6G-INTEGRATION-01-E17: Integration testing report

6G-INTEGRATION

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Executive Summary

This document provides a detailed description of the solution implemented by Ericsson for the 6G-Integration project, aimed at developing a portable gNB using a Non-Terrestrial Network (NTN) as backhaul or multi-access radio access point. The solution pursues to seamlessly integrate a Public Network and a Non-Public Network (PNI-NPN).

With version 17 ("Rel17") of the 3GPP, specifications for integrating non-terrestrial networks (NTN) into 5G infrastructure have been introduced, marking a significant step towards global connectivity. NTN networks, which include satellites in low (LEO), medium (MEO), and geostationary (GEO) orbits, as well as high-altitude platforms (HAPs), extend 5G coverage to remote regions. Rel17 optimizes traffic management between terrestrial and non-terrestrial networks, improving latency, resilience, and spectral efficiency, solidifying NTN as a key pillar for next-generation critical services.

Ericsson's proposal is based on a distributed 5G network under a non-public network (NPN), providing 5G "stand-alone" (SA) radio coverage in mid-band (n77, sub-6GHz - FR1). The backhaul for the network is established through an NTN network, specifically using a satellite link to ensure connectivity in remote locations or areas with limited terrestrial infrastructure. This satellite link is provided by Inster (Oesia group), partner in the 6G-Integration project.

This report includes the architecture of the implemented network, with detailed technical information about the equipment used to build the "testbed".

Three different use cases were conducted with the NPN NTN system at 5TONIC laboratory, verifying the e2e connectivity and performance of the NTN as backhaul, measured with Iperf tests for throughput evaluation and RTT tests for latency analysis, over the satellite backhaul. Also, with NTN as backup backhaul, it was verified that the traffic can be switched from a satellite backhaul to a fixed backhaul, assuring the 5G NPN system reliability. Finally, last use case was centered in testing the switching functionality of the ATSSS technology, being routed the traffic at the beginning towards the 5G infrastructure (3GPP access), but then re-routed via the satellite link (non-3GPP access) providing direct internet access.

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Resumen ejecutivo

Este documento proporciona una descripción detallada de la solución implementada para el proyecto 6G-Integration, cuyo objetivo es desarrollar un gNB portátil utilizando una Red No Terrestre (NTN) como "backhaul" o punto de acceso de radio multiacceso. La solución persigue crear una integración fluida entre una Red Pública y una Red No Pública (PNI-NPN).

Con la versión 17 ("Rel17") del 3GPP, se han incorporado las especificaciones para integrar redes no terrestres (NTN) en la infraestructura 5G, lo que marca un avance hacia una conectividad global. Las redes NTN, que incluyen satélites en órbitas bajas (LEO), medias (MEO) y geoestacionarias (GEO), así como plataformas de gran altitud (HAPs), extienden la cobertura 5G a regiones remotas. Rel17 optimiza la gestión del tráfico entre redes terrestres y no terrestres, mejorando la latencia, resiliencia y eficiencia espectral, lo que consolida a las NTN como un pilar clave para servicios críticos de próxima generación.

La propuesta de Ericsson se basa en una red 5G distribuida bajo una red no pública (NPN), que proporciona acceso radio con cobertura 5G "stand-alone" (SA) en bandas medias (n77, sub-6GHz - FR1). El "backhaul" de la red se establece mediante una red NTN, utilizando un enlace satelital para garantizar la conectividad en ubicaciones remotas o con infraestructura terrestre limitada. Dicho enlace satelital está proporcionado por Inster (Grupo Oesia), copartícipe en el proyecto 6G-Integration.

El entregable también incluye la arquitectura de la red implementada, con información técnica detallada sobre los equipos utilizados para construir el "testbed". Se han verificado tres casos de uso diferentes con el sistema "NPN NTN" en el laboratorio de 5TONIC.

El primero, verificando la conectividad de extremo a extremo y el rendimiento de la red no terrestre "NTN" como red de transporte, medido a través de pruebas de Iperf y pruebas de "RTT" para el análisis de latencia, sobre el "backhaul" satelital. Además, con el NTN como red de transporte de respaldo, se verificó que el tráfico puede alternarse de un "backhaul" satelital a un "backhaul" fijo, asegurando la fiabilidad del sistema NPN 5G. Finalmente, el último caso de uso se centró en probar la funcionalidad de conmutación de la tecnología "ATSSS", donde el tráfico inicialmente se dirigía por la infraestructura 5G (3GPP), cambiando a posteriori a través del enlace satelital (no 3GPP), proporcionando en este caso, acceso directo a internet.

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Glossary

3GPP	3rd Generation Partnership Project
5G	5th Generation technology standard for cellular networks
5GC	5G Core
5GS	5G System
AMF	Access and Mobility Management Function
ATSSS	Access Traffic Steering, Switching and Splitting
ATSSS-LL	ATSSS Lower Layer
AUSF	Authentication Server Function
B5G	Beyond 5G
CSP	Communication Service Providers
GEO	Geostationary Orbit
gNB	Next Generation NodeB
HAP	High Altitude Platform
IRU	Integrated Radio Unit
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MPTCP	MultiPath TCP
NPN	Non-Public Network
NRF	Network Repository Function
NSSF	Network Slice Selection Function
NTN	Non-Terrestrial Network
PCF	Policy Control Function
PNI-NPN	Public Network Integrated Non-Public Network
SMF	Session Management Function

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TCP	Transport Control Protocol
UE	User Equipment
UDM	Unified Data Management
UDR	Unified Data Repository
UPF	User Plane Function

1 Solution Description

1.1 Overview

The evolution towards Beyond 5G (B5G) networks marks a critical milestone in telecommunications, with a strong focus on the seamless integration of Non-Terrestrial Networks (NTN) and terrestrial infrastructures. This integration, essential for extending connectivity to underserved regions and for enhancing network resilience, leverages advanced NTN technologies such as satellites and High-Altitude Platforms (HAPs). These components play a pivotal role in expanding the reach of networks by addressing connectivity challenges in remote areas and improving overall capacity.

NTN elements, including satellites operating across Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Orbit (GEO), are complemented by HAPs situated in the stratosphere. Satellites provide global reach and are instrumental in broadband and IoT applications, while HAPs offer localized, high-capacity coverage, particularly valuable in disaster recovery scenarios and areas with challenging terrain. The integration of these technologies into terrestrial networks, as outlined in 3GPP Release 17 (R17), enables the delivery of reliable and efficient connectivity in diverse environments. However, this integration necessitates overcoming challenges such as signal delays and Doppler effects, ensuring service continuity and optimal spectrum usage to achieve seamless operation.

A 5G Non-Public Network (NPN) testbed has been deployed at 5TONIC premises, to be used to evaluate the synergy between NTNs and terrestrial networks. This set-up demonstrates the ability to leverage satellite backhaul for connecting isolated 5G segments to public networks operated by Communication Service Providers (CSPs). The testbed also supports critical use cases, such as delivering enhanced mobile broadband (eMBB) in remote areas, enabling global IoT device communication, and providing resilient solutions for public safety and disaster recovery operations. These capabilities highlight the transformative potential of NTNs in addressing the diverse demands of modern connectivity.

Complementing this integration is implementing Access Traffic Steering, Switching, and Splitting (ATSSS) technology, which optimizes traffic management by dynamically routing data between 3GPP and non-3GPP networks like Wi-Fi. By integrating mechanisms for traffic steering, switching, and splitting, ATSSS ensures uninterrupted and efficient connectivity across multiple access technology types. Technologies such as MultiPath TCP (MPTCP) and ATSSS-LL enhance the flexibility and robustness of this approach, enabling simultaneous use of multiple links to improve bandwidth utilization and service resilience.

This initiative represents a forward-thinking approach to network evolution, combining advanced 5G capabilities, NTN integration, and ATSSS to address critical connectivity challenges. By validating these innovations within a real-world testbed, the project paves the way for more resilient, high-performance networks, supporting an ever-growing array of applications and delivering a significant leap forward in global telecommunications infrastructure.

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1.2 Portable Deployment Infrastructure

All servers, the router, and most of the necessary components for this project are housed in the portable rack of the 5G NPN system. This portable infrastructure has been installed, configured, and validated in the 5TONIC laboratory.

Rack equipment requires a space of 1x1 m2 in an indoor room.

The flight portable rack includes, as part of the gNodeB, one 5G Baseband 6648 , a IRU 8846 with a Radio DOT 4479 system integrated and operating in FR1 frequencies (midband - band n78), all Ericsson commercial products.

The synchronization in time and phase, needed for the 5G TDD RAN, is provided by an antenna and GPS module connected through the Ericsson Router 6675 (IEEE 1588 PTP protocol), which also serves as a traffic aggregator for the rest of NPN network components and connection to the control planes of the 5GC.

Baseband, IRU and Router 6675 are powered by the power supply unit (PSU) hosted in the portable rack.

The Local Packet Gateway (LPG) of Ericsson is also connected to the Router 6675, which provides the user plane (UPF) function of the 5GC. Additionally, an Ericsson CRU 0101 application server is connected, allowing the deployment of the user traffic part locally on the 5G NPN equipment.

Moreover, a Mini PC with Linux OS and 1GE interface is provided, allowing operation with the CPE terminals to check its status and performance by running traffic through the iPerf application, as an example. The Mini PC also has the function of obtaining different network metrics to monitor the proper functioning of the whole NPN equipment.

Finally, the User Equipment/Customer Premises Equipment (UE/CPE) consists of one unit of Askey NUQ3000M terminals, which supports 5G SA mid band. CPEs can be managed either through its graphical interface (GUI) or via AT commands from the Mini PC, where it is connected through a USB cable and Ethernet (interface which is providing the power (PoE), to the Askey terminal).

In Figure 1, can be seen the 5G NPN portable system, informally called as "Flamingo", where the different components described are located:

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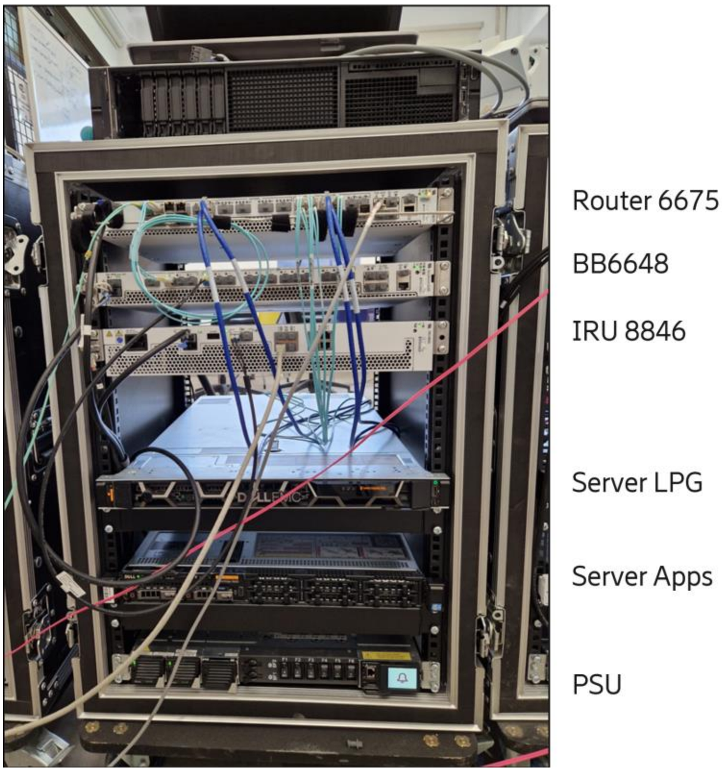

Figure 1 - 5G NPN portable system "Flamingo"

In Figure 2, it is shown more in detail the Ericsson solution and diagram connection of the 5G NPN NTN system for 6G-Integration project:

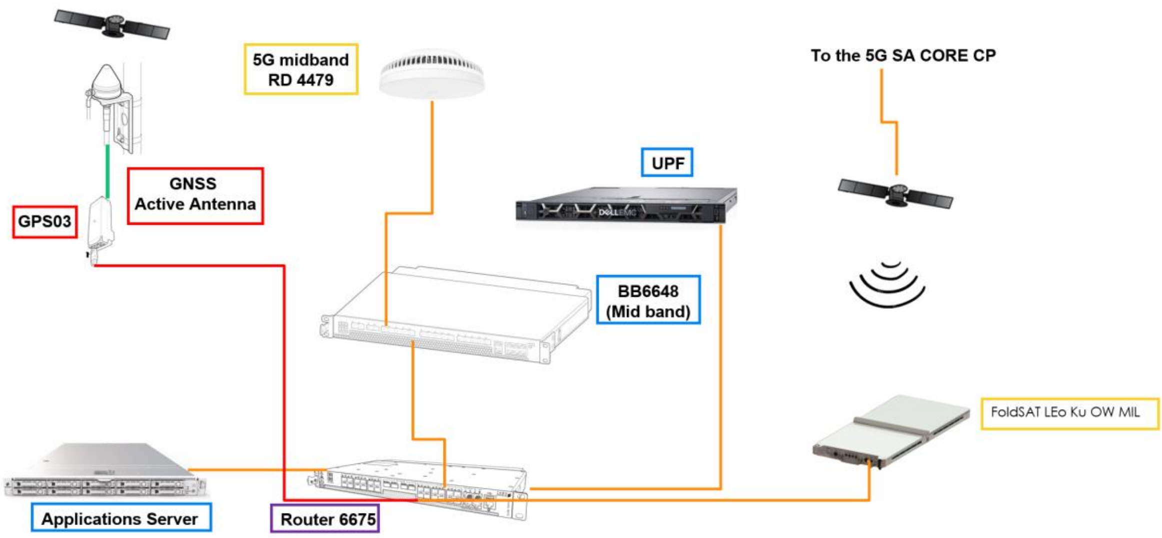

Figure 2 - Solution diagram of the 5G NPN NTN

Next, it is summarized the components of the 5G NPN NTN system. More detailed information of each equipment can be found on *Solution Equipment* section.

