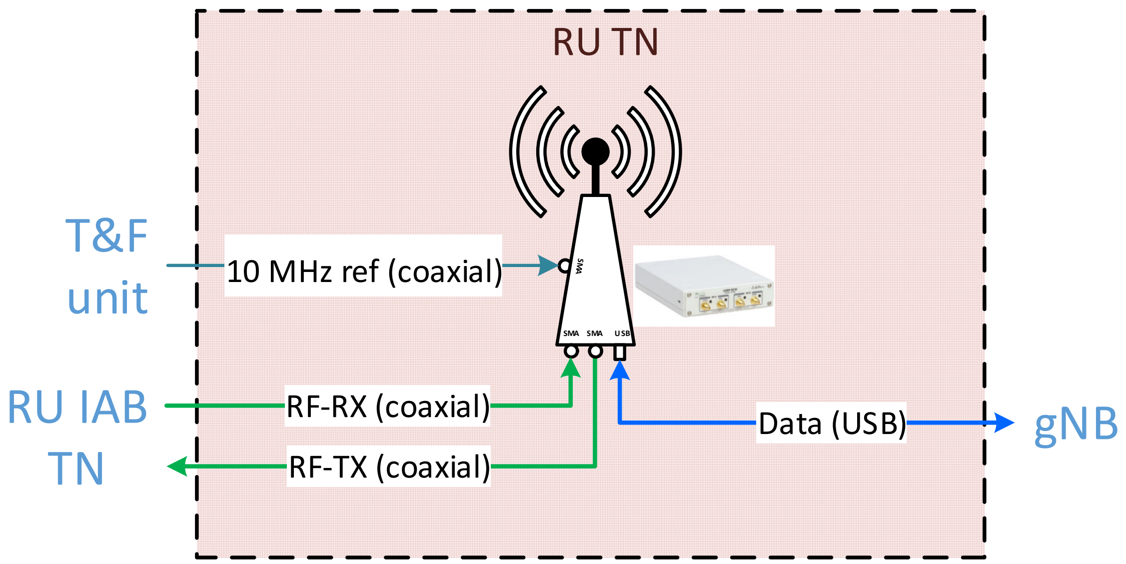


Figure 13: RU TN interfaces

The RU TN is connected to the TX/RX RF - RU IAB TN signals through SMA connectors. The RU TN is connected to the 10MHz reference clock through an SMA connector. The gNB server and RU frontend are connected through an USB-3 link.

2.5.6.3 Form factor

The USRP B210 hardware is housed in an alloy enclosure as evident in Figure 14.

Figure 14: B210 USRP overall casing

Its related dimensions are approximatively: Width 97 mm x Length: 155 mm x Height: 15 mm.

2.5.7 RU NTN

2.5.7.1 Description

The RU NTN component is a Software Define Radio module that carries conversion between gNB digital carrier physical layer frames and RF signal on satellite backhaul user access link.

The equipment installed on the bench relied on a COTS Ettus Research USRP B210 reference according to these following main specifications:

- Compute processing chipset Xilinx Spartan 6 XC6SLX150 FPGA.
- RF frequency input/ouput range from 70 MHz to 6 GHz.
- Instantaneous bandwidth up to 56 MHz.
- USB-3.0 SuperSpeed bus.

A proper IP software is implemented to cover PoC bench application.

2.5.7.2 Interface

The RU NTN interfaces are depicted in Figure 15.

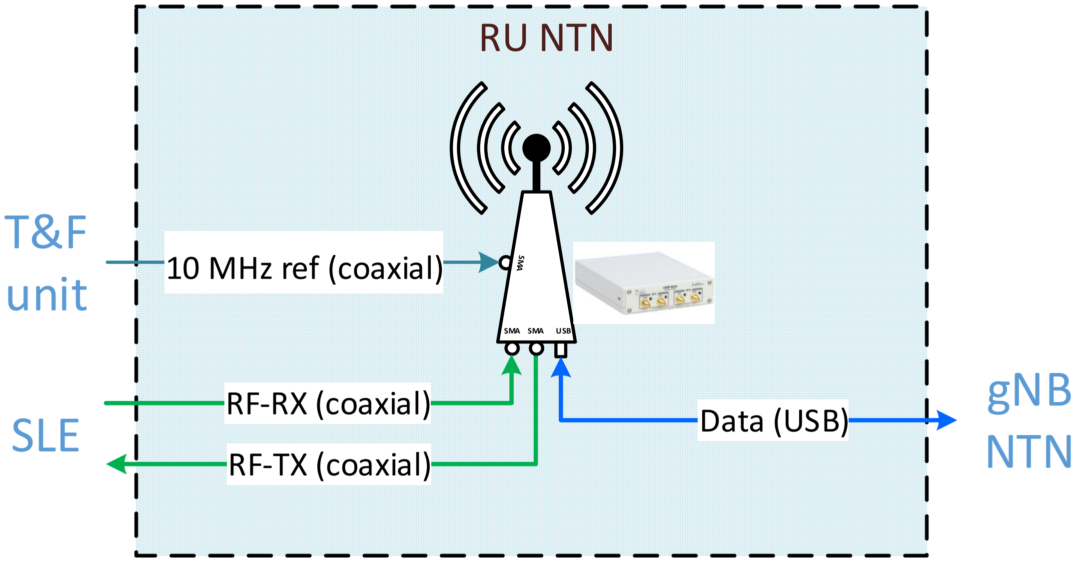


Figure 15: RU NTN interfaces

The RU NTN is connected to the SLE TX/RX - RF NTN signals through SMA connectors. The RU NTN is connected to the 10MHz reference clock through an SMA connector. The gNB server and RU frontend are connected through an USB-3 link.

2.5.7.3 Form factor

Refer to section 2.5.6.3

2.5.8 SLE

2.5.8.1 Description

The SLE (Satellite Link Emulator) is provided by National Instrument. The system is based on a PXI rack and a set of PXi cards. The cards are:

- One PC card for interfacing and managing the SLE (PXIe-8881)
- Two PXIe-5842 VST for the acquisition and generation of the RF signal
- Two PXIe-7915 FPGA co-processing hosting the SLE main functions.

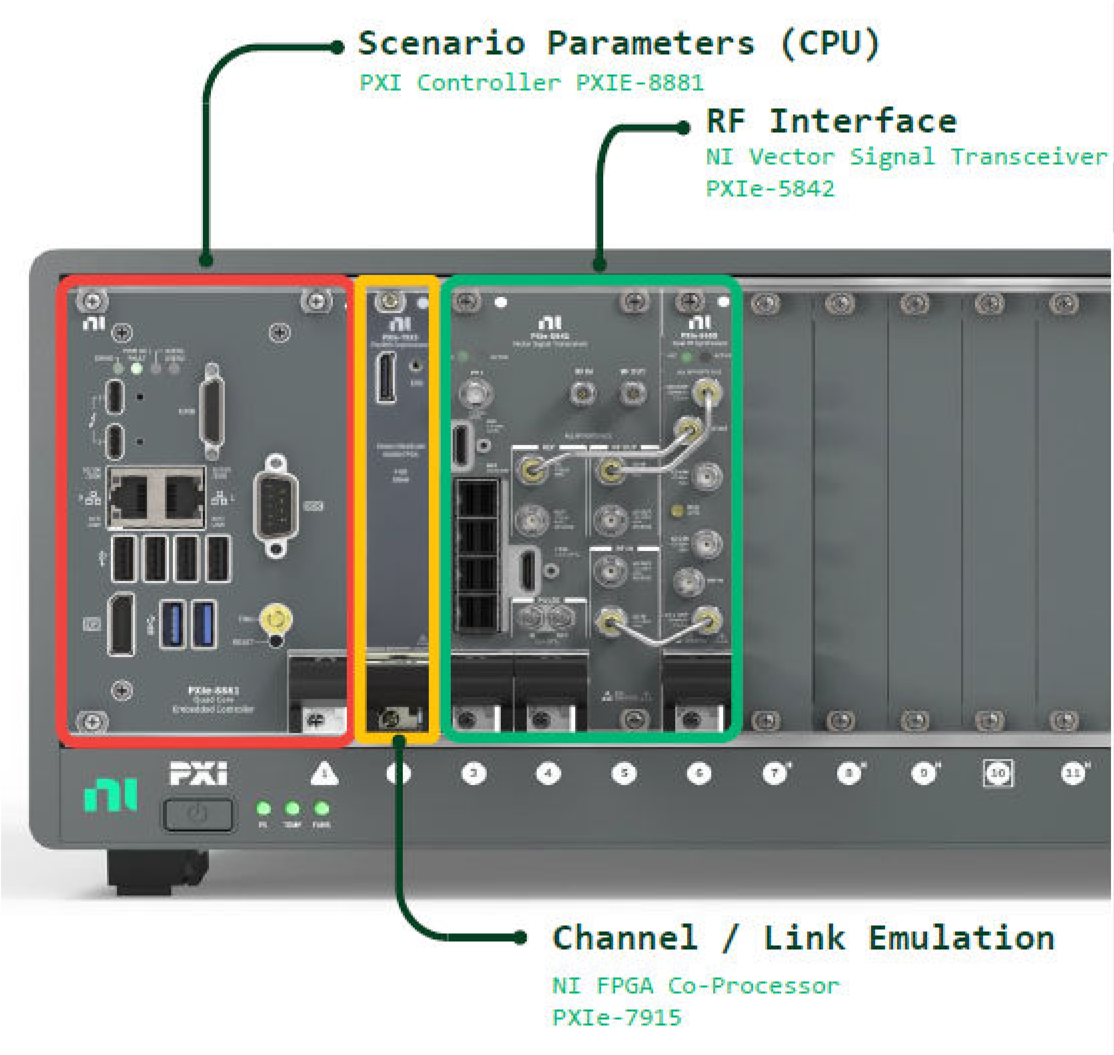


Figure 16: SLE front panel layout (one channel layout)

2.5.8.2 Interface

The SLE is connected to the RF signal through specific coaxial RF connection. The SLE is connected to the local remote control network through 1 x RJ45 link. The SLE has a synchro input based on a 10MHz clock

2.5.8.3 Form factor

The SLE is based on a NI PXIe-1095 cabinet platform.