RadioDot 4479 (B78L, 3300-3500 MHz), a single-band indoor radio optimized for capacity deployments.

Baseband 6648 is the baseband processing unit for mid-band. It handles the digital processing required for signals received from the antennas before routing them through the network.

UPF (User Plane Function) is a crucial component of the 5G Core network, responsible for handling user data traffic. It processes data coming from the BB6648 unit.

Router 6675 is the routing device that connects the network to the 5G Standalone (SA) Core Control Plane (CP) through the NTN network.

FoldSAT LEO is the Inster satellite terminal that provides the backhaul connection between RAN and 5GC.

GNSS Active Antenna and GPS Module (GRU 04 01), compose the Global Navigation Satellite System (GNSS) antenna system, likely used for precise timing and location synchronization.

- **Note:** GPS cable connected to the Router 6675 is a standard RJ45 cable but with a special PIN definition.

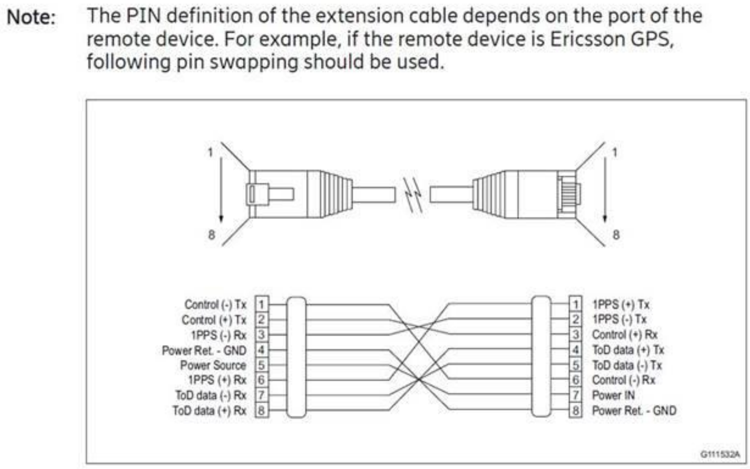

Figure 3 - GPS cable special PIN definition for Router 6675

On the other hand, the Control Plane of the 5G Core is deployed in the central Data Center of 5TONIC (Figure 4).

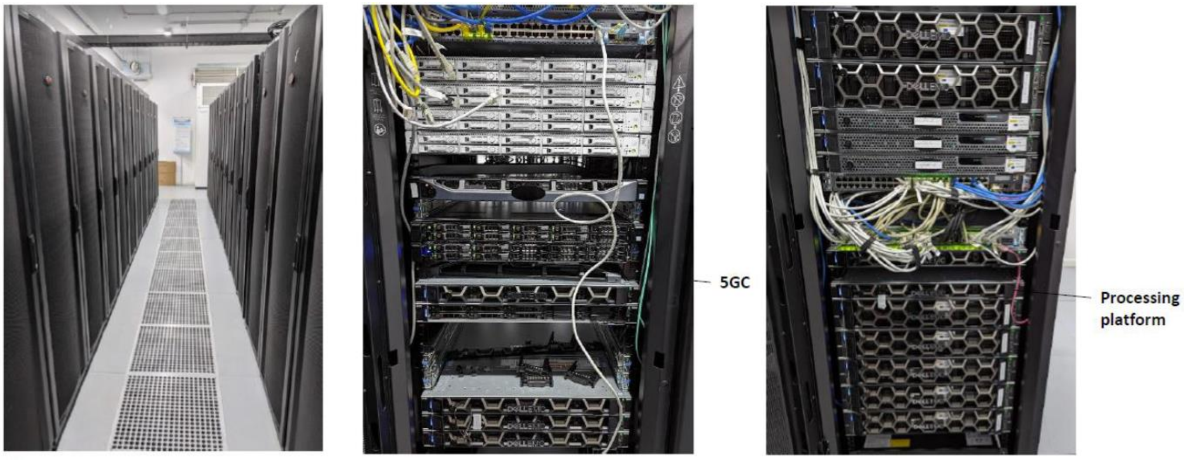

Figure 4 - Central data center servers located at 5TONIC, Madrid

It contains the core network functions required to support the 5G System:

- Basic NF: NRF, NSSF
- Subscriber NF: UDM, UDR
- Control NF: AMF, SMF, PCF
- User Plane NF: UPF
- Exposing: NEF

This 5G Core is the cloud-native version of the Ericsson 5GC and runs on Kubernetes.

In addition to the equipment within the rack, the deployment includes the Inster FoldSat LEO terminal, located externally to ensure satellite coverage, as it serves as an integrator for NTN networks. This device is directly connected to the router in the portable rack, enabling seamless communication between the terrestrial and non-terrestrial segments of the network.

1.3 Network Architecture

Figure 5 illustrates the proposed distributed 5G architecture diagram with NTN as backhaul for the 3GPP 5G network, interconnecting the flight-rack functions (RAN, UPF and local applications server) with the 5TONIC central servers (5GC -Control functionalities- and central applications server).

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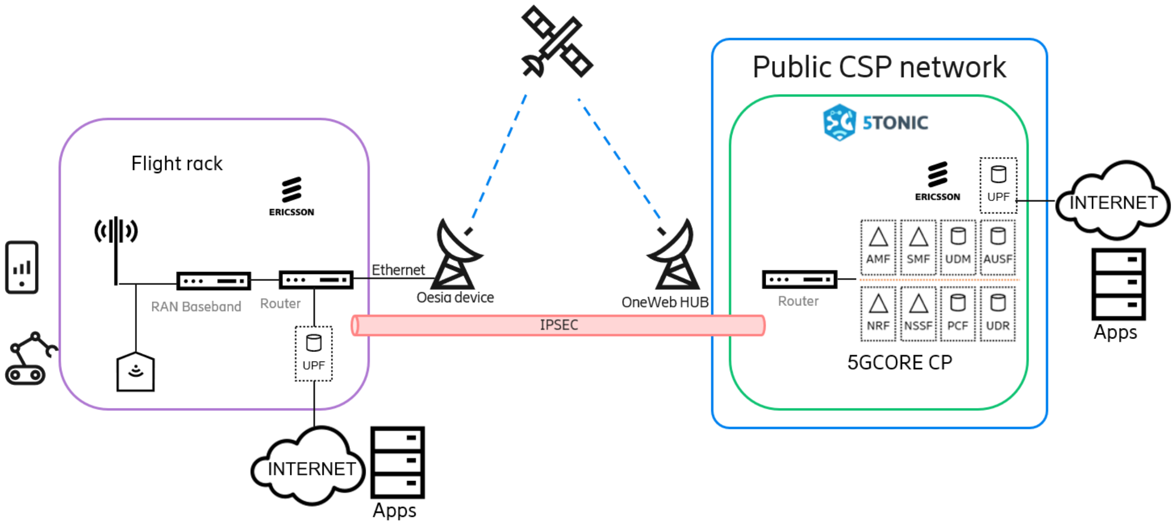

Figure 5 - Distributed 5G architecture with NTN as backhaul

The diagram provides a visual representation of the network architecture. Below is an in-depth explanation of the key components and their interactions within this architecture:

1.3.1 Key Components

- **Flight Rack:**

RAN Baseband: This equipment handles the radio access network processing. It interfaces with the router and is responsible for managing the radio signals received from and transmitted to the user equipment (UE).

Router: Connects the RAN Baseband to the 5G Core via an IPSec tunnel over a satellite connection. It facilitates the secure routing of data packets between the RAN Baseband and the 5G Core while also establishing a second connection to the Application Server, enabling local access to specific customer applications.

UPF (User Plane Function): Handles data traffic routing and forwarding. It interfaces with the internet for local data traffic and the router for data requiring backhaul.

- **Inster FoldSat LEO Terminal:**

The Inster FoldSat LEO terminal (Oesia device) is positioned outdoors to guarantee satellite coverage, acting as integrator for NTN networks. It connects directly to the router within the flight rack.

- **5G Core:**

5G Core can be divided into the Control Plane (CP) and User Plane (UP).

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- Control Plane (CP) Functions:

  - AMF (Access and Mobility Management Function): Manages connection and mobility aspects, handling user registration, connection setup, and mobility.
  - SMF (Session Management Function): Manages session contexts and configurations, establishing and maintaining user sessions.
  - UDM (Unified Data Management): Manages subscription data, storing user profiles, and authentication information.
  - AUSF (Authentication Server Function): Handles authentication, verifying user credentials and ensuring secure access.
  - NRF (Network Repository Function): Stores and manages NF (Network Function) profiles, facilitating service discovery and interaction between network functions.
  - NSSF (Network Slice Selection Function): Handles network slice selection, enabling differentiated service levels by directing traffic to appropriate network slices.
  - PCF (Policy Control Function): Manages policy decisions, enforcing rules for QoS (Quality of Service), resource allocation, and service access.
  - UDR (Unified Data Repository): Stores structured data used by various network functions for operations like subscriber management, policy control, and session management.

- User Plane (UP) Functions:

  UPF (User Plane Function): Handles data traffic routing and forwarding, interfacing with the internet and the 5G Core Network. It manages packet forwarding, QoS enforcement, and traffic shaping.

1.3.2 Data Flow and Interactions

- **User Equipment (UE) Connectivity:**

  The UE connects to the flight rack's RAN Baseband, which processes the radio signals and forwards data packets to the router.

- **Backhaul Connectivity:**

  The router within the flight rack establishes an IPSec tunnel with the 5TONIC site router to securely transmit data packets over a satellite link.

- **Integration with 5G Core Network:**

  The router in 5tonic lab forwards the data packets to the 5G Core network's UPF.

The 5G Core network processes these packets, manages session and mobility, applies policies, and routes the data appropriately, either towards the internet or other parts of the network.

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2 Solution Equipment

2.1 Radio Access Network - Equipment

2.1.1 Baseband 6648

Baseband 6648 is developed for 5G high-capacity sites and is the natural choice for sites with 5G midband and 5G highband implementations.

Clear benefits with Baseband 6648 are higher capacity and simplified installation using 25G interfaces to new AIR and Radio products for midband and highband.

Figure 6 - Baseband 6648 (Front and rear views)

Baseband 6648 provides switching, traffic management, timing, baseband processing, and radio interfacing. The baseband units are in the 19-inch format. Baseband 6648 has 12 Common Public Radio Interface (CPRI or eCPRI) ports, enabling increased connectivity for radio units.

Baseband 6648 is self-contained 19-inch unit with an easily removable fan tray unit. Each unit can be installed standalone in any 19-inch rack. The units support both horizontal and vertical installation.

Baseband 6648 facilitates a scalable, modular system with one or more indoor 19-inch baseband units and various external radios.

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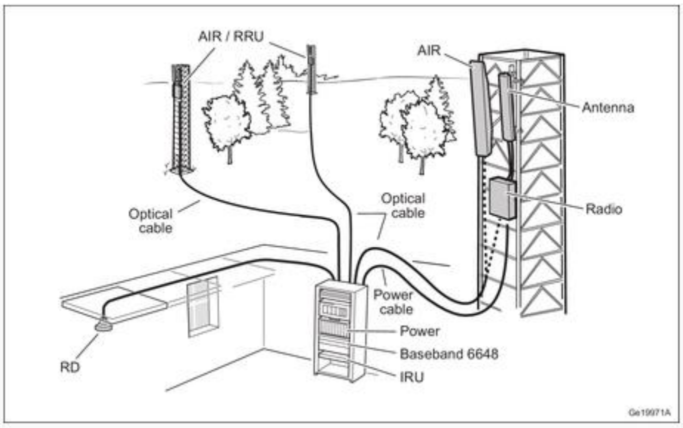

Figure 7 – 19 Inch Baseband connected to external radios

The unit has the following functions:

- Timing function
- Loadable software
- Downlink (DL) baseband processing
- Uplink (UL) baseband processing
- IP traffic management
- Radio interface
- Backhaul handling
- External synchronization

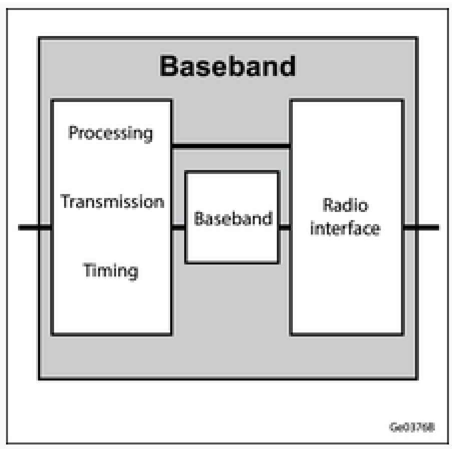

Figure 8 - Baseband unit block diagram

Baseband 6648 - Technical data

The unit has the following dimensions:

Table 1 - Baseband 6648 dimensions and weight

Baseband	Height	Width	Depth With Protrusion	Depth Without Protrusion	Weight
Baseband 6648	44 mm (1U)	483 mm (19-inch)	383 mm	352 mm	Max 8.5 kg

The unit has the following environmental characteristics:

Table 2 - Baseband 6648 environmental data

Description	Value
Temperature	0°C to +55°C
Relative humidity	5–95%
Absolute humidity	1–29 g/m3
Maximum temperature change	0.5°C/min

The unit has the following power characteristics:

Table 3 - Baseband 6648 DC power supply requirements

Condition	Value
Nominal voltage	−48 V DC
Operating voltage range	−38.0 to −58.5 V DC(1)
Non-destructive range	0 to −60 V DC

(1) During cold startup the supply voltage must be between -46 V DC and -58.5 V DC.

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Baseband 6648 - Hardware Architecture and Interfaces

Baseband 6648 has the following hardware characteristics:

- 1 x 4x25 Gbps (QSFP28)
- 3 x 25/10/1Gbps ports (SFP28/SFP+/SFP)
- 1 x 100Mbps/1Gbps RJ45 electrical port
- Support for NR (5G high/mid/low band) or LTE
- Support for Mixed Mode baseband NR (5G) + LTE
- 12 x 2.5/4.9/9.8/10.1/10.3/24.3/25 Gbps Radio Interface ports
  - 12 CPRI ports or 12 eCPRI ports or 12 ports with a mix of CPRI and eCPRI

The hardware is prepared for the following 5G-NR capacities:

- Users: 10k
- Mixed mode: NR+LTE
- Maximum throughput:
  - DL 10-15Gbps
  - UL 3Gbps
- Band support:
  - NR High-band: 4800MHz (3 sectors , 2 layers, 800MHz carries)
  - NR Mid-band: 9600MHz (3 sectors , 16 layers, 200MHz carries; 6 sectors, 16 layers, 100MHz carriers)
  - NR Low band: 4800MHz (20MHz, 4T4R carries)

Baseband 6648 has the following front panel interfaces:

Figure 9 - Baseband 6648 (Front panel interfaces)

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Table 4 - Baseband 6648 front panel interfaces

Ports	Quantity	Comments
Power	2	-48V
LMT	1	RJ45
TN/IDL	4	3 x SFP28 (25G) 1 x QSFP28 (4x 25G)
Radio Interface	12	SFP+/SFP28
Sync	1	RJ45
External alarms	8	2 x RJ45
USB 3.0	1	USB C

2.1.2 IRU 8846

The Indoor Radio Unit (IRU) is a component in the Radio Dot System (RDS). The IRU must be used together with Radio Dots to have full radio functionality.

The IRU has three purposes:

- Provides an interface to the Baseband unit through a CPRI cable.
- Provides signaling and power interface to the Radio Dot over the Radio Dot Interface (RDI).
- Collects external alarms and transmits them to the Baseband Unit.

Indoor Radio Unit (IRU) 8846 provides support for connectivity to up to 8 single band 4T4R Radio Dots with a single CAT 6A cable. IRU 8846 can be mounted in a standard 19" rack, or in a remote location using the included wall mounting brackets. Distributing Indoor Radio Units throughout a building allows for flexible, scalable deployment of Radio Dot System across a variety of venue sizes. It can utilize either AC or DC power supply.

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Figure 10 – IRU 8846

IRU 8846 - Technical data

<u>The unit has the following dimensions:</u>

Table 5 – IRU 8846 dimensions and weight

Baseband	Height	Width	Depth	Weight
IRU 8846	70 mm (1.5U)	442 mm (19-inch)	347 mm	Max 8.62 kg

<u>The unit has the following environmental characteristics:</u>

Table 6 – IRU 8846 environmental data

Description	Value
Temperature	5°C to +50°C
Relative humidity	10–95%
Absolute Humidity (g/m3)	1 to 25
Maximum Temperature Change (ºC/min)	0.5

<u>The unit has the following power characteristics:</u>

Table 7 – IRU 8846 DC power supply requirements

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Condition	Value
Nominal voltage	−48 V DC
Normal voltage range at radio input	-36.0 to -58.5 V DC
Maximum Current	20 A
Inrush current	27 A
Hold up time	10 ms

Table 8 – IRU 8846 AC power supply requirements

Condition	Value
Nominal voltage	100-250 V AC
Voltage Rage with Tolerance	90-275 V AC
Max Non-destructive Voltage Range	325 V AC
Nominal frequency range	45-65 Hz
Maximum Current	9 A
Inrush current	22.2 A
Power supply cable impedance	0.03 ohm

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Hold up time	20 ms

IRU 8846 Main features

IRU 8846 supports the following:

- Two CPRI ports.
- Ethernet based RDI ports to connect Dots:
- 8 ports of 10 Gbps
- Two alarm ports.
- Power Supply input: AC and DC.
- Mixed mode and multi-standard operation.
- Up to eight branches per Dot.

2.1.3 Dot 4479 B78L

Dot 4479 B78L is a single-band indoor radio optimized for capacity deployments. Features include:

- 250 mW output power per antenna branch
- Instantaneous bandwidth (IBW) is 100 MHz with 4 x 4 MIMO TDD
- Flexible IT-like deployment with CAT6A and hybrid fiber cables for extended reach

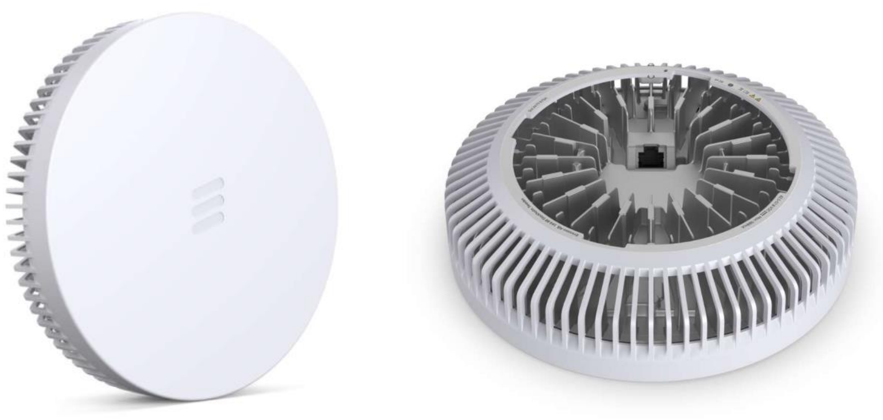

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Figure 11 – Dot 4479 B78L (Front and interface view)

Dot 4479 B78L – Components

The Radio Dot components are shown in the following figure. Refer to Table for the components descriptions.

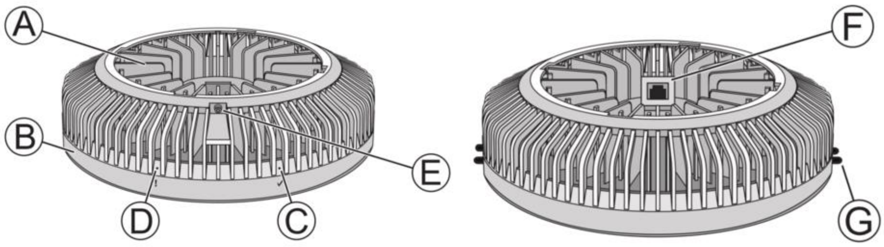

Figure 12 – Dot 4479 B78L components

Table 9 – Dot 4479 B78L components

Position	Component
A	Cooling flanges
B	Housing
C	Optical indicator
D	Optical indicator
E	Locking screw
F	RDI interface (RJ45) for electrical Ethernet
G	External Antenna Connector

Dot 4479 B78L - Technical data

This section describes the physical characteristics and environmental data.

Table 10 – Dot 4479 B78L unit dimensions

Unit Type	Height (H) × Width (W) × Depth (D)
Dot 4479 B78L	53 × 200 × 200 mm

Table 11 - Dot 4479 B78L unit weight

Unit Type	Unit Weight
Dot 4479 B78L	1 kg

Table 12 - Dot 4479 B78L antenna gain

Unit Type	Average Gain (dBi)	Peak Gain (dBi)
Dot 4479 B78L	0.09	5.70

Table 13 – Dot 4479 B78L operating environment

Description	Value
Temperature	5°C to +40°C
Relative humidity	5–85%
Absolute Humidity (g/m3)	1 to 25
Maximum Temperature Change (ºC/min)	0.5

Dot 4479 B78L – Main Features

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The Dot 4479 B78L is a high-capacity single band Radio Dot with internal antennas. It is available for the TDD B78L (3500 MHz – 3800 MHz) band.

The Dot has the following features:

- 4 TX and 4 RX branches per Dot
- 256-QAM Downlink and 256-QAM Uplink
- Output Power with 4T4R capability:
- TDD: 4 x 24 dBm / Dot (250 mW / Branch) DL power
- Power supply over LAN cable (PoE++)
- Supports TDD NR + LTE Mixed

  Mode, TDD NR +NR MORAN and TDD LTE + LTE MORAN configurations

Dot 4479 B78L – Limitations

The following applies:

- Only 20 MHz is supported with LTE.
- 2x2 MIMO configuration is not supported for mixed mode and multi carrier.
- A 2x2 carrier can be NR or LTE.
- In 2x2 mode, both RF branch pair A/B and C/D must have a carrier with the same bandwidth.
- Dot 4479 only supports Contiguous Carriers regardless if it is Mixed mode or not.
- Minimum software required for Dot 4479 is 19.Q3.

2.1.4 GNSS Antenna and GPS Module

The Global Navigation Satellite System (GNSS) receiver system receives a GNSS timing signal that is used to synchronize the GNB.

GPS signal is needed to have a Time & Phase Synchronization required for 5G with TDD (Time-Division Duplexing) strategy. Precise signal is needed to synch the DL and UL frames and to synch between 5G nodes.

The main components in the GNSS receiver system are the GNSS active antenna and the GNSS receiver unit.

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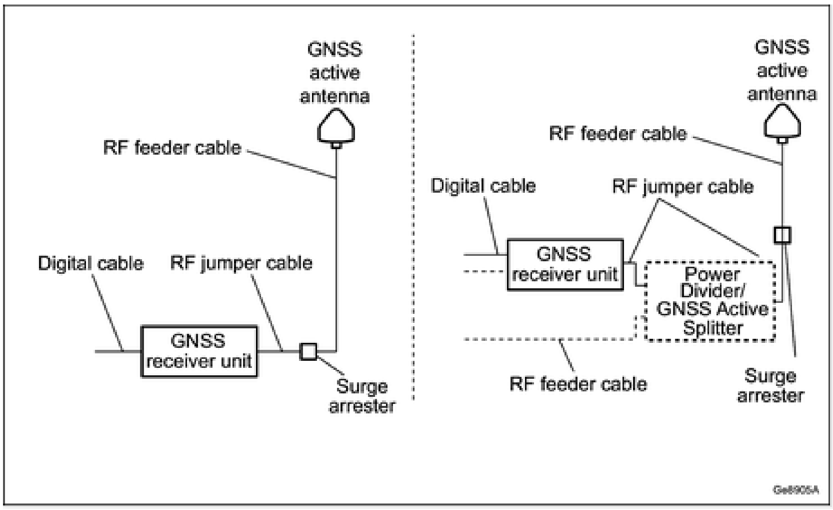

Figure 13 - Cables in the GNSS receiver system

The GNSS receiver unit is powered by the GNB through digital interfaces. The GNSS receiver unit supplies power through the RF interface to the GNSS active antenna and, if used, to the GNSS active splitter and inline amplifier.