2.5.9 UE IAB NTN 20 MHz

2.5.9.1 Description

The UE IAB NTN device is responsible for backhauling the cellular traffic that is fed into the IAB switch through the NTN link. The UE IAB NTN is compliant with the Rel. 17 and implements the necessary features to support NTN. The UE protocol stack, which terminates at Layer 3, runs on a workstation Linux computer with following main specifications.

- CPU: Intel-Core i7 (or equivalent).
- RAM: 32 GB (minimum).
- Storage: 1 TB SSD.

This server is connected to a COTS SDR frontend module B210 from Ettus Research as a RU module (refer to section 2.5.7.1).

2.5.9.2 Interface

The UE IAB NTN assembly interfaces are depicted in Figure 17.

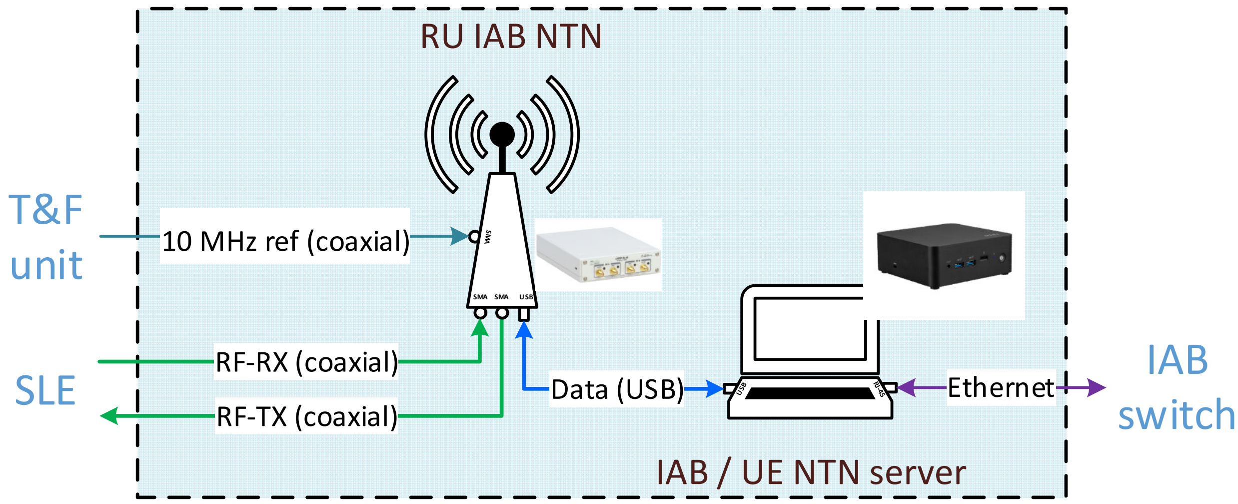


Figure 17: UE IAB NTN interfaces

The RU frontend is connected to the SLE TX/RX RF NTN signals through SMA connectors. The RU frontend is connected to the 10MHz reference clock through an SMA connector. The UE server and RU frontend are connected through an USB-3 link. The UE server is interfaced with the data network switch via an RJ45 2.5G port.

2.5.9.3 Form factor

The UE server is housed in a compact volume chassis (< 1 liter).

Figure 18: UE server overall casing

The RU module USRP B210 hardware is housed in an alloy enclosure (refer to section 2.5.6.3).

2.5.10 UE IAB TN

2.5.10.1 Description

The UE IAB NTN device is responsible for backhauling the cellular traffic that is fed into the IAB switch through the TN link. The UE protocol stack, which terminates at Layer 3, runs on a workstation Linux computer with following specifications:

- CPU: Intel-Core i7 (or equivalent).
- RAM: 32 GB (minimum).
- Storage: 1 TB SSD.

This server is connected to a COTS SDR frontend B210 USRP module from Ettus Research as a RU module (refer to section 2.5.7.1).

2.5.10.2 Interface

The UE IAB NTN assembly interfaces are depicted in Figure 19.

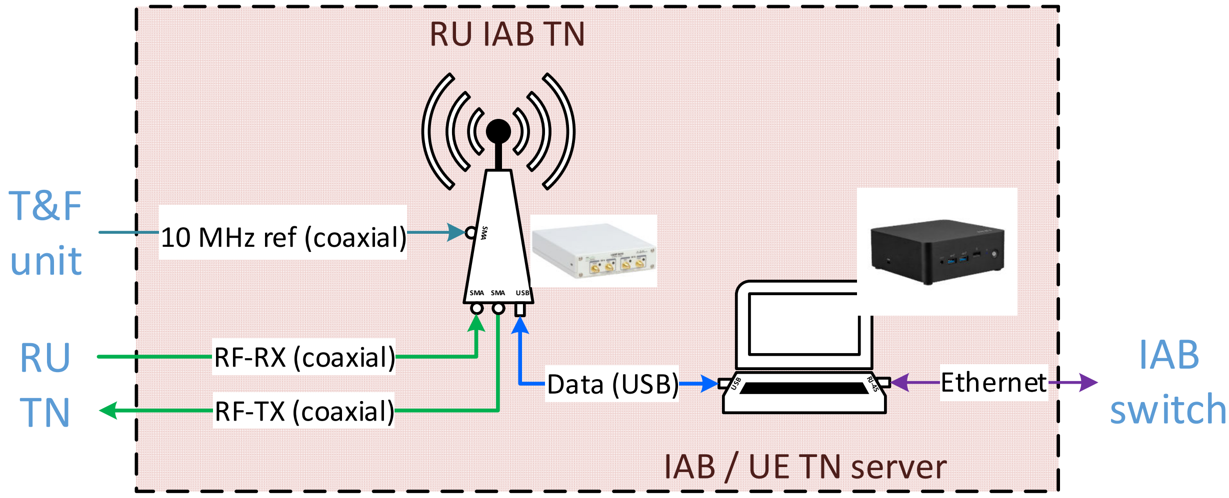


Figure 19: UE IAB TN interfaces

The RU frontend is connected to the TX/RX RF TN signals through SMA connectors. The RU frontend is connected to the 10MHz reference clock through an SMA connector. The UE server and RU frontend are connected through USB 3.0 link. The UE server is interfaced with the data network switch via an RJ45 2.5G.

2.5.10.3 Form factor

Refer to section 2.5.9.3.

2.5.11 IAB server

2.5.11.1 Description

The IAB server is designed to hold multiple applications (CN DU & RU, switching application between TN and NTN). For this purpose, a DELL computer is provided. The main characteristics of this computer are:

- Processor: I7-14700 with 20 cores
- 32 GB of RAM
- HDD 1 TB
- Operating system: Linux Ubuntu 22.02

2.5.11.2 Interface

The system is equipped with:

- 1 RJ45 @1 Gbit/s, associated to the motherboard
- 4 SFP+ @10 Gbit/s Intell X710

2.5.11.3 Form factor

The PC fits in a standard compact tower casing:

Figure 20: IAB server overall enclosure

Its volume is less ~27 liters.

2.5.12 RU final end user bridge

2.5.12.1 Description

The RU of final end user bridge component is a Software Define Radio module that carries conversion between digital carrier physical layer frames of the gNB associated to IAB switch (hosted on same server) and RF signal on final end user TN indirect access link. This is a COTS SDR frontend module B210 from Ettus Research as a RU module (refer to section 2.5.6.1).

2.5.12.2 Interface

The RU final end user UE bridge interfaces are depicted in Figure 21.

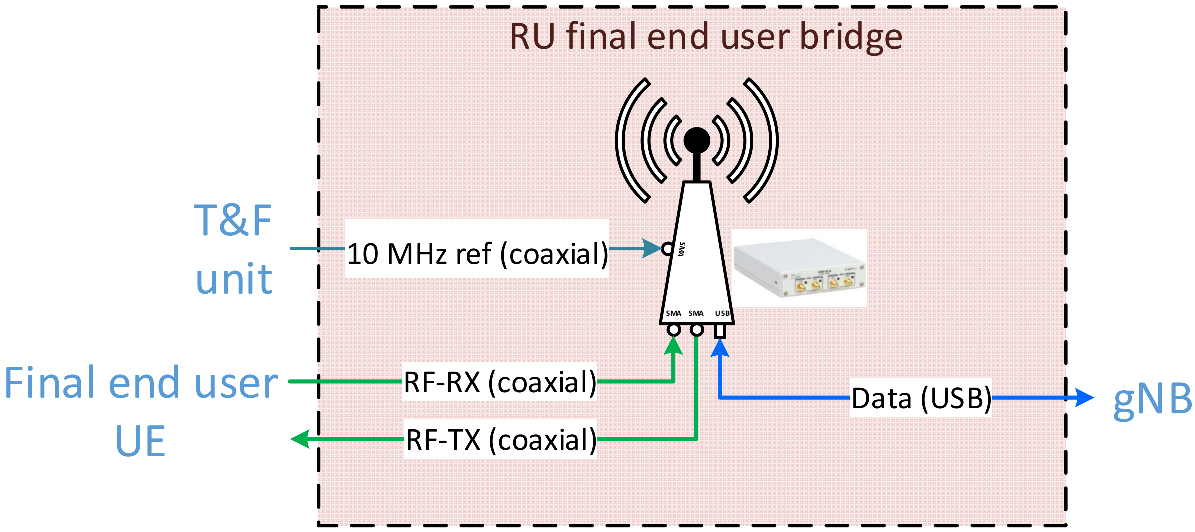


Figure 21: RU final end user bridge interfaces

The RU final end user UE bridge is connected to the TX/RX RF signals of TN indirect access link through SMA connectors. The RU final end user bridge frontend is connected to the 10 MHz reference clock through an SMA connector. The gNB hosted in IAB server and RU frontend are connected through an USB-3 link.