When the GNSS receiver unit is powered, it continuously sends status sentences to the GNB and searches for satellites on received RF signals. An indicator shows that the power is activated.

The GNSS active antenna receives signals from the GNSS satellites. The signals are sent through the RF cables to the GNSS receiver units.

When the GNSS receiver unit locks to the satellites, this is shown on the indicator, and the unit starts to send One Pulse Per Second (1PPS) and time of day information to the GNB.

Active Antenna - Technical data

The GNSS active antenna is powered by the GNSS receiver unit, which can be up to 170 m from the antenna when a 0.5-inch cable is used, or 90 m from antenna when a 0.25-inch cable is used.

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Figure 14 - GNSS active antenna

GNSS Active Antenna Interfaces

N-type (female)

GNSS Active Antenna Size

Table 14 - GNSS active antenna size

Unit	Width	Height	Depth
GPS active antenna (Rosenberger)	69 mm	74 mm 94 mm (1) 178 mm (2)	69 mm 87 mm (2) 103 mm (2) (3)

(1) Including RF connector
(2) Including brackets
(3) Including earth lug

GNSS Active Antenna Technical Data

Table 15 - GPS/GNSS active antenna technical data

	GPS Active Antenna KRE 101 2182/1, Rosenberger

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Satellite system support	GPS
Frequency	1575.42 ± 10 MHz
Gain(2)	35 ± 5 dBi
Out-of-band rejection	>40 dB at 1575.42 ± 50 MHz >45 dB at 1575.42 ± 70 MHz
Operating temperature	−40°C to + 55°C
Operating voltage	+4 V DC to +6 V DC
Non-destructive abnormal voltage	-32 V DC to + 4 V DC +6 V DC to + 32 V DC
Current consumption	≤35 mA
Encapsulation class	IP 65
Active antenna delay(3)	40 ns

(1) Use of BeiDou requires client SW (RBS or Router 6000) to support the configuration of GPS 03 to use BeiDou
(2) At zenith including LNA gain
(3) Used when delay compensation is defined in RBS SW

GNSS Antenna System Characteristics

The antenna system gain is the RF front-end gain with the GNSS antenna, RF cable, and RF jumper cable before the GNSS receiver.

Table 16 - GNSS antenna system characteristics

Antenna system gain	15–35 dB (1)
Frequency band	L1

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Nominal impedance	50 Ohm
Noise	< 3 dB
Operating voltage	4–6 V DC
GRU antenna port current consumption	< 65 mA(2)
Lightning current immunity	±5 kA, 10/350 µs and ±20 kA, 8/20 µs
Maximum capacitive load	30 uF(3)

(1) Minimum recommended system gain is 20 dB
(2) Shared amongst any active component that draws power from the GRU antenna port
(3) Valid for GPS 02 R3A and newer

GNSS Receiver Unit (GRU 04 01) - Technical data

GRU 04 01 support GPS and GLONASS by default after power on.

Figure 15 - GNSS receiver unit

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In multi-GNSS constellations such as GPS and GLONASS as well as GPS and BDS, GRU 04 01 use the best satellites from both GNSS constellations.

GRU 04 01 supports configurations with:

- One or two DUs or Baseband through individual GNSS digital interfaces

GRU 04 01 have built-in surge protection, so a separate surge arrester is required only if a GNSS active splitter or a power divider is used.

GNSS Receiver Unit Interfaces

Table 17 - GNSS receiver unit interfaces

Unit	Connector
GRU 04 01	SMA connector (female) 2 × RJ-45 (female)

GNSS Receiver Unit Size

Table 18 - GNSS receiver unit size

Unit	Width	Height	Depth
GRU 04 01	37 mm	32 mm	103 mm

GNSS Receiver Unit Technical Data

Table 19 - GNSS receiver unit, technical data

	GRU 04 01
Operating voltage (digital interface)	+8 V DC to +30 V DC(1)

Non-destructive voltage (digital interface)	0 V DC to +30 V DC
Output voltage (RF interface)	+4.8 V DC to +6 V DC
Maximum output current (RF interface)	50 mA(2)
Encapsulation class	IP 20
Other	Short-circuit safe
Lightning current immunity(3)	±1.5 kA, 2 Ohm, 10/350 µs according to IEC 62305-1, direct injection to antenna port center conductor

(1) +8 V DC to +13 V DC for GRU 04 01 and GRU 04 02 when power is supplied directly from a DU
(2) If the digital cable is 2 m or shorter, the output current is up to 65 mA.
(3) Only for GPS 02 R2B and later. Performance criterion C as defined in IEC 61000-6-2

2.2 Transmission - Equipment

2.2.1 Router 6675

The Router 6675 is a high-capacity pre-aggregation and aggregation router, designed to enable high quality network service delivery while at the same time lowering operating costs through features such as a completely filter-less mechanical design. It provides high density 10G and 100GE port densities, with 320Gbps switching capacity in a compact and hardened 1RU form factor enabling lower rental costs and lower OPEX.

It supports VPN services over IP/MPLS networks, service provider SDN, service exposure using NETCONF/YANG, extensive quality of service and precise synchronization features.

The Router 6675 has strong security features such as IPSec, vendor credential and vendor software authentication ensuring data security even in insecure environments.

The Router 6675 is part of the Ericsson Router 6000 Series, a radio integrated, service provider SDN enabled and subscriber aware IP transport family of products. The Router 6000 offers a range of high-performance routers with resiliency features and form factors optimized for the various needs of metro and backhaul networks.

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With 320Gbps of switching capacity, the Router 6675 delivers performance needed to fully support LTE, LTE Advanced, 5G, access sites for years to come.

Figure 16 - Router 6675 (Front view)

Router 6675 - Technical data

The Ericsson R6000 is a radio integrated family of products. Ericsson R6000 offers a range of high-performance routers with resiliency features and form factors optimized for the various needs of metro and backhaul networks. The Ericsson R6000 is tightly integrated with Ericsson Radio and Microwave to provide high-capacity mobile backhaul with unprecedented quality of experience.

The main hardware components of an Ericsson R6000 product are the Line Card and the Route Processor card:

The Line Card houses the traffic ports.

- For Router 6675, only one Line Card is embedded in the node and not replaceable.

The Route Processor (RP) is the main processor of the system and supports Operation, Administration and Maintenance (OAM), and routing functions.

- For Router 6675, only one RP is embedded in the node and not replaceable.

The Router 6675 includes the following parts:

- One Rack Unit (RU) chassis that fits into the 19-inch rack.
- A fan tray with five high-performance fans, which can still effectively cool the chassis even when one fan fails.
- Dual Direct Current (DC) power feeding with front cabling. 320 Gbps throughput with full duplex.
- 24 Gbit DRAM packet buffer.

- Variety of interfaces including:
  - Twenty-four 1GE SFP/10GE SFP+ ports

- Four 40GE QSFP+/100GE QSFP28 ports. The router supports 1×100GE, 1×40GE, 4×10GE, 4×25GE, 1×10GE QSA mode, or 1×25GE QSA mode on each 40GE/100GE port.
- One 100/1000 Base-T Ethernet for Out-of-Band management (LMT)
- One RJ45 console port
- One RJ45 alarm port for 3 input and 1 output alarm contacts
- One USB 2.0 Type A port used as USB storage
    - Note: The 6675 does not support USB 1.1 devices.
- One RJ45 1PPS+TOD (ITU-T G.703 Amd1) port
- One RJ48C port for 2.048 MHz, E1/T1 (BITS) input/output

Mechanical details:

- System weight: 8kg / 17.6lbs
- Dimension (H x W x D): 1RU 43.6mm x 442.8mm x 315mm
- Air flow: Filter-less design, Front to Back with field swappable fan tray

Electrical details:

- Power supply DC: -48 VDC, dual feed
- Power consumption: Typical 79 Watts, Max (with optics) 225 Watts

2.3 Satellite - Equipment

2.3.1 FoldSAT LEO Ku OW MIL

Figure 17 – FoldSAT Leo Ku OW MIL Terminal

Developed to ensure portability, ease of use, and quick deployment, this terminal provides a practical solution for military operations and emergency response scenarios in diverse environments. Optimized for the Eutelsat-OneWeb Ku-Band LEO satellite constellation, it delivers dependable connectivity even in areas beyond the reach of conventional networks.

Featuring a foldable, lightweight design and external battery support, the terminal provides fast and reliable data, video, and voice communication, even in challenging conditions. Its compact, low-profile antenna enhances operational efficiency, making it suitable for demanding environments. Built to meet MIL-STD 810H and MIL-STD 461G standards, the terminal is equipped with a Wi-Fi 6 modem, durable military-grade components, and essential accessories such as a tripod and an optional transit case, ensuring robust performance in diverse scenarios.

The Inster FoldSat LEO Terminal integrates advanced technology with robust durability, ensuring reliable performance for a wide range of civilian and military applications.

<u>Main features:</u>

- Full duplex, foldable, person-portable, flat panel antena
- Lightweight and self-aligning
- Supports external GNSS input
- Throughput up to 195 Mbps/32 Mbps (DL/UL)
- Operates with external OTS batteries
- Wi-Fi 6 capability

<u>Dimensions:</u>

- L44.7 cm x W37.4 cm x H11.6 cm (folded)
- L85.5 cm x W37.4 cm x H5.7 cm (unfolded)

<u>UT Weight:</u>

- 12.1 Kg

<u>UT Package Configuration:</u>

- 21.7 kg (UT, Tripod, MIL AC-DC Power supply, power cables, ethernetcable)

<u>Input voltage range:</u>

- 18 VDC to 36 VDC (terminal) 85-264 VAC (AC/DC External accessory)

<u>Power Consumption:</u>

- Peak: 190 W Typical: 150 W

<u>Operating Temperature:</u>

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- -40°C to +55°C

Storage Temperature:

- -40°C to +85°C

Power Options:

- MIL AC-DC converter, Vehicle power, Mil Grade battery (180 mins autonomy with 294 Wh battery)

Antenna technology:

- Full-duplex Ku-band electronically steered antena

Scanning range Azimuth:

- 0 to 360º

Polarization:

- RX: RHCP. TX: LHCP

RX band:

- 10.7 to 12.7 GHz

TX Band:

- 14.0 to 14.5 GHz

Downlink data throughput:

- up to 195 Mbps

Uplink data throughput:

- up to 32 Mbps

Satellite modem:

- Embedded Eutelsat-OneWeb modem

Interfaces:

- 1 Port Gigabit Ethernet and Wi-Fi 6

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<u>Panel lights:</u>

- 4 x Night Vision Goggle LED

<u>Ingress protection:</u>

- IP65

<u>Certifications:</u>

- CE, FCC, UKCA, ISED, ACMA, RoHs, MIL-STD 810H, MIL-STD 461G

2.4 Core Network - Equipment

2.4.1 Local Packet Gateway 1.3

Figure 18 – Local Packet Gateway 1.3

The Local Packet Gateway (LPG) is an important part of the Dual-Mode 5G Cloud Core solution, which also includes the Packet Core Controller (PCC) and other Cloud Core products. The LPG provides a single-server bare-metal cloud-native solution to host the Packet Core Gateway (PCG). The LPG can be located at customer premises close to the network edge for optimum performance.

The LPG consists of the following parts:

- A hardware platform
- A software platform
- The PCG

The LPG can be deployed at enterprise level on premise or at a mobile network operator network. The LPG can be deployed on a specified single server to provide lightweight Kubernetes (K3s) in a bare-metal environment in order to deploy the PCG.

After the PCG is deployed through the LPG, the PCG can provide the following 5GS functionality:

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For 5GS:

- LTE
- NR
- Wi-Fi

Architecture

The LPG provides the functionality of the UPF in the 5GS. In the 5GS network, the LPG can act as a UPF.

The LPG architecture is built around microservices running in containers provided by the PCG. Each microservice in the LPG is mapped to a pod type. In the LPG, K3s CaaS, which is a lightweight Cloud Native Computing Foundation (CNCF)-certified Kubernetes™ distribution, is used to manage and deploy containerized microservices. K3s runs on the underlying operating system and the supported hardware.

The LPG architecture can be divided into four layers:

- The PCG
- K3 Container as a Service (CaaS)
- The operating system
- Hardware

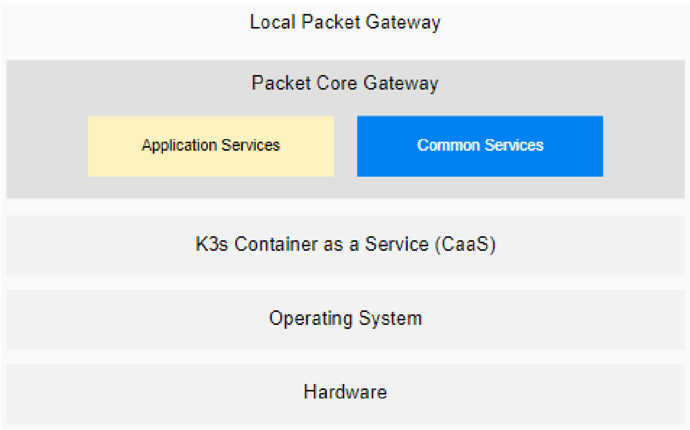

Figure 19 - LPG architecture

<u>Packet Core Gateway</u>

The microservices in the PCG are divided into application services and common services.

Application Services:
Application services implement protocols, functions, and procedures that are required to comply with the network function behaviors specified in 3GPP standards.
Some microservices used in the application services are shared across multiple network functions. This means that one microservice can affect more than one network function. The division into microservices allows for separate scaling and life cycle management.

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Note: Scaling is not allowed in the LPG.

The user plane application services consist of the Routing Engine, the PC UP Data Plane, the PCFW, the PC UP PFCP Endpoint and the internal support services.

Common Services:

Common services implement support functions that are common to several microservices within the PCG such as operation and maintenance, data storage, load balancing, and external network-cluster integration. Examples of common services are performance management, fault management, and user management. This common management layer allows for easy integration of new network functions.

K3s (CaaS):

K3s CaaS is built for Edge computing. K3s implements the Kubernetes API completely while not being functionally different from Kubernetes. However, K3s does not include the optional components of Kubernetes that are not critical to run a bare minimum cluster. The storage volume plug-ins and cloud provider APIs are also excluded, but the following essential elements are included:

- Container runtime
- Overlay network
- DNS server
- Container network interface
- Ingress controller
- Local storage provisioner
- Embedded service load balancer
- Integrated network policy controller
- Lightweight database for cluster state management

By default, every installation of K3s includes a control plane, primary node agent, and a container runtime that are sufficient to run the Kubernetes workload. In a K3s cluster, a node that runs the control plane components along with the node agent is called a server while a node that only runs the node agent is called an agent.

The LPG takes advantage of the K3s behavior to create a single Kubernetes cluster with only one server node running in the K3s CaaS on the single server. This single node is sufficient to run the Kubernetes workload, meaning that the application layer can be deployed on top. The LPG uses Helm for application deployment.

The LPG runs the PCG as an application, which requires the LPG to use some K3s components to ensure compatibility and proper operation.

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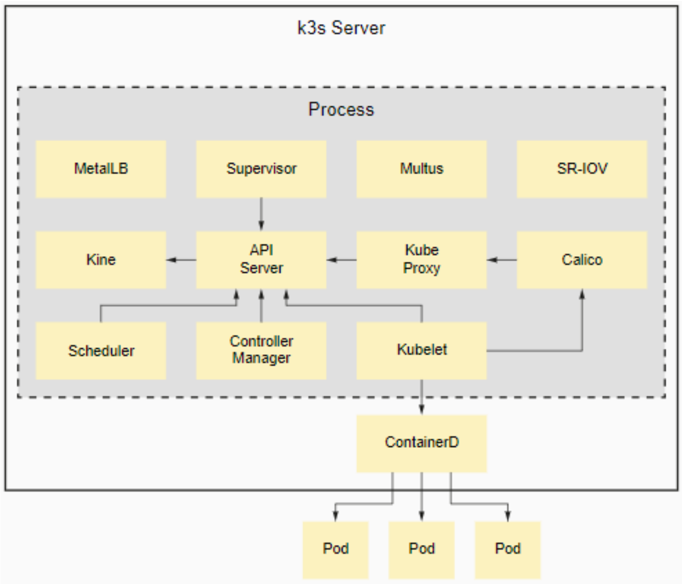

Figure 20 - K3s architecture

Operating System:

The SUSE Linux Enterprise Server 15 Service Package 4 operating system is used to run the CaaS layer. The operating system contains only the necessary parts to complete the direct networking configurations. Also, the components required to install and operate the CaaS layer are included in the operating system.

Hardware:

The LPG only supports one server type for installing the operating system, the CaaS layer, and the PCG.

Table 20 - LPG hardware

Vendor Code	Description
Dell EMC™ R640 14G	A carrier-grade or NEBS level 3 server based on Intel Xeon SP Cascade Lake Dell EMC R640 14G

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Table 21 - Main characteristics of Dell EMC R640 14G

Functional Block	Characteristics
CPU	Xeon G-6230R 2x26c
Memory	384GB
Storage	2x960GB SSD SATA RI
Network	2x1GbE, 2x10GbE, 6x25GbE ports

Table 22 - Physical and environmental parameters

Description	Value
C13 Power Connector	2
Weight	22.0 kg
Height	1U
Depth	757.75 mm
Minimum Operating Temperature	-5 °C
Maximum Operating Temperature	40 °C
Theoretical Current Amp@208V	2.2 A
Theoretical Power	491.00 VA
Cubic Feet Per Minute	51 cu ft/min

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Heat Dissipation	1675.4 BTU
Acoustic Noise - Sound Power	78.0 dB

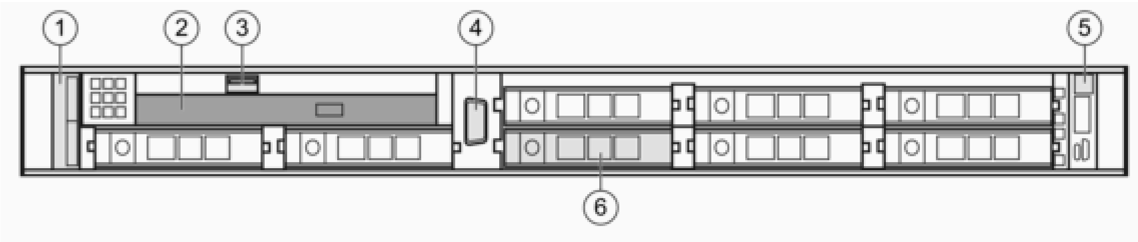

Figure 21 - Dell EMC R640 (Front panel view)

Table 23 - Front panel operators

Item	Ports, Panels, or Slots
1	Left control panel
2	Optical drive (currently not included)
3	USB port (currently not included)
4	VGA port
5	Right control panel
6	Drive slots (x8)

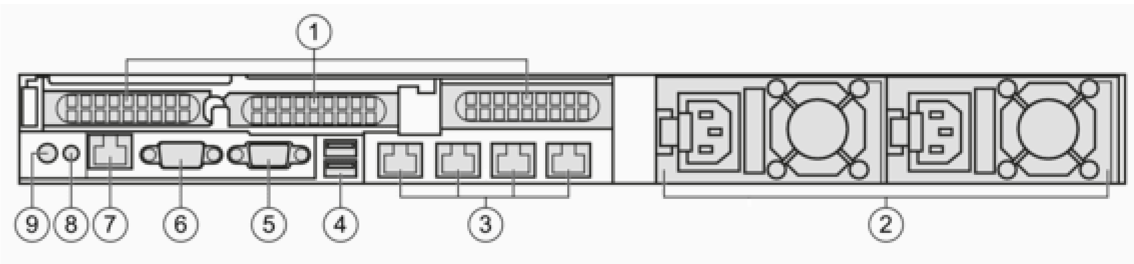

Figure 22 - Dell EMC R640 (Rear panel view)

Table 24 - Rear panel operators

Item	Ports, Panels, or Slots
1	PCIe expansion card slot (x3)
2	Power supply unit (x2)
3	NIC port on network daughter card (NDC) (x4)
4	USB 3.0 port (x2)
5	VGA port
6	Serial port
7	iDRAC9 dedicated network port
8	System status indicator cable port
9	System identification button

Software:

The LPG platform software is delivered in an ISO package that is based on the ISO-9660 standard. The LPG platform ISO contains the following:

- The operating system
- Related packages and software
- The CaaS software
- Related plug-ins and scripts used to install different LPG components

The PCG is delivered in a VNF package compliant with the ETSI NFV-SOL 004 specification, which is based on the TOSCA CSAR standard.

The CSAR package is a ZIP file that contains the following:

- Metadata
- VNF Descriptor (VNF)
- Helm charts

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- Docker images

The VNFD is partly compliant with the ETSI NFV-SOL 001 specification, which is based on the TOSCA standard. ETSI NFV-SOL 001 does not support deployment on Kubernetes, and as a result, the TOSCA VNFD is complemented with Helm charts that specify deployment using Kubernetes. The same Helm charts are used for manual life cycle management.

2.4.2 Ericsson CRU 0101 - Applications Sever

Figure 23 – Ericsson CRU 0101 applications server (Front view)

The system is a 2-socket 1U server powered by the Intel® Xeon® processor E5-2600 v3 family.

It features significant performance with 24 DDR4 RDIMM/LRDIMM memory slots, 4 hotplug disk drives for 3.5" HDD SKU or 10 hot-plug disk drives for 2.5" HDD SKU, up to 2 PCIe expansion slots, and 1GbE/10GbE Base-T/10G SFP+ networking options.

These rich features list as below:

- Greener and More Powerful
- Full-Featured Design for Demanding Virtualization Workload
- Flexible and Scalable I/O options

Ericsson CRU 0101 - System Specifications:

Specifications	Description
Form factor	1U rack mount
Chassis dimensions (W x H x D)	17.24 x 1.7 x 29.21 inches 438 x 43.2 x 742 mm
Processor	**Processor type:** Intel® Xeon® processor E5-2600 v3 product family **Max. TDP support:** ● 145W with limited HDD Qty ● 135W with max configuration **Number of processors:** 2 **Internal Interconnect:** 6.4 / 8.0 / 9.6 GT/s **Last Level Cache (LLC):** Up to 35 MB
Chipset	Intel® C610
Memory	**Total slots:** 24 **Capacity:** Up to 384GB RDIMM / Up to 768GB LRDIMM **Memory type:** 2133 MHz DDR4 RDIMM / LRDIMM **Memory size:** 16 GB, 8 GB RDIMM / 32 GB LRDIMM
Storage controller	**Onboard (Intel® C610):** ● 10x SATA 6Gb/s ports ● SATA RAID 0, 1, 10 **Optional controller:** ● Quanta LSI® 2308 6Gb/s SAS mezzanine, RAID 0, 1, 10 ● Quanta LSI® 3008 12Gb/s SAS mezzanine, RAID 0, 1, 10 ● Quanta LSI® 2108 6Gb/s RAID mezzanine, RAID 0, 1, 5, 10, RAID 6 with additional RAID key ● Quanta LSI® 2208 6Gb/s RAID mezzanine, RAID 0, 1, 5, 10, RAID 6 with additional RAID key

Figure 24 - Ericsson CRU 0101 system specifications (1/2)