2.5.12.3 Form Factor

Refer to section 2.5.6.3.

2.5.13 UE Final User

2.5.13.1 Description

The UE final end user is the device responsible for initiating the communication with the cellular network. The UE protocol stack, which terminates at Layer 3, runs on a workstation Linux computer with following specifications:

- CPU: Intel-Core i7 (or equivalent).
- RAM: 32 GB (minimum).
- Storage: 1 TB SSD.

This computer will be connected with a COTS SDR B210 USRP module frontend from Ettus Research as a RU module (refer to section 2.5.6.3).

2.5.13.2 Interface

The UE final end user assembly interfaces are depicted in Figure 22.

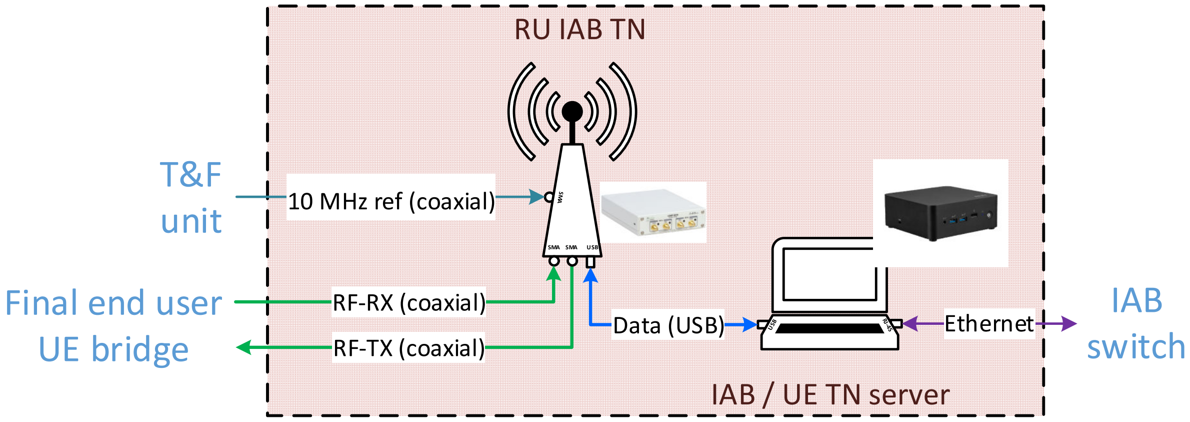


Figure 22: UE Final end user interfaces

The RU frontend is connected to the TX/RX RF signals of TN indirect access link through SMA connectors. The RU frontend is connected to the 10MHz reference clock through an SMA connector. The UE server and the RU frontend are connected through USB 3.0 link.

2.5.13.3 Form factor

Refer to section 2.5.6.3.

2.5.14 WAN/LAN gateway

2.5.14.1 Description

The WAN/LAN gateway is composed of two main equipment. The first one is the WAN/LAN access point with routing firewall and DHCP capacities. The second one is a 24 ports 1 Gbit/s switch for connecting all remote control network over a dedicate LAN through a fixed IP addressing.

2.5.14.2 Interface

The interface is based on RJ45 connectors and SFTP-category 6 cabling.

2.5.14.3 Form factor

The form factor is equivalent to 1U – 19 inches rack module.

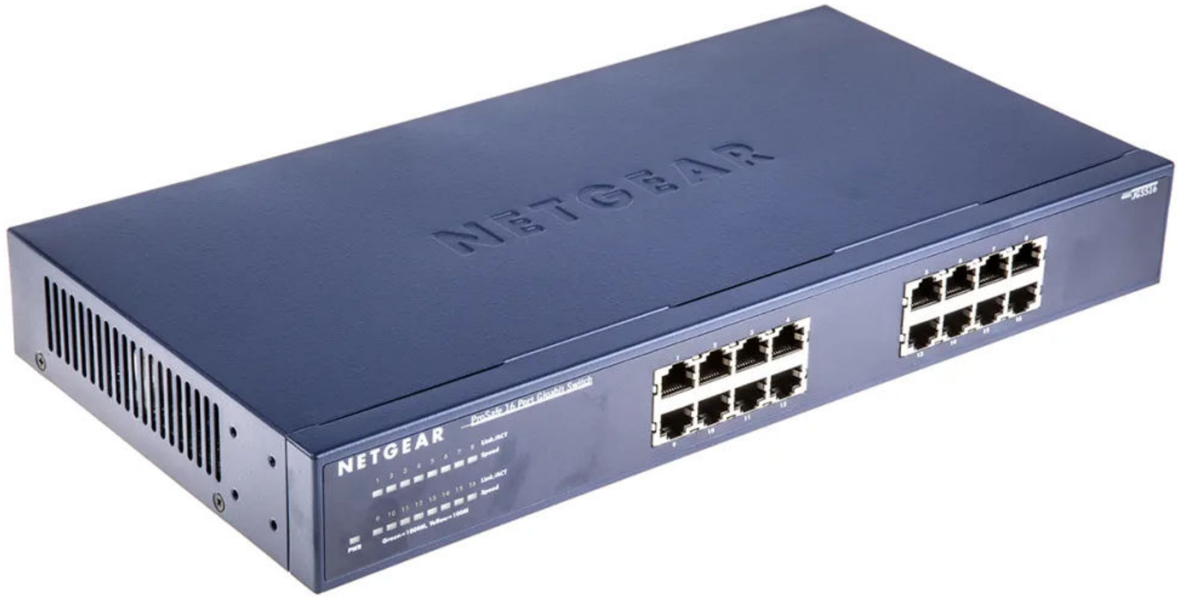


Figure 23: LAN switch overall casing

Its related dimensions are approximately: Width 328 mm x Length: 69 mm x Height: 43 mm.

2.6 SOFTWARE COMPONENT

This chapter detailed the main characteristics of the software component that will be implemented in the PoC. After a rapid definition of the goal of the component, the need of the component is described as the implementation potentials (Virtual machine, containers, dedicated component, resources sharing …).

In terms of needs, the following parameters can be precisely defined:

- Computing power (number of cores, frequency, memory)
- Interfaces capacity: network capacity (estimate of the volume)
- Synchronisation constrains: time precision, oscillator reference …

The chapter interface presents the component interaction (overview), when defined, the specification as reference (based on 3GPP TS or other reference).

2.6.1 Traffic generator

2.6.1.1 Description

The traffic generator component enables to provide some user data traffic load toward the PoC bench end-to-end network with setting capabilities as for performances assessment (packet sizes, protocols, throughput, …).

2.6.1.2 Hosting needs and principle

The CN server machine hosts a Linux/Debian based ProxMox virtualization environment platform which instance a dedicated Kernel Virtual Machine of a Linux based operating system to run the traffic generator application with following resources allocation:

- CPU: x2 cores
- Memory: 2 GB
- Storage: 10 GB

A 10 Gbit/s network interfaces is also emulated in consistence to physical host machine capacities (refer to section 2.5.4.2).

2.6.1.3 Interface description

The traffic generator connects with CN user component over IP layer 3 channel protocols like TCP or UDP depending of traffic type to apply.

2.6.2 Core Network User

2.6.2.1 Description

The CN user component implement all 5G network features and functionality described in section 2.4.5 of D6.1 document [4]. It manages data end-to-end connectivity between traffic generator and UE final end user with associated User and Control planes flows encapsulation for transportation through either TN or NTN backhaul path.

2.6.2.2 Hosting needs and principle

The CN server machine hosts a Linux/Debian based ProxMox virtualization environment platform which instance a dedicated Kernel Virtual Machine of a Linux based operating system to run the CN user application with following resources allocation:

- CPU: x6 cores
- Memory: 8 GB
- Storage: 30 GB

A 10 Gbit/s network interfaces is also emulated in consistence to physical host machine capacities (refer to section 2.5.4.2).

2.6.2.3 Interface description

Following Figure 24 shows the global interaction related to CN user component over the PoC bench topology:

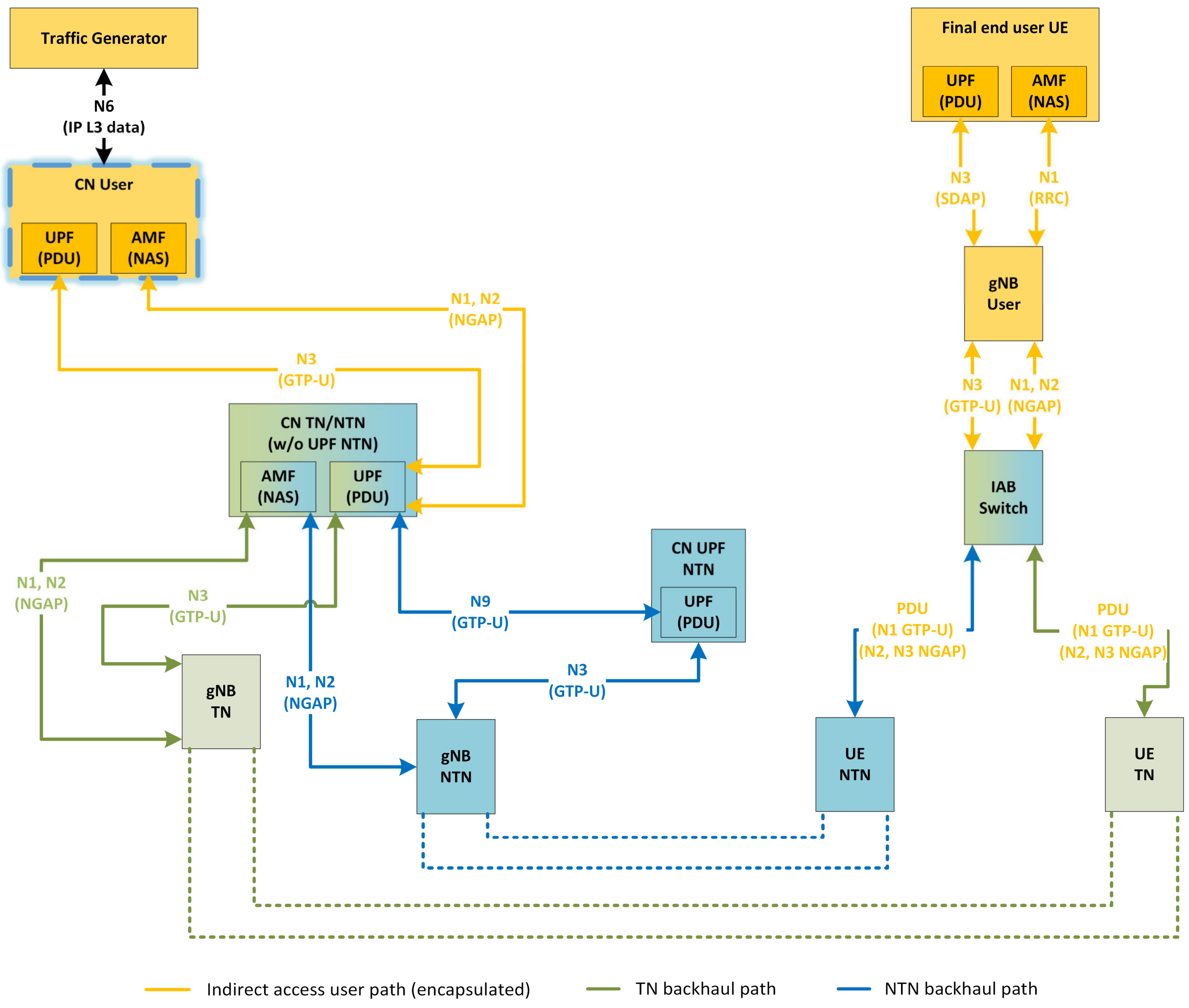


Figure 24: Global interaction CN user over PoC bench topology

A N6 interface IP layer 3 data content provider interface is considered between the traffic generator, then an interface with CN UPF TN component encompasses N1, N2 NGAP Control Plane AMF and N3 GTP-U User Plane UPF frames as encapsulated PDU for TN/NTN backhaul transport.

2.6.3 Core Network TN/NTN (w/o UPF NTN)

2.6.3.1 Description

This component implement all 5G network features and functionality described in section 2.4.5 of D6.1 document [4]. It manages backhaul transportation through either TN or NTN paths of CN user CP and UP encapsulated frames.

2.6.3.2 Hosting needs and principle

The CN server machine hosts a Linux/Debian based ProxMox virtualization environment platform which instance a dedicated Kernel Virtual Machine of a Linux based operating system to run the CN TN/NTN application with following resources allocation:

- CPU: x6 cores
- Memory: 8 GB
- Storage: 30 GB

A 10 Gbit/s network interfaces is also emulated in consistence to physical host machine capacities (refer to section 2.5.4.2).

2.6.3.3 Interface description

Following Figure 25 shows the global interaction related to CN TN/NTN component over the PoC bench topology:

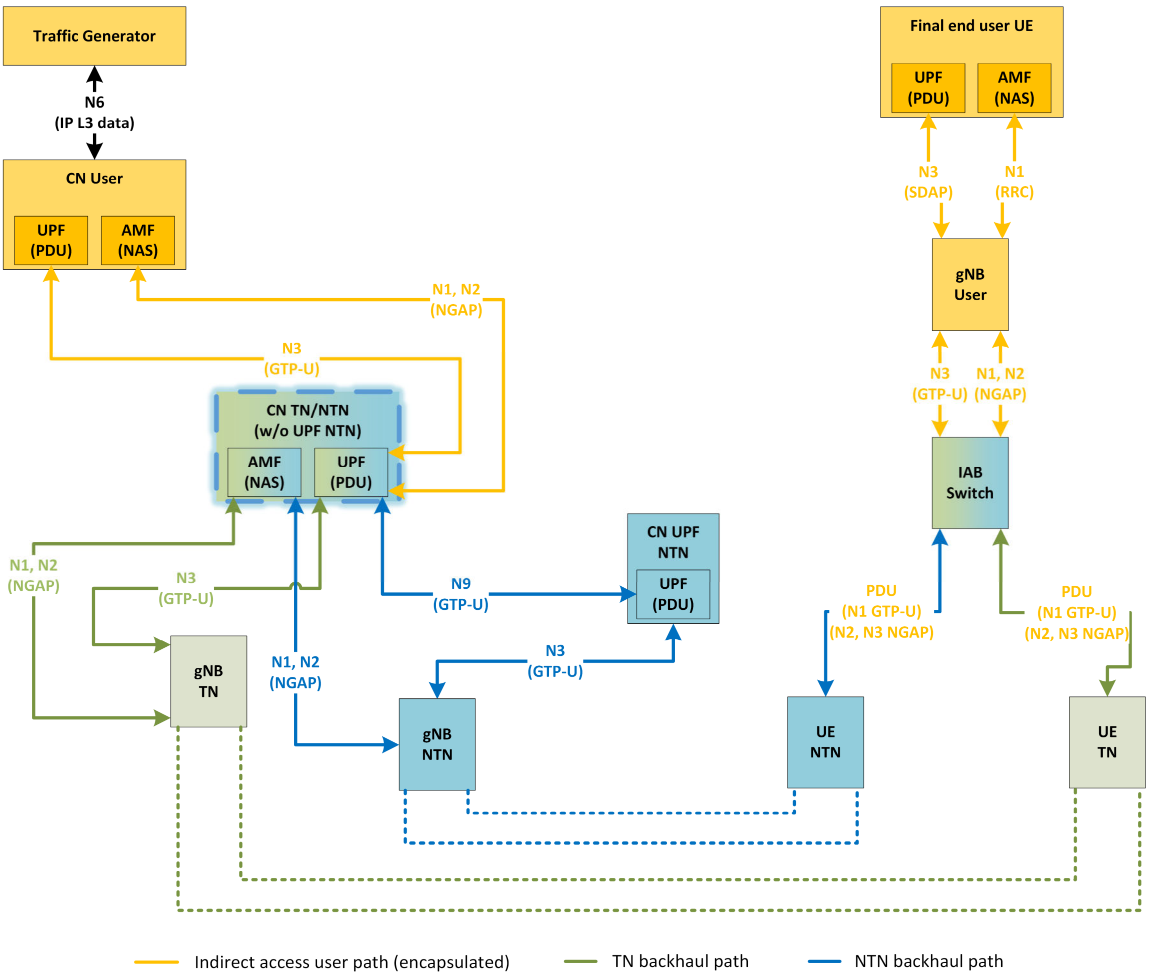


Figure 25: Global interaction CN TN/NTN (without NTN UPF) over PoC bench topology

An interface with CN user component encompasses N1, N2 NGAP Control Plane AMF and N3 GTP-U User Plane UPF frames as encapsulated PDU of CN UPF TN.

They are then transported through TN backhaul path by a N3 GTP-U interface between CN TN and gNB TN or N9 GTP-U interface with UPF NTN which forward data to NTN backhaul path. Associated N1, N2 NGAP Control Plane interfaces are considered between CN AMF TN/NTN and both gNB TN and gNB NTN.

2.6.4 Core Network UPF NTN

2.6.4.1 Description

The dedicated UPF NTN component covers CN user CP and UP encapsulated frames backhaul transportation through NTN path.

2.6.4.2 Hosting needs and principle

The CN server machine hosts a Linux/Debian based ProxMox virtualization environment platform which instance a dedicated Kernel Virtual Machine of a Linux based operating system to run the CN UPF NTN application with following resources allocation:

- CPU: x4 cores
- Memory: 4 GB
- Storage: 30 GB

A 10 Gbit/s network interfaces is also emulated in consistence to physical host machine capacities (refer to section 2.5.4.2).