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Specifications	Description
Networking	**LOM:** ● Intel® I350 dual-port 1GbE or Intel® X540 dual-port 10GbE BASE-T ● Dedicated 1GbE management port **Optional NIC:** (more options refer to the AVL) ● Quanta Intel® i350 dual-port OCP mezzanine ● Quanta Intel® X540 dual-port 10GbE BASE-T OCP mezzanine ● Quanta Intel® 82599ES dual-port 10G SFP+ OCP mezzanine
Expansion slots	**Riser 1** ● (default): One x8 PCIe 3.0 SAS mezzanine slot (CPU0) ● (option 2): One x16 PCIe 3.0, Low profile MD-2 (CPU0) **Riser 2** ● One x16 PCIe 3.0, Low profile MD-2 (CPU1) **OCP mezz slot** ● One x8 PCIe Connector (CPU0)
Storage	● 4x 3.5" hot-plug HDD/SSD (3.5" HDD SKU) ● 10x 2.5" hot-plug HDD/SSD (2.5" HDD SKU; requiring additional LSI SAS/ MegaRAID card to connect to the expander backplane) ● 10x 2.5" hot-plug HDD/SSD (2.5" HDD SKU: including 2x optional 2.5" NVMe PCIe SSD)
Onboard storage	2x SATADOM (optional*) (*Option not supported if these on-board SATA ports are used up to activate front HDD 0-1 for 2.5" HDD SKU)
Video	Integrated Aspeed AST2400 with 8MB DDR3 video memory
Front I/O	● Power/ID/Reset Buttons ● LAN/HDD/Status/ID LEDs ● 2x USB 2.0 ports (3.5" HDD SKU)
Rear I/O	● 2x USB 3.0 ports ● 1x VGA port ● 1x RS232 serial Port ● 2x 1 GbE or 10G BASE-T RJ45 port ● 1x GbE RJ45 management port ● 1x ID LED ● 1x Port 80 Debug Port (optional)
Optical drive	NA
TPM	Yes (optional)
Power supply	1 High efficiency redundant hot-plug 500W PSU, 80 Plus Platinum (2nd PSU optional)
Fan	6x dual rotor fans (11+1 redundant)
System management	IPMI v2.0 Compliant, on board "KVM over IP" support
Weight (Max. configuration)	● 15.77 Kg (3.5" HDD SKU) ● 14.5 Kg (2.5" HDD SKU)

Specifications	Description
Operating environment	● Operating temperature: 5°C to 40°C (41°F to 104°F) ● Non-operating temperature: -40°C to 70°C (-40°F to 158°F) ● Operating relative humidity: 50% to 85%RH. ● Non-operating relative humidity: 20% to 90%RH

Figure 25 - Ericsson CRU 0101 system specifications (2/2)

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System front view:

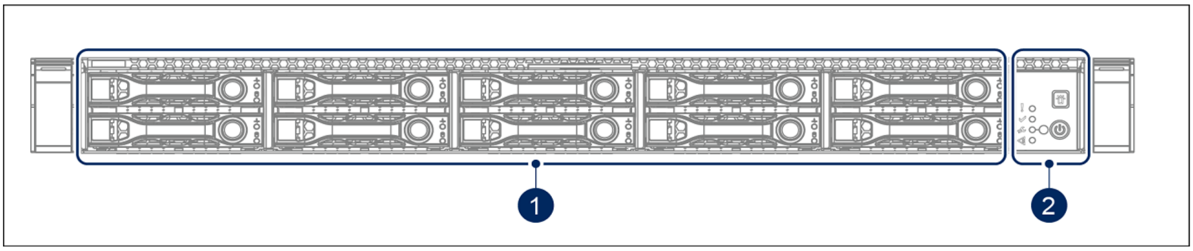

Figure 26 – Ericsson CRU 0101 (Front panel view)

Table 25 - CRU 0101 front panel components

No.	Item	Description
1	Drive Bays	10 × SAS HDD
2	Front Control Panel	

System rear view:

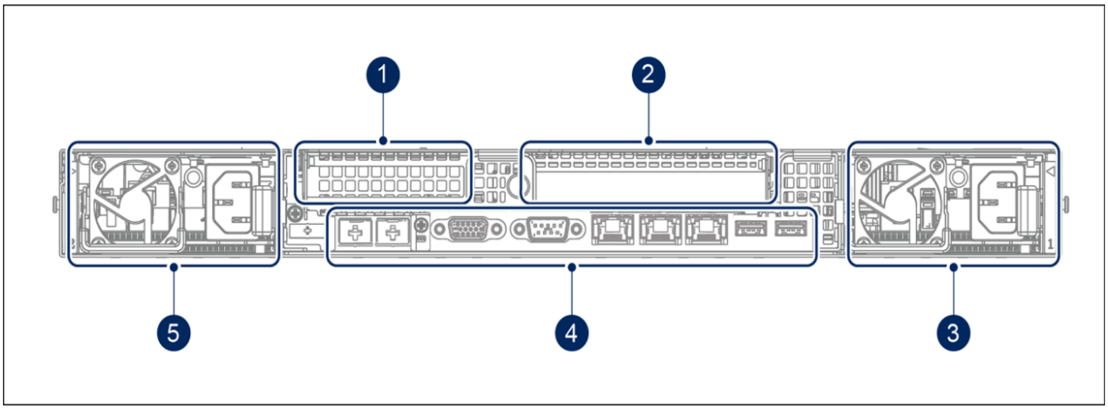

Figure 27 - Ericsson CRU 0101 (Rear panel view)

Table 26 - CRU 0101 rear view components

No.	Item	Description
1	Expansion Slot	PCIe expansion slot with PCIe × 8 signal

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2	Expansion Slot	PCIe expansion slot with PCIe × 8 signal
3	Power Sub-System	Main PSU (PSU1)
4	System Input Output ports	
5	Power Sub-System	Secondary PSU (PSU2)

<u>System rear I/O:</u>

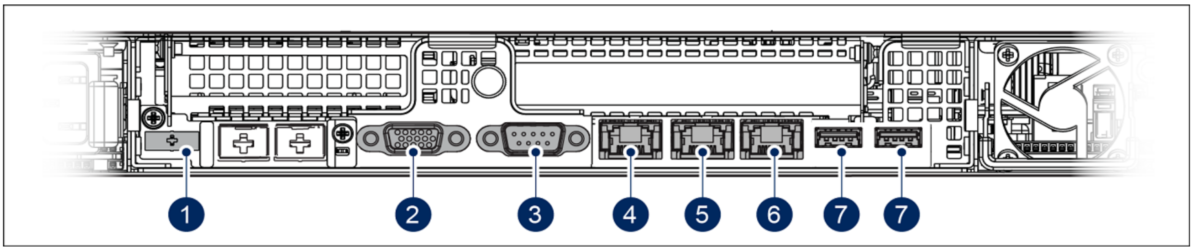

Figure 28 - Ericsson CRU 0101 (Rear I/O components)

Table 27 - CRU 0101 rear input & output components

No.	Item	Description
1	OCP connector	OCP debug connector (optional)
2	VGA connector	Maximum display resolution: 1920 × 1200 32 bpp @ 60 Hz (reduced blanking)
3	COM port A	DB9 port (Serial_A) for a/the debug or terminal concentrator
4	NIC 2	RJ45 connector
5	NIC 1	RJ45 connector

6	Dedicated NIC	NIC to BMC
7	USB ports	USB ports (2.0 or 3.0)

2.5 Customer Premises - Equipment

2.5.1 Askey NUQ3000M – CPE

NUQ3000M 5G NR ODU combines ultimate performance and revolutionary high-speed 5G technology to boost your broadband access network.

This device has outstanding reception of 5G mmWave signal (26~28GHz and 39GHz) and Sub-6 5G NR. It enables carriers and service providers to perform a wide array of high-quality applications.

It offers flexibility and supports 5G NR and 4G LTE, up to Cat.20, to achieve high performance gigabit speed access.

Figure 29 - Askey NUQ3000M CPE and PoE units

Technical specifications:

- Chipset: Qualcomm SDX65, 3GPP Release16
- 5G NR: mmWave & Sub-6 bands
- Sub-6 supports NSA & SA dual modes
- mmWave supports NSA mode (NR-DC 5G SA)
- LTE DL Cat.20
- LTE and 5G NR ENDC

Physical specifications:

- LED: Power and Signal
- Reset Button
- SIM Card slot: Nano SIM (4FF), (eSIM option)
- Ethernet: 1 x RJ45 Waterproof Connector, 5Gbps, PoE PD supported
- Size:170 x 100 x 36.95 (LxWxD, mm)

Qualcomm® Snapdragon™ X65 5G Modem-RF System

Qualcomm Snapdragon X65 5G Modem-RF System is the world's first 10 Gigabit 5G and first 3GPP Release 16 modem-to-antenna solution. It is designed with an upgradable architecture to rapidly commercialize 5G Release 16 and extend 5G in mobile broadband, fixed wireless, industrial IoT and 5G private network applications.

Qualcomm® Snapdragon™ X65 5G Modem-RF System Built to extend 5G into more application segments:

- Mobile broadband – smartphones, tablets, PCs, mobile hotspots
- Fixed wireless – CPEs, home broadband, routers
- Industrial IoT
- 5G private networks

Features:

- 10 Gbps peak speeds in 5G standalone and non-standalone modes
- 3GPP Release 16 support
- Upgradable architecture for rapid feature rollout
- 5G mmWave-sub6 aggregation
- Global 5G band support including the new n259 (41 GHz), n70, n53
- Advanced power-saving tech
- Qualcomm® 5G PowerSave 2.0
- Qualcomm® Wideband Envelope Tracking (7th gen)
- Qualcomm® AI-Enhanced Signal Boost

Specifications:

- 5G Chipset: Qualcomm® Snapdragon™ X65 Modem-RF System
- 5G Spectrum: mmWave-sub6 aggregation, sub-6 carrier aggregation (FDD-TDD, FDD-FDD, TDD-TDD), FDD-TDD support for uplink-CA, Dynamic Spectrum Sharing (DSS)

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- 5G Modes: FDD, TDD, SA (standalone), NSA (non-standalone)
- 5G mmWave specs: 1000 MHz bandwidth, 10 carriers, 2x2 MIMO
- 5G sub-6 GHz specs: 300 MHz bandwidth, 256-QAM, 4x4 MIMO
- 5G Peak Download Speed: 10 Gbps
- 5G Global Multi-SIM support
- Cellular Technology: 5G NR, LTE, LAA, WCDMA (DB-DC-HSDPA), TD-SCDMA, CDMA 1x, GSM/ EDGE, CBRS

2.5.2 HP Z2 Mini G9 – Mini PC

Figure 30 - HP Z2 Mini G9 (Front and rear views)

Operating Systems:

- Support your unique user needs with a choice of Windows 11 Pro, WSL2 or Linux® operating systems.

Intel® Core™ Processors:

- Bring your ideas to life quickly and run multiple apps simultaneously with the latest Intel® Core™ vPro® processors. For added performance, choose the K-Series.

Professional Graphics:

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- Design, render and simulate seamlessly with up to NVIDIA RTX A2000 graphics with PCIe G5 high speed bandwidth.

Memory:

- Experience fast performance when working on complex design tasks with 2 DIMMS for up to 64GB DDR5 memory at an increased memory speed of up to 4800MHz.

Storage:

- Get up to 8TB with dual M.2 storage slots and RAID data storage capabilities for added performance or reliability.

Flexible I/O Modules:

- Configure to the needs of today with flexibility for the future with up to two flexible I/O ports and 13 I/O options to fill them with, including DP 1.4, VGA, HDMI, Dual USB Type-A, USB Type-C® with Alt-DP or 2nd Serial and more.

Multi-Display Support:

- See all your windows in perfect detail with support for up to 8 displays at 4K resolution

WiFi Connectivity:

- Wi-Fi 7 offers up to 2.5 faster file transfer speeds than Wi-Fi 6E.

ISV Certified:

- Work with confidence knowing your desktop is certified with leading software applications to ensure peak performance.

HP Wolf Security:

- HP Wolf Security for Business creates a hardware-enforced, always-on, resilient defense. From the BIOS to the browser, above, in, and below the OS, these constantly evolving solutions help protect your PC from modern threats.

Tool-less Access:

- Evolve your work. Evolve your rig. With a tool-less sliding access cover, you can easily get into the the interior, and customize your Z to fit your needs.

Network Connectivity:

- Connect and collaborate quickly with 10Gb Ethernet interface.