2.6.4.3 Interface description

Following Figure 26 shows the global interaction related to UPF NTN component over the PoC bench topology:

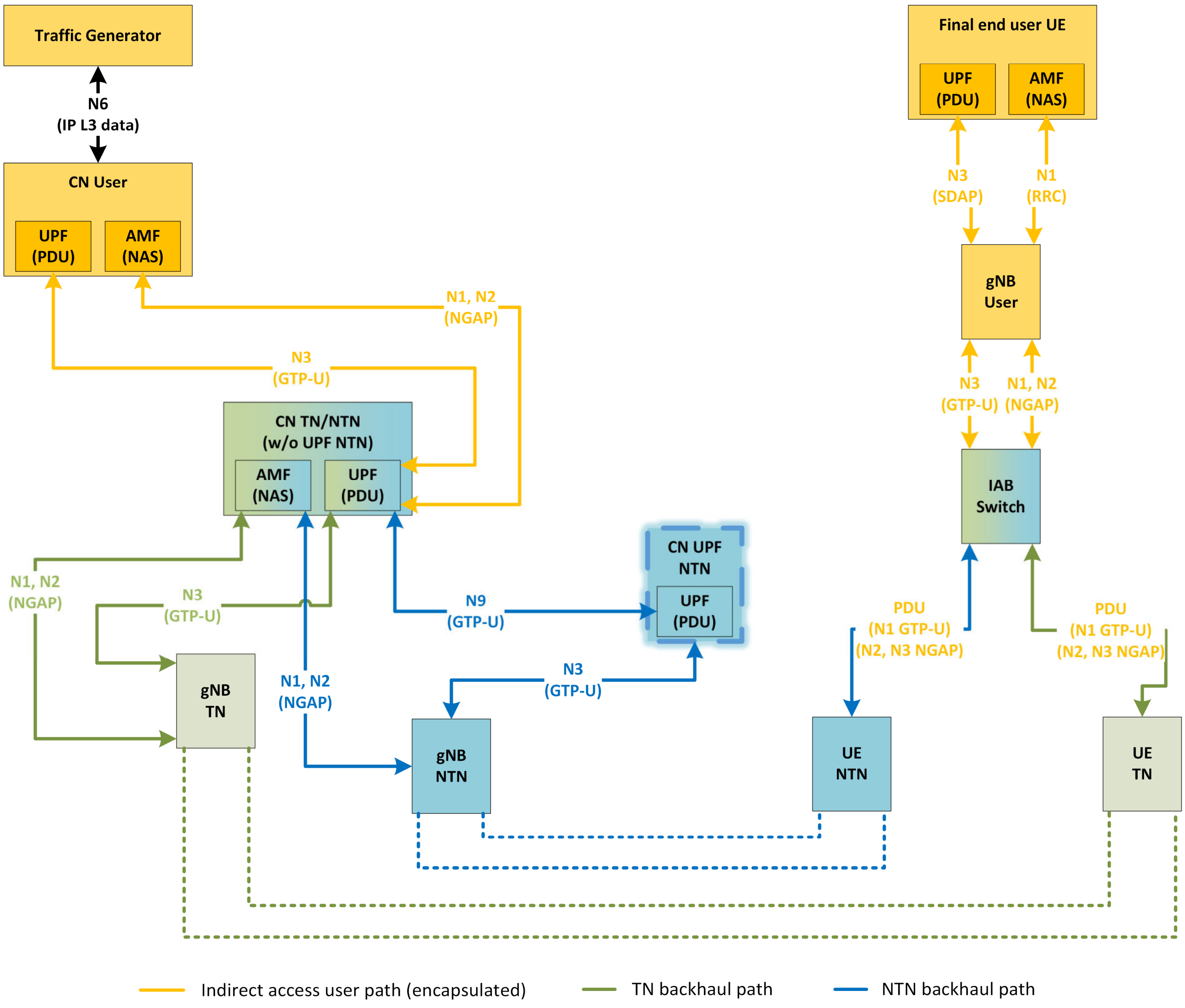


Figure 26: Global interaction CN TN/NTN (without NTN UPF) over PoC bench topology

A N9 GTP-U interface provide CN user CP and UP encapsulated frames forwarding between CN UPF TN and UPF NTN to then carry backhaul transportation through an NTN path by a N3 GTP-U interface with gNB.

2.6.5 Network Emulator

2.6.5.1 Description

A network emulation is implemented as to simulate the transit delay of ground gateway-satellite feeder link. Referring to section 2.1, this component also allows to apply the different functional split configuration of the PoC bench.

2.6.5.2 Hosting needs and principle

The implementation of this functionality is based on Linux utility traffic control tc-netem command with a script layer running to update a variable delay every 100 ms for an NTN LEO satellite trajectory transit delay characteristics simulation.

It is directly applied at component network interface level.

2.6.5.3 Interface description

Depending on functional split configuration to consider, the network emulation is adjusted at following components interfaces position:

- Split#1: CU NTN
- Split#2: Between DU-CU NTN
- Split#3: Between CN TN/NTN without NTN UPF and NTN – UPF

The section 2.9 describes related PoC bench data flow.

2.6.6 CU NTN

2.6.6.1 Description

The Central Unit (CU) is responsible for the higher-layer processing functions of the 5G gNB and serves as the interface between the RAN and the Core Network. It is logically split into two subcomponents: the CU-CP (Control Plane) and CU-UP (User Plane), which interact respectively with the Access and Mobility Management Function (AMF) and the User Plane Function (UPF) in the 5G Core via the NG interfaces. The CU can also interface with one or more Distributed Units (DUs) over the F1 interface.

Protocols:

- Toward the Core Network:
  - CU-CP: NG-AP over SCTP/IP (N2 interface).
  - CU-UP: GTP-U over UDP/IP (N3 interface).
- Toward the DU:
  - F1-AP (control plane) and F1-U (user plane).

NTN Mode Operation: NTN functionality is enabled on top of the standard CU implementation through appropriate configuration parameters. In NTN mode:

- The CU extends **PDCP and RLC buffer sizes** to accommodate the higher latency and jitter associated with satellite links.
- **Timers (e.g., reordering, discard, status reporting)** are adjusted to ensure robust communication over long round-trip times.

This allows the CU to maintain full compatibility with terrestrial network design while enabling support for satellite-based access in NTN scenarios.

2.6.6.2 Hosting needs and principle

The srsCU binary runs as a native process within the host operating system, without the use of virtual machines or containers. This lightweight deployment ensures minimal overhead and allows for direct access to system resources.

Following Figure 27 illustrates the CPU and memory usage of the srsCU under maximum load conditions. The measurements were taken in a representative test scenario to reflect peak processing and memory demands. No persistent storage is required during runtime, as all operational data is handled in memory.

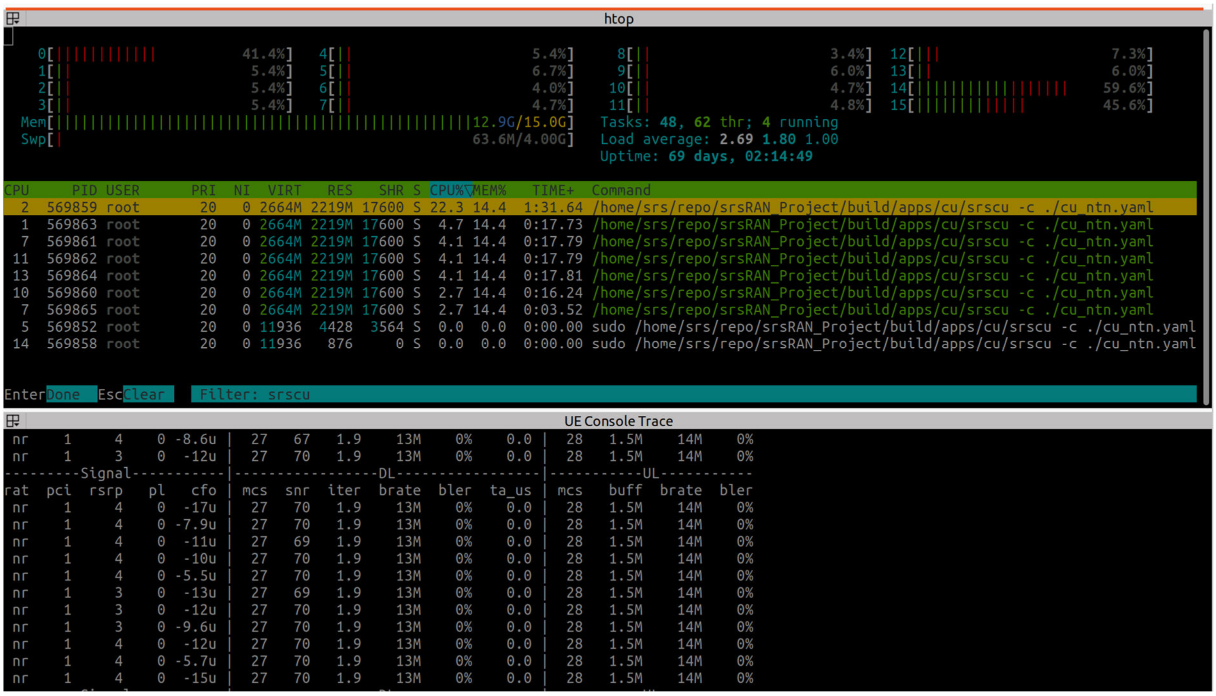


Figure 27: Max load conditions resources usage of srsCU process - 5 MHz channel BW.

2.6.6.3 Interface description

The CU includes several interfaces connecting it to the 5G Core Network, DUs, and internal stack modules. Below is a breakdown of the key interfaces:

- **NG Interface (CU ↔ Core Network)**
  - ***N2 (CU-CP ↔ AMF)***
    - *Function*: Control-plane signalling (e.g., UE registration, mobility management).
    - *Type*: Control.
    - *Protocol*: NG-AP over SCTP/IP.
    - *Typical Data Rates*: Low (signalling traffic).
  - ***N3 (CU-UP ↔ UPF)***
    - *Function*: User-plane data forwarding between the CU and Core Network.
    - *Type*: Data.
    - *Protocol*: GTP-U over UDP/IP.
    - *Typical Data Rates*: From Mbps to several Gbps depending on UE traffic.

- **F1 Interface (CU ↔ DU)**
  - ***F1-AP (Control Plane)***
    - *Function*: Signalling between CU-CP and DU (e.g., UE context setup, resource config).
    - *Type*: Control.
    - *Protocol*: F1-AP over SCTP/IP.
    - *Data Rates*: Low to moderate (depends on UE activity and mobility).
  - ***F1-U (User Plane)***
    - *Function*: Transfer of user data between CU-UP and DU.
    - *Type*: Data.
    - *Protocol*: GTP-U over UDP/IP.
    - *Data Rates*: High — similar to N3 interface (Mbps to Gbps).

For a detailed analysis of data rate and latency requirements, please refer to Section 2, *"O-RAN Architecture,"* in deliverable D4.6 [3].

2.6.7 CU TN

2.6.7.1 Description

Same as in CU NTN mode (refer to section 2.6.6.1).

2.6.7.2 Hosting needs and principle

Same as in CU NTN mode (refer to section 2.6.6.2).

2.6.7.3 Interface description

Same as in CU NTN mode (refer to section 2.6.6.3).

2.6.8 DU NTN

2.6.8.1 Description

The Distributed Unit (DU) is a key component of the 5G gNB architecture responsible for handling lower-layer protocol stack functions, notably the RLC, MAC, and parts of the PHY layer. It interfaces with the Central Unit (CU) over the F1 interface, enabling flexible deployment and efficient resource management.

The srsDU supports both Split 7.2 and Split 8 configurations for connecting with Radio Units:

- Split 7.2: Uses the O-RAN Open Fronthaul (OFH) interface to connect with compliant RUs, providing flexibility and interoperability in multi-vendor environments.

- Split 8: Interfaces directly with Software Defined Radios (SDRs), specifically the Ettus USRP B210, using the UHD driver to implement the full PHY layer within the DU.

NTN Mode Operation: The DU supports Non-Terrestrial Network (NTN) operation as an optional mode, activated via specific configuration parameters layered on top of the standard DU implementation. In NTN mode:

- The DU begins transmitting SIB19, which provides UE-specific information necessary for satellite-based connectivity.

- It uses the cell-specific-k-offset parameter to accommodate the extended round-trip time characteristic of NTN links, ensuring timing alignment and proper HARQ operation over satellite channels.

This design allows the DU to maintain compatibility with terrestrial 5G architecture while enabling seamless support for satellite-based extensions.

2.6.8.2 Hosting needs and principle

The srsDU binary runs as a native process within the host operating system, without the use of virtual machines or containers. This lightweight deployment ensures minimal overhead and allows for direct access to system resources.

Following Figure 28 illustrates the CPU and memory usage of the srsDU under maximum load conditions (in a 5 MHz cell bandwidth). The measurements were taken in a representative test scenario to reflect peak processing and memory demands. No persistent storage is required during runtime, as all operational data is handled in memory.

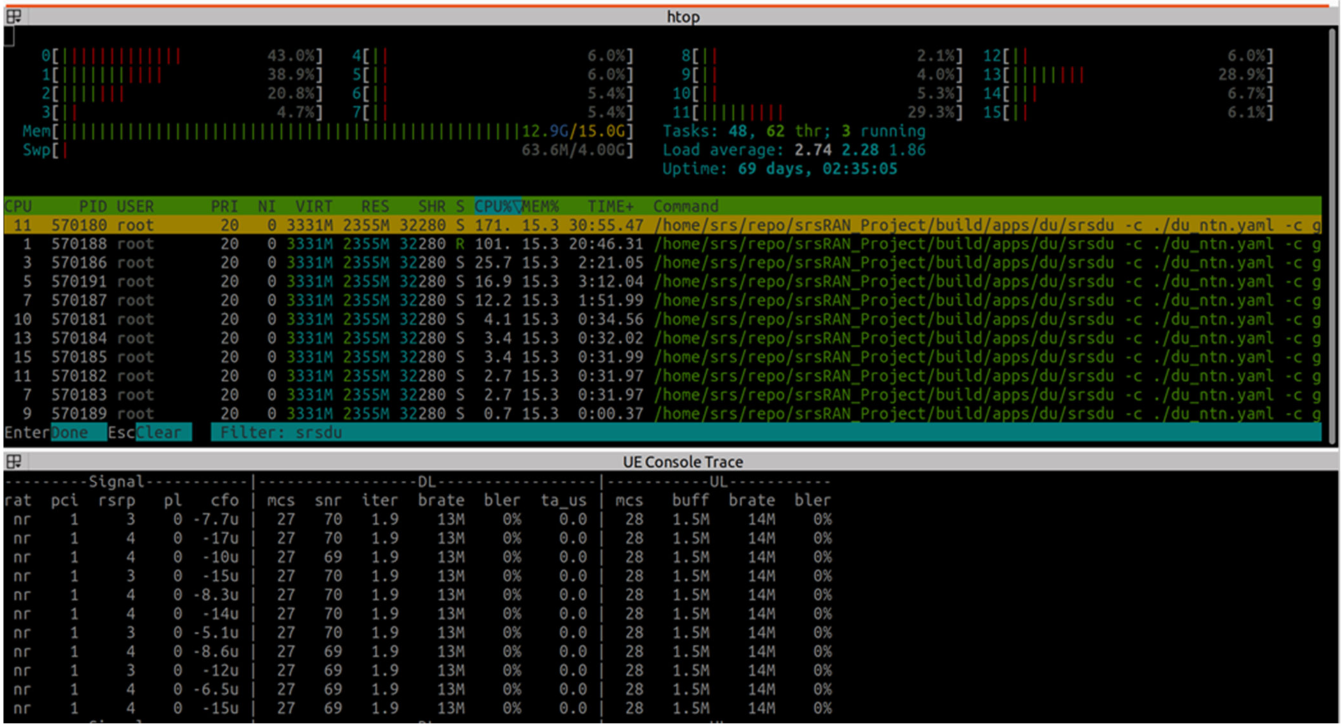


Figure 28: Max load conditions resources usage of srsDU process - 5 MHz channel BW.

2.6.8.3 Interface description

The DU software architecture is modular, with well-defined interfaces between its functional components and external entities. Below is a breakdown of the key interfaces:

- **F1 Interface:**
  - *Function:* Control and user plane communication between the DU and Central Unit.
  - *Protocols:*
    - F1-AP (control): SCTP over IP.
    - F1-U (user): GTP-U over UDP/IP.
  - *Typical Data Rates*: Depends on user traffic; ranges from a few Mbps to several Gbps.

- **Open Fronthaul Interface (DU ↔ RU) — Split 7.2:**
  - *Function:* Real-time transport of lower-PHY (I/Q) data between DU and RU.
  - *Type:* Time-critical data transport.
  - *Protocols:*
    - O-RAN C/U-Plane using eCPRI over Ethernet.
    - Sync via IEEE 1588v2 (PTP) and S-plane (management).
  - *Typical Data Rates*: Depends on BW and MIMO config, several Gbps per RU carrier.

- **Split 8 Interface (DU ↔ SDR, e.g., Ettus USRP B210)**
  - *Function:* DU includes full PHY; I/Q samples are directly exchanged with SDR.

- *Type:* Real-time I/Q data streaming.
- *Protocols:* UHD (Ettus proprietary), typically over USB 3.0 or Ethernet.
- *Typical Data Rates:* Depends on bandwidth and MIMO configuration:
  - USB 3.0: up to ~50–80 MB/s (400–600 Mbps).
  - Ethernet (if used): 1 Gbps or more.

For a detailed analysis of data rate and latency requirements, please refer to Section 2, *"O-RAN Architecture,"* in deliverable D4.6 [4].

2.6.9 DU TN

2.6.9.1 Description

Same as in DU NTN mode (refer to section 2.6.8.1).

2.6.9.2 Hosting needs and principle

Same as in DU NTN mode (refer to section 2.6.8.2).

2.6.9.3 Interface description

Same as in DU NTN mode (refer to section 2.6.8.3).

2.6.10 RU TN

2.6.10.1 Description

Refer to section 2.5.6.1.

2.6.10.2 Hosting needs and principle

Refer to section 2.5.6.1.

2.6.10.3 Interface description

Refer to section 2.6.8.3.

2.6.11 RU NTN

2.6.11.1 Description

Refer to section 2.5.7.1.

2.6.11.2 Hosting needs and principle

Refer to section 2.5.7.1.

2.6.11.3 Interface description

Refer to section 2.6.8.3.

Co-funded by the European Union

2.6.12 UE IAB NTN 20 MHz

2.6.12.1 Description

This network element implements a UE protocol stack that terminates at layer 3. It supports the RRC procedures defined in D6.1 PoC Functional Architecture, for non-terrestrial deployments. The UE supports all FR1 bands with 15 kHz subcarrier spacing and up to 20 MHZ bandwidth. To enable direct satellite connectivity in FR1, the functionalities specified in Release 17 have been implemented. The UE stack modifications are described in D4.2 Development and Test Plan.

2.6.12.2 Hosting needs and principle

It will run as an application on a Linux-based operating system. It will be implemented on a dedicated machine, as it is specified in Section 0.

2.6.12.3 Interface description

To transmit and receive radio signals, the UE will require an SDR hardware. The interface with this hardware is described in Section 0.

2.6.13 UE IAB TN

2.6.13.1 Description

This network element implements a UE protocol stack that terminates at layer 3. It supports the RRC procedures defined in D6.1 PoC Functional Architecture, for terrestrial deployments. The UE supports all FR1 bands with 15 kHz subcarrier spacing and up to 20 MHz bandwidth.

2.6.13.2 Hosting needs and principle

It will run as an application on a Linux-based operating system. It will be implemented on a dedicated machine, as it is specified in Section 2.5.10.

2.6.13.3 Interface description

To transmit and receive radio signals, the UE will require an SDR hardware. The interface with this hardware is described in Section 2.5.10.

2.6.14 IAB Switch

2.6.14.1 Description

This component allows connectivity with CN user and indirect access TN path at UE final end user edge by routing traffic of either TN or NTN backhaul paths.