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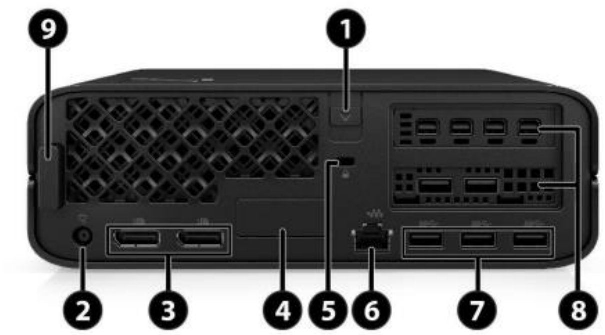
Front-Side View

1. Power button
2. Universal audio jack (with CTIA & OMTP headset support)
3. Antenna
4. 1 USB-A 10Gbps port (charge port supports up to 5V/2.1A)
5. 2 USB-C® 20Gbps port (charging supported up to 5V/3A)

Figure 31 - HP Z2 Mini G9 (Front-side view connections)



Rear View

1. Cover release latch
2. Power connector
3. (2) DisplayPort 1.4
4. Flex IO left side, choice of: (1) VGA, (1) HDMI 2.0b, (1) DisplayPort™ 1.4, (1) Dual USB-A 5Gbps port, (1) 1GbE LAN, (1) USB-C® 10Gbps port (Alt Mode), (1) Thunderbolt™ 3 with USB4 40Gbps, (1) 1Gbps Fiber LC NIC, (1) 2.5GbE LAN, (1) USB-based Serial port, (1) 10GbE LAN
5. Security cable slot
6. (1) 1GbE LAN
7. (3) USB-A 10Gbps port
8. PCIe, choice of: Graphic Cards[3], (1) Dual USB-A 10Gbps port, (1) Serial port
9. Antenna

Figure 32 - HP Z2 Mini G9 (Rear view connections)

Mechanical details:

Chassis Dimensions (H x W x D)	H: 2.7" [69mm] (Standard desktop orientation) W: 8.3" [211mm] D: 8.6" [218mm]
Packaged Dimensions	H: 11.73" (298mm) W: 6.69" (170mm) D: 19.65" (499mm)

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Rack Dimensions	5U
Weight	Exact weights depend upon configuration Minimum: 2.4kg (5.29lbs.) Maximum: 3.1kg (6.83lbs.)
Temperature	Operating: 5° to 35° C (40° to 95° F) Above 1524 m (5,000 feet) altitude, the maximum operating temperature is reduced by 1° C (1.8° F) for every 305 m (1,000 feet) increase in elevation Non-operating: -40° to 60° C (-40° to 140° F) Maximum rate of change: 10°C/hr

Figure 33 - HP Z2 Mini G9 mechanical details

2.6 Miscellaneous - Equipment

2.6.1 Delta CellD 40 – DPS 850B-48-3 – Power Supply Unit

CellD systems are small, just like cells. They can be embedded in the telecom infrastructure and are often used in outdoor solutions. The products in this series are light and designed especially for installations with limited space offering high density of the installed power. The system includes high efficiency rectifiers, AC and DC connections, battery connection and either ORION or PSC 3 controller. In addition to advanced supervision, short depth and easy installation are the success factors of the system. Delta is known for quality and product reliability – in this solution that has been combined to optimize the total cost of ownership.

Figure 34 - Delta PSU (Front View)

Features & Benefits

- 19" rack mounted system up to 2.55 kW
- Complete integrated system in 1U
- High efficiency rectifiers up to 95,2 %
- All connections easily accessible from the top, or optionally rear side
- All battery and load breakers accessible at the front
- Sliding mechanism to support easy access to the top output connections
- Option for enhanced monitoring and controlling

Applications

- Mobile telecommunication
- Fixed line telecommunication
- Broadband networks
- Data centers
- Switching centers
- Modular UPS configurations

Technical Specifications

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	DPS 850B-48-3 CellD 40
Rectifier module	DPR 850B-48 (max. 3 pcs.)
Efficiency	95.2 %
Install power (max. config.)	2.55 kW
Input current (per 1 phase)	12 A_{RMS}
Input protection (recom.)	25 A gL/gG type
Height (overall)	43.6 mm (1U)
Width (body)	444 mm (19")
Depth (overall)	280 mm
Weight	4.1 kg

AC input	
AC configuration	(L + N + PE)
Input voltage range	80 … 300 V_{RMS}
Frequency range	45 - 66 Hz
Mains connection	Screw terminals/ optionally 2 m cable (schuko / open end)
Input protection	N loss Internal OVP Inbuilt fuses (L+N) High input voltage

DC output	
Output voltage range	42-58 V_{DC}; 53.5 $V_{DC\ nom.}$
Output current (max.)	40 A
Load breakers	6 x (2 - 30 A) or 2 x (6 - 50 A)
Battery breakers	2 x 50 A
LVD (battery)	Yes
PLD (not critical loads)	No
Output protection	Inbuilt fuses (both poles) Over-temperature protection

Control / Monitoring	
Controller	ORION or PSC 3
Local interface	Display, menu structure, key-pads, LEDs
Remote monitoring	6 alarm relays, modems, WEB Interface, SNMP protocol

Others	
Operating temperature	-45 - +65 °C
Humidity (relative)	95 % max, non cond.
Environment standard	ETSI EN 300 019-1-3
Safety standard	IEC 60950
EMC standard	EN 300 386

Figure 35 - Delta PSU technical specifications

2.6.2 Fonestar FRS-160 - Flight Rack 19"

19" black-finished flight rack case for professional mixer or other equipment. Manufactured in coated plywood. Protection against impacts based on 25 mm high-density foam

Hermetically closing lid, carrying handles, rubber feet, and metal protective corner pieces. Robust construction for transporting and protecting the equipment inside the rack.

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Figure 36 - Fonestar FRS-160 Flight rack (Front view)

<u>Mechanical details:</u>

Capacity:

- Rack unit: 16U / 19'' = 71.2 cm

Size:

- Outside (with wheels): 60 x 97.5 x 77.5 cm
- Inside: 48.5 x 71.2 x 57 cm

Weight:

- 47 Kg

3 Performance Tests and Results

Performance validation tests of the satellite backhaul (NTN) using a portable gNB and the radio multi-access point were carried out using "Flamingo" Flight Rack unit and the Inster FoldSat LEO terminal.

The system was integrated, configured and tested at 5TONIC premises (Leganés, Madrid). In Figure 37 and Figure 38, can be seen the indoor equipment of the testbed, composed by the flight rack (with the gNodeB, LPG and server) and the radio access based on the Ericsson Radio DOT system, both located indoors in the 5TONIC X3 laboratory room.

Figure 37 – 5TONIC premises – Lab

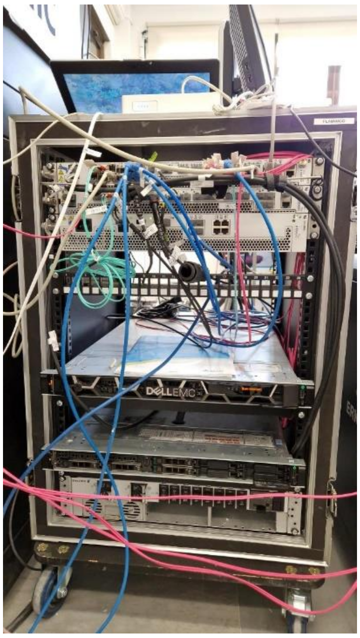

Figure 38 – "Flamingo" Flight Rack

Outdoors in 5TONIC premises, in order to be in line of sight with LEO satellites and assure optimal satellite coverage, it was located the FoldSat LEO Ku OW MIL terminal, as represented in Figure 39.

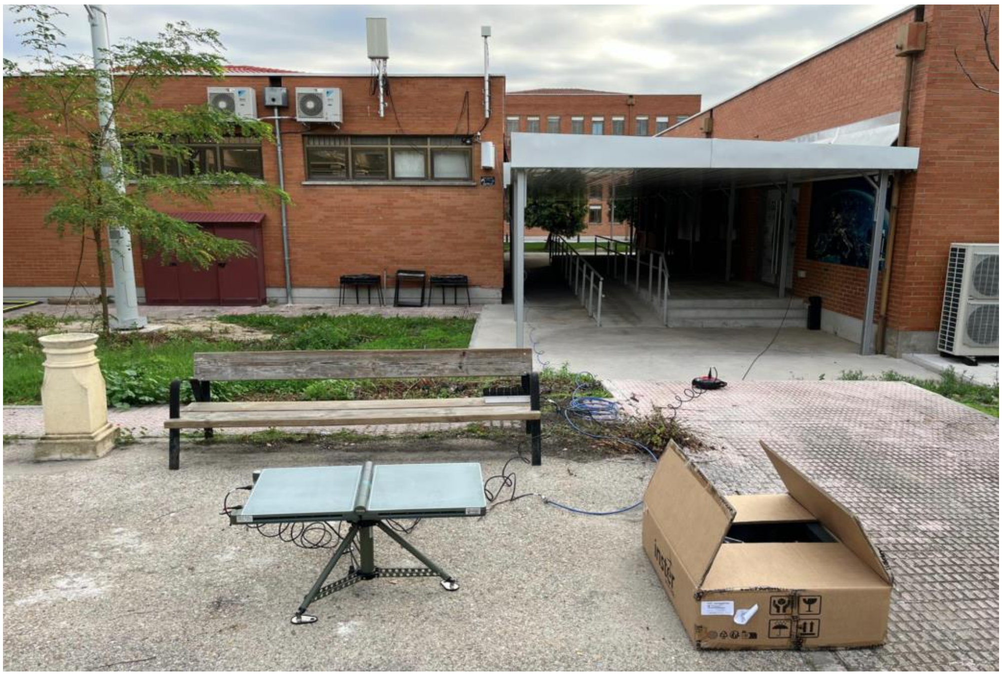

Figure 39 – 5TONIC premises – FoldSat LEO Ku OW MIL Teminal

In this chapter are described the methodology and measurement conditions followed by the different test performed.

Table 28 - "Flamingo" RAN details used for the tests

Sectors	Radio HW	NR Band - arfcn
FLAMINGO_5G_DOT-1	RD4479 B78L	Mid-band - N78 636666

Table 28 summarizes the HW configuration of the 5G cells involved in the testing ("Flamingo" mid-band gNodeB).

Table 29 – "Flamingo" RAN configuration

Band	Bandwidth	TDD pattern	Power	DL modulation	UL modulation	DL Layers	UL Layers
Mid-band (MB)	100 MHz	4:1 (10:2:2 - DDDSU)	1W	256 QAM	64 QAM	4	1

Table 29 highlights the RAN configuration parameters considered during the use case executions.

3.1 Use case 1 – NTN as backhaul

The objective of this first use case was to enable the E2E connectivity and execute the performance tests when having the NTN as backhaul, provided by the Inster FoldSat LEO terminal connected by ethernet to the flight-rack router.

As can be seen in Figure 40, an IPSEC tunnel was established between the router located in "Flamingo" flight-rack and the router located in 5TONIC data center, where the 5GC is located. The traffic across the NTN backhaul was encapsulated into the IPSEC tunnel.

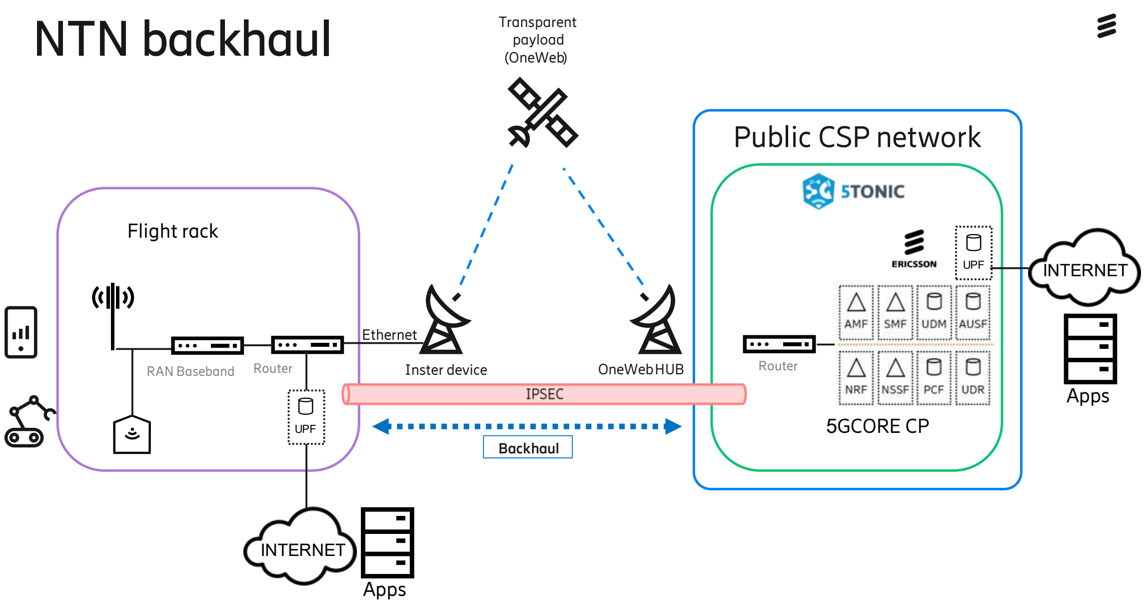

Figure 40 – Network architecture with NTN as backhaul (Use Case 1)

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Tests were carried out using the "Flamingo" NPN local *Mini PC* (1GE interface) connected to the *Askey NUQ300M CPE*, and the applications server located in the central 5GC infrastructure.