2.6.14.2 Hosting needs and principle

Related implementation is performed by a network script layer application running on the same host Linux based operating system of gNB CU and DU user components with following resources usage allocation:

- CPU: x2 cores
- Memory: 2 GB
- Storage: 10 GB

A 10 Gbit/s network interfaces is also emulated in consistence to physical host machine capacities (refer to section 2.5.4.2).

2.6.14.3 Interface description

Following Figure 29: Global interaction CN TN/NTN (without NTN UPF) over PoC bench topology shows the global interaction related to this switching component over PoC bench topology:

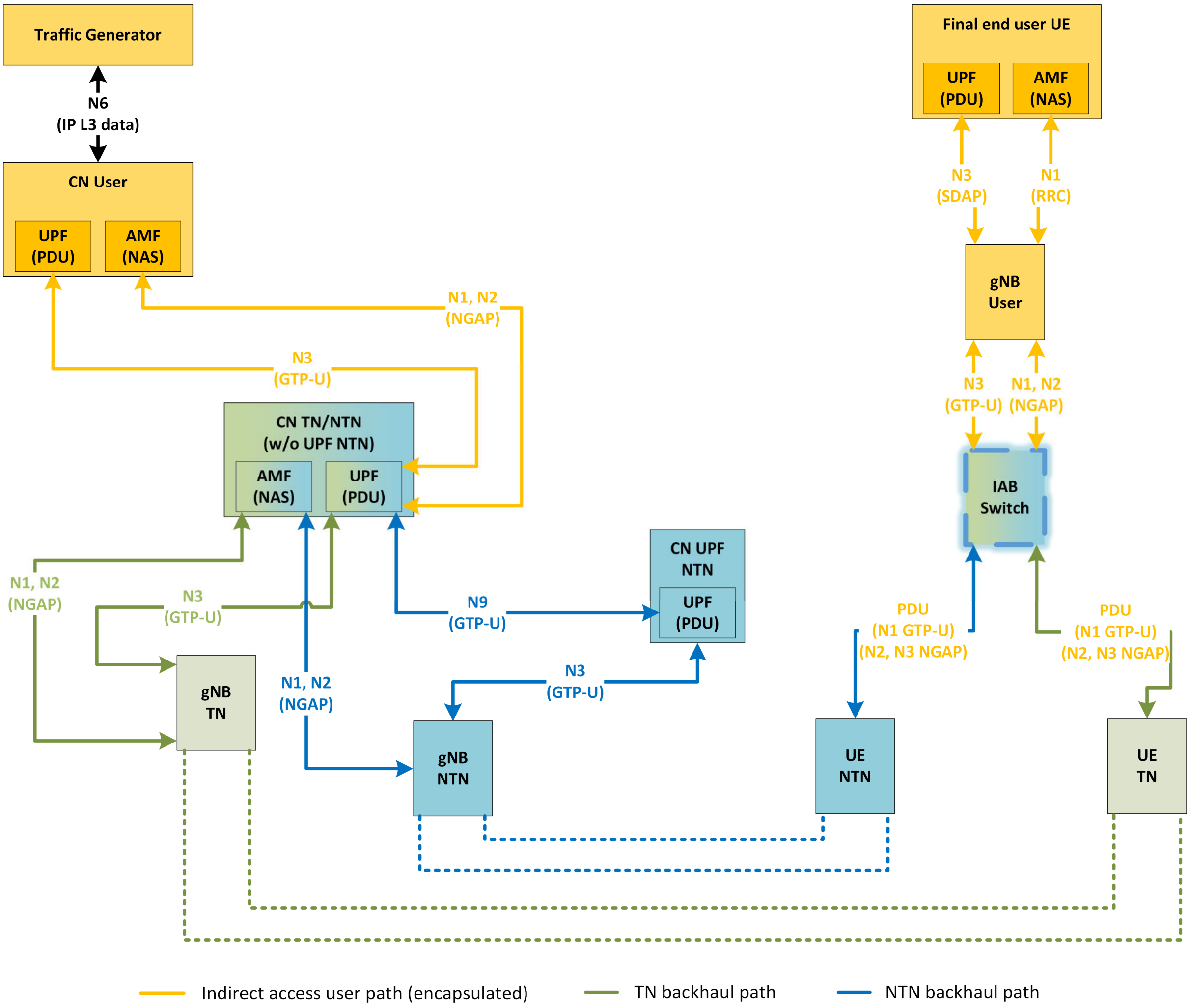


Figure 29: Global interaction CN TN/NTN (without NTN UPF) over PoC bench topology

It is interfaced with both UE TN and NTN backhaul paths for aggregated N3 GTP-U UP and N1, N2 NGAP CP frames dispatching or forwarding between CN user and gNB user.

2.6.15 CU System

2.6.15.1 Description

Same as in CU NTN mode (refer to section 2.6.6.1).

2.6.15.2 Hosting needs and principle

Same as in CU NTN mode (refer to section 2.6.6.2).

2.6.15.3 Interface description

Same as in CU NTN mode (refer to section 2.6.6.3).

2.6.16 DU System

2.6.16.1 Description

Same as in DU NTN mode (refer to section 2.6.8.1).

2.6.16.2 Hosting needs and principle

Same as in DU NTN mode (refer to section 2.6.8.2).

2.6.16.3 Interface description

Same as in DU NTN mode (refer to section 2.6.8.3).

2.6.17 RU user bridge

2.6.17.1 Description

Refer to section 2.5.12.1.

2.6.17.2 Hosting needs and principle

Refer to section 2.5.12.1.

2.6.17.3 Interface description

Refer to section 2.6.8.3.

2.6.18 UE final user

2.6.18.1 Description

This network element implements a UE protocol stack that terminates at layer 3. It supports the RRC procedures defined in D6.1 PoC Functional Architecture, for terrestrial deployments. The UE supports all FR1 bands with 15 KHz subcarrier spacing and up to 20 MHz bandwidth.

2.6.18.2 Hosting needs and principle

It will run as an application on a Linux-based operating system. It will be implemented on a dedicated machine, as it is specified in Section 2.5.13.

2.6.18.3 Interface description

To transmit and receive radio signals, the UE will require an SDR hardware. The interface with this hardware is described in Section 2.5.13.

2.7 CONFIGURATION OF THE BENCH

2.7.1 TN/NTN data Network configuration

This chapter presents the configuration of the hardware used for the PoC bench local data network. It presents the IP addressing plan and the reserved set of IP address as mapped in figure regarding modules and computers.

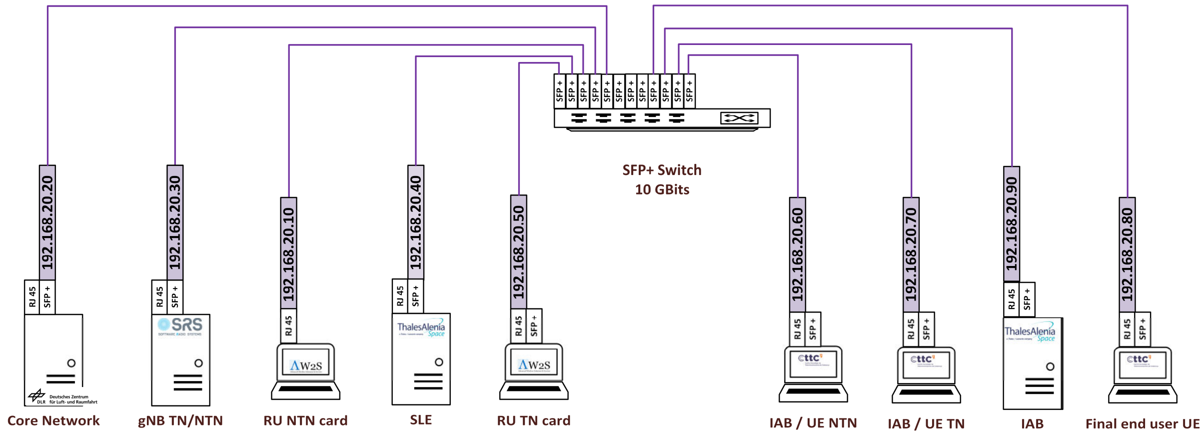


Figure 30: PoC test bench data network IP mapping

The subnet mask is 255.255.255.0 and address format is 192.168.20.xxx.

Due to the specificity of this network, no DHCP server will be implemented, and only fixed address will be allowed to ensure the TN/NTN network identification.

If non-fixed address is needed therefore a specific DHCP server will be introduce.

Physical infrastructure then relies on a 10 Gbit/s switch (refer to section 2.5.2 Fibrolan RX-FALCON equipment description) and SFTP-category 6 Ethernet cabling equipped with RJ-45 or SFP+ interfaces.

2.7.2 Remote control network configuration

The PoC bench local remote-control network which is separated from the local data network regarding the address subnetwork configuration. Each equipment is addressed with a specific IPv4 address. The subnet mask is 255.255.255.0 and the address format is 192.16.10.xxx. The range 10 to 100 are reserved for the PoC components. For other equipment, a DHCP server is used to give automatic address in the range 101-200.

2.7.3 VPN configuration

Referring to section 2.4.2 a local VPN server based on WireGuard protocol allow partners remote connection to PoC bench components respectively.

2.8 INTERFACES

2.8.1 TN/TNT interface

The TN/NTN interfaces are defined in the 3GPP 5G NR Technical Specification. The main characteristics of those interfaces are presented in the D6.1 [4].