Performance metrics considered were:

- RTT ICMP tests
- Iperf DL TCP traffic
- Iperf UL TCP traffic
- Iperf DL UDP traffic
- Iperf UL UDP traffic

For Iperf traffic tests, the client and server were located in Mini PC / Applications server depending on the direction measured (DL/UL). Subsequently, the obtained performance data are presented.

Figure 41 to Figure 44 illustrate the Iperf traffic test results for both protocols TCP/UDP and both link directions, downlink and uplink.

```
ericsson@mini-pc01:~$ iperf3 -c 10.3.3.30 -t 20 -R
Connecting to host 10.3.3.30, port 5201
Reverse mode, remote host 10.3.3.30 is sending
[  5] local 192.168.1.3 port 33692 connected to 10.3.3.30 port 5201
[ ID] Interval           Transfer     Bitrate
[  5]   0.00-1.00   sec   640 KBytes  5.24 Mbits/sec
[  5]   1.00-2.00   sec   896 KBytes  7.34 Mbits/sec
[  5]   2.00-3.00   sec  1.62 MBytes  13.6 Mbits/sec
[  5]   3.00-4.00   sec  2.50 MBytes  21.0 Mbits/sec
[  5]   4.00-5.00   sec  3.25 MBytes  27.3 Mbits/sec
[  5]   5.00-6.00   sec  5.12 MBytes  42.9 Mbits/sec
[  5]   6.00-7.00   sec  7.00 MBytes  58.8 Mbits/sec
[  5]   7.00-8.00   sec  7.50 MBytes  62.9 Mbits/sec
[  5]   8.00-9.00   sec  8.75 MBytes  73.4 Mbits/sec
[  5]   9.00-10.00  sec  8.50 MBytes  71.2 Mbits/sec
[  5]  10.00-11.00  sec  8.62 MBytes  72.4 Mbits/sec
[  5]  11.00-12.00  sec  8.50 MBytes  71.3 Mbits/sec
[  5]  12.00-13.00  sec  8.62 MBytes  72.4 Mbits/sec
[  5]  13.00-14.00  sec  8.12 MBytes  68.1 Mbits/sec
[  5]  14.00-15.00  sec  8.88 MBytes  74.5 Mbits/sec
[  5]  15.00-16.00  sec  8.62 MBytes  72.3 Mbits/sec
[  5]  16.00-17.00  sec  8.50 MBytes  71.4 Mbits/sec
[  5]  17.00-18.00  sec  8.12 MBytes  68.1 Mbits/sec
[  5]  18.00-19.00  sec  8.62 MBytes  72.4 Mbits/sec
[  5]  19.00-20.00  sec  8.50 MBytes  71.2 Mbits/sec
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-20.13  sec   134 MBytes  55.8 Mbits/sec   15             sender
[  5]   0.00-20.00  sec   131 MBytes  54.9 Mbits/sec                  receiver
```

Figure 41 - DL TCP throughput rates (Use Case 1 – NTN as backhaul)

```
ericsson@mini-pc01:~$ iperf3 -c 10.3.3.30 -t 20
Connecting to host 10.3.3.30, port 5201
[  5] local 192.168.1.3 port 41458 connected to 10.3.3.30 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[  5]   0.00-1.00   sec   128 KBytes  1.05 Mbits/sec    0   38.8 KBytes
[  5]   1.00-2.00   sec   384 KBytes  3.15 Mbits/sec    0   50.8 KBytes
[  5]   2.00-3.00   sec   256 KBytes  2.10 Mbits/sec    0   65.6 KBytes
[  5]   3.00-4.00   sec   512 KBytes  4.19 Mbits/sec    0   87.0 KBytes
[  5]   4.00-5.00   sec   640 KBytes  5.25 Mbits/sec    0    115 KBytes
[  5]   5.00-6.00   sec   768 KBytes  6.29 Mbits/sec    0    150 KBytes
[  5]   6.00-7.00   sec  1.00 MBytes  8.40 Mbits/sec    0    198 KBytes
[  5]   7.00-8.00   sec  1.38 MBytes  11.5 Mbits/sec    0    258 KBytes
[  5]   8.00-9.00   sec  1.50 MBytes  12.6 Mbits/sec    0    345 KBytes
[  5]   9.00-10.00  sec  2.00 MBytes  16.8 Mbits/sec    0    464 KBytes
[  5]  10.00-11.00  sec  2.00 MBytes  16.8 Mbits/sec    0    605 KBytes
[  5]  11.00-12.00  sec  2.38 MBytes  19.9 Mbits/sec   20    680 KBytes
[  5]  12.00-13.00  sec  1.62 MBytes  13.6 Mbits/sec    0    682 KBytes
[  5]  13.00-14.00  sec  1.50 MBytes  12.6 Mbits/sec    0    686 KBytes
[  5]  14.00-15.00  sec   896 KBytes  7.33 Mbits/sec    0    694 KBytes
[  5]  15.00-16.00  sec   768 KBytes  6.30 Mbits/sec    0    714 KBytes
[  5]  16.00-17.00  sec  1.62 MBytes  13.6 Mbits/sec    0    755 KBytes
[  5]  17.00-18.00  sec  1.88 MBytes  15.7 Mbits/sec    0    807 KBytes
[  5]  18.00-19.00  sec  2.00 MBytes  16.8 Mbits/sec    0    875 KBytes
[  5]  19.00-20.00  sec  2.12 MBytes  17.8 Mbits/sec    0    966 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[  5]   0.00-20.00  sec  25.2 MBytes  10.6 Mbits/sec   20             sender
[  5]   0.00-20.53  sec  24.0 MBytes  9.78 Mbits/sec                  receiver
```

Figure 42 - UL TCP throughput rates (Use Case 1 – NTN as backhaul)

```
ericsson@mini-pc01:~$ iperf3 -c 10.3.3.30 -t 20 -u -b 75M -R
Connecting to host 10.3.3.30, port 5201
Reverse mode, remote host 10.3.3.30 is sending
[  5] local 192.168.1.3 port 56758 connected to 10.3.3.30 port 5201
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  8.92 MBytes  74.8 Mbits/sec  0.142 ms  428/8048 (5.3%)
[  5]   1.00-2.00   sec  8.74 MBytes  73.3 Mbits/sec  0.122 ms  0/7464 (0%)
[  5]   2.00-3.00   sec  8.72 MBytes  73.1 Mbits/sec  0.123 ms  0/7444 (0%)
[  5]   3.00-4.00   sec  8.72 MBytes  73.2 Mbits/sec  0.136 ms  0/7442 (0%)
[  5]   4.00-5.00   sec  8.69 MBytes  72.9 Mbits/sec  0.153 ms  18/7441 (0.24%)
[  5]   5.00-6.00   sec  8.71 MBytes  73.1 Mbits/sec  0.618 ms  15/7450 (0.2%)
[  5]   6.00-7.00   sec  7.91 MBytes  66.4 Mbits/sec  0.155 ms  0/6758 (0%)
[  5]   7.00-8.00   sec  9.25 MBytes  77.6 Mbits/sec  0.146 ms  0/7902 (0%)
[  5]   8.00-9.00   sec  8.20 MBytes  68.8 Mbits/sec  0.174 ms  0/6999 (0%)
[  5]   9.00-10.00  sec  8.86 MBytes  74.3 Mbits/sec  0.413 ms  0/7565 (0%)
[  5]  10.00-11.00  sec  8.00 MBytes  67.1 Mbits/sec  0.805 ms  0/6837 (0%)
[  5]  11.00-12.00  sec  7.23 MBytes  60.7 Mbits/sec  0.178 ms  23/6195 (0.37%)
[  5]  12.00-13.00  sec  11.0 MBytes  91.9 Mbits/sec  0.159 ms  0/9353 (0%)
[  5]  13.00-14.00  sec  7.01 MBytes  58.8 Mbits/sec  0.127 ms  0/5989 (0%)
[  5]  14.00-15.00  sec  10.4 MBytes  87.5 Mbits/sec  0.141 ms  0/8908 (0%)
[  5]  15.00-16.00  sec  8.39 MBytes  70.4 Mbits/sec  0.107 ms  0/7165 (0%)
[  5]  16.00-17.00  sec  8.76 MBytes  73.5 Mbits/sec  0.153 ms  58/7537 (0.77%)
[  5]  17.00-18.00  sec  7.46 MBytes  62.6 Mbits/sec  0.145 ms  0/6368 (0%)
[  5]  18.00-19.00  sec  10.1 MBytes  84.9 Mbits/sec  0.122 ms  0/8637 (0%)
[  5]  19.00-20.00  sec  8.72 MBytes  73.1 Mbits/sec  0.111 ms  4/7446 (0.054%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-20.18  sec   180 MBytes  75.0 Mbits/sec  0.000 ms  0/0 (0%)  sender
[  5]   0.00-20.00  sec   174 MBytes  72.9 Mbits/sec  0.111 ms  546/148948 (0.37%)  receiver
```

Figure 43 - DL UDP throughput rates (Use Case 1 – NTN as backhaul)

```
Server listening on 5201
-----------------------------------------------------------
Accepted connection from 10.3.202.66, port 30923
[  5] local 10.3.3.30 port 5201 connected to 10.3.202.66 port 30674
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[  5]   0.00-1.00   sec  1013 KBytes  8.30 Mbits/sec  0.714 ms  0/845 (0%)
[  5]   1.00-2.00   sec  1.75 MBytes  14.7 Mbits/sec  0.534 ms  1602/3100 (52%)
[  5]   2.00-3.00   sec  1.81 MBytes  15.2 Mbits/sec  1.337 ms  8102/9646 (84%)
[  5]   3.00-4.00   sec  1.78 MBytes  14.9 Mbits/sec  0.380 ms  7772/9290 (84%)
[  5]   4.00-5.00   sec  1.85 MBytes  15.5 Mbits/sec  0.485 ms  1951/3529 (55%)
[  5]   5.00-6.00   sec  1.74 MBytes  14.6 Mbits/sec  1.464 ms  7763/9250 (84%)
[  5]   6.00-7.00   sec  1.81 MBytes  15.2 Mbits/sec  1.472 ms  8328/9875 (84%)
[  5]   7.00-8.00   sec  1.82 MBytes  15.3 Mbits/sec  0.874 ms  2286/3841 (60%)
[  5]   8.00-9.00   sec  1.77 MBytes  14.9 Mbits/sec  0.846 ms  7858/9370 (84%)
[  5]   9.00-10.00  sec  1.64 MBytes  13.7 Mbits/sec  1.278 ms  7917/9315 (85%)
[  5]  10.00-11.00  sec  1.36 MBytes  11.4 Mbits/sec  0.768 ms  1395/2553 (55%)
[  5]  11.00-12.00  sec  1.74 MBytes  14.6 Mbits/sec  1.074 ms  9944/11427 (87%)
[  5]  12.00-13.00  sec  1.81 MBytes  15.2 Mbits/sec  0.762 ms  8061/9608 (84%)
[  5]  13.00-14.00  sec  1.75 MBytes  14.7 Mbits/sec  0.746 ms  1805/3301 (55%)
[  5]  14.00-15.00  sec  1.85 MBytes  15.5 Mbits/sec  0.459 ms  7820/9400 (83%)
[  5]  15.00-16.00  sec  1.77 MBytes  14.9 Mbits/sec  0.783 ms  7606/9120 (83%)
[  5]  16.00-17.00  sec  1.77 MBytes  14.9 Mbits/sec  29.307 ms  7625/9139 (83%)
[  5]  17.00-18.00  sec  1.85 MBytes  15.6 Mbits/sec  0.476 ms  1837/3420 (54%)
[  5]  18.00-19.00  sec  1.72 MBytes  14.4 Mbits/sec  0.298 ms  7715/9180 (84%)
[  5]  19.00-20.00  sec  1.79 MBytes  15.0 Mbits/sec  0.689 ms  7748/9279 (84%)
[  5]  20.00-21.00  sec  1.65 MBytes  13.9 Mbits/sec  0.833 ms  1614/3025 (53%)
[  5]  21.00-21.26  sec   344 KBytes  10.7 Mbits/sec  2.883 ms  351/638 (55%)
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Jitter    Lost/Total Datagrams
[SUM]  0.0-21.3 sec  8 datagrams received out-of-order
[  5]   0.00-21.26  sec  36.4 MBytes  14.3 Mbits/sec  2.883 ms  117100/148151 (79%)  receiver
-----------------------------------------------------------
Server listening on 5201
-----------------------------------------------------------
```

Figure 44 - UL UDP throughput rates (Use Case 1 – NTN as backhaul)

Table 30 – Iperf traffic test results (Satellite backhaul vs Fixed [F.O based] backhaul)

Backhaul	TCP DL	TCP UL	UDP DL	UDP UL	Jitter DL