2.8.2 TLE Sharing

The satellite trajectory is a specificity of the NTN network behaviour. The TLE (Two Line Element) is a format to describe the trajectory of the satellite regarding few parameters such as position location and velocity at a defined time. The propagation law gives the orbit of the satellite in time. The TLE is updated as needed (when deviation between real trajectory and prediction are no more converging). Based on this reference, two transformations are performed. The first one is for the NTN. The TLE is transformed into a message for the destination UE (SIB 19). The second one is for the SLE for computing the Doppler and delay effect of the satellite over the UE position.

2.9 RECONFIGURATION PRINCIPLE

This chapter is dedicated to the reconfiguration of the flux for covering the 3 splits defined in the D6.1. The main evolution concerns the input data and output data of the network emulator. This component simulates the feeder link (see component description). The three splits are presented one by one. The first split with the full gNB on-board is presented here after.

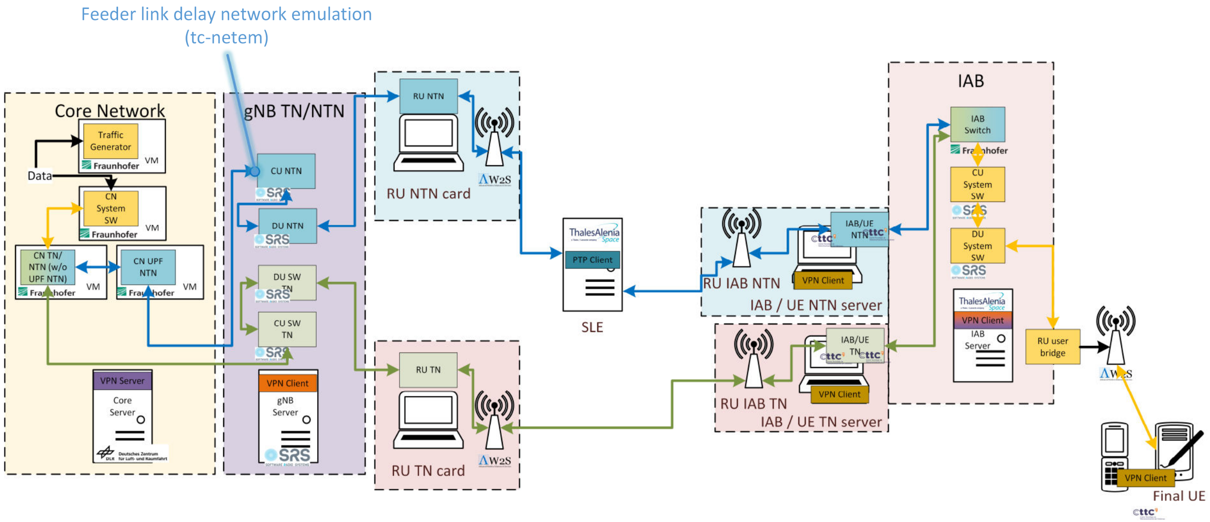


Figure 31: Data flow for Full gNB on-board

The maximum load on the Ethernet links is a two-way link.

For the second split, corresponding to the CU/DU splitting, the data flow is the following:

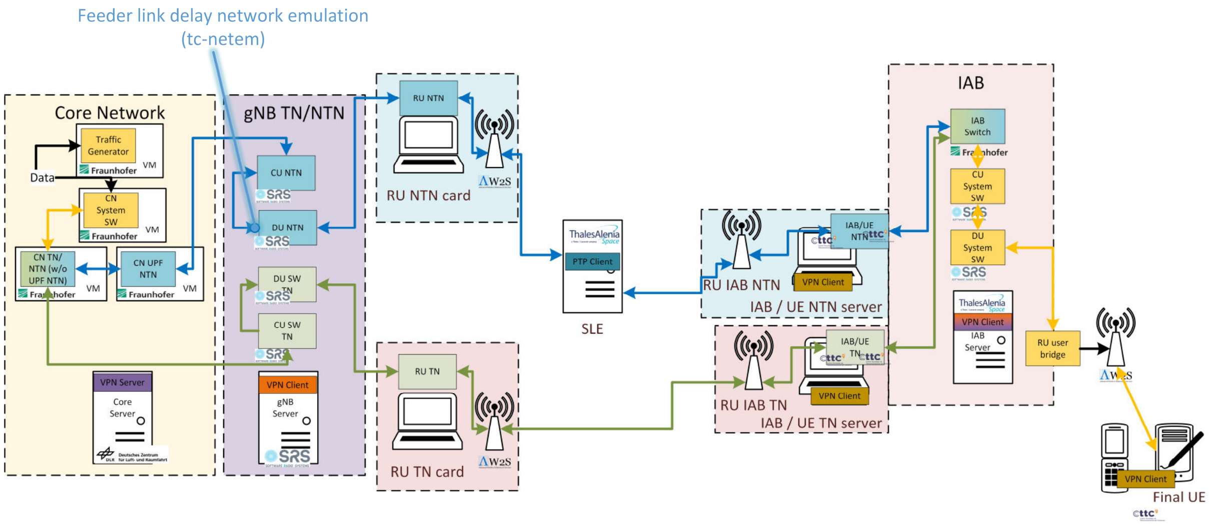


Figure 32: Data flow for the CU/DU splitting

The maximum load on the Ethernet links is a two-way link.

The third split is the full gNB on-board with UPF 5GC functions.

The data flow is presented here after.

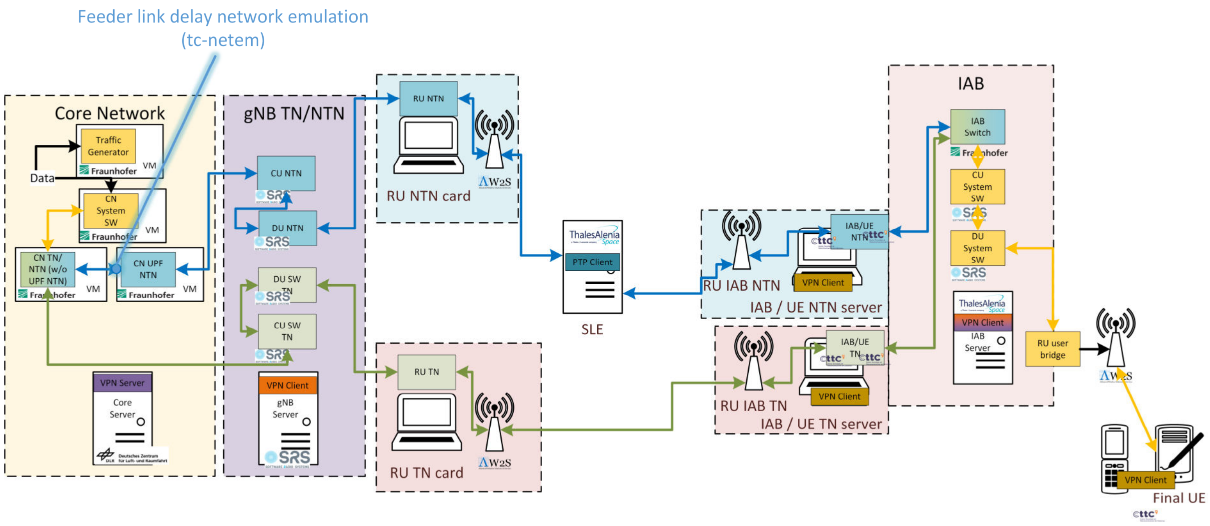


Figure 33: Data flow or full gNB on-board with UPF function

The maximum load on the Ethernet links is a two-way link.

3 CONCLUSIONS

3.1 POSSIBLE EVOLUTION SYNTHESIS

Previously evolution noticed in D6.2 [5] document such as remote control principle or component implementation has been taking into account for the PoC bench final design described through this deliverable. Related configuration will then provide the necessary features for next T6.3 and T6.4 scenario demonstration testing.

3.2 SYNTHESIS OF DELIVERIES

The following table reminds the component of the PoC bench.

Description	Provider	Reference / description	Quantity	Delivered by
Server for the Core network	Refer to section 2.5.4	Refer to section 2.5.4	1	DLR
Server for the gNB	Refer to section 2.5.5	Refer to section 2.5.5	1	SRS
RU NTN	Refer to section 2.5.7	Refer to section 2.5.7	1	AW2S
RU TN	Refer to section 2.5.6	Refer to section 2.5.6	1	AW2S
Satellite Link Emulator	Refer to section 2.5.8	Refer to section 2.5.8	1	TAS
RU 20 MHz bandwidth for IAB	Refer to section 0	Refer to section 0	1	CTTC
RU TN for IAB	Refer to section 2.5.10	Refer to section 2.5.10	1	CTTC
Server for IAB	Refer to section 2.5.11	Refer to section 2.5.11	1	TAS
PTP generator	Refer to section 2.5.1	Refer to section 2.5.1	1	TAS
Switch TN/NTN	Refer to section 2.5.2	Refer to section 2.5.2	1	TAS

Description	Provider	Reference / description	Quantity	Delivered by
10MHz reference	refer to section 2.5.1	refer to section 2.5.1	1	TAS
Internet Access Point	Thales	N/A	1	TAS
Switch / router	Thales	N/A	1	TAS
Converter SFP+ -> RJ 45	Miscellaneous	N/A	5	Partners
SFP+ cables	Miscellaneous	N/A	15	Partners
RJ45 cables	Miscellaneous	N/A	10	Partners
RF cables	Miscellaneous	N/A	10	Partners

REFERENCES

[1] D2.1: Scenarios, use cases and services.

[2] D3.2: End to end ground and space integrated architecture

[3] D4.6: Final report on AI-based radio resource management, RAN Softwarisation and onboard processing

[4] D6.1: PoC functional architecture document

[5] D6.2: PoC preliminary design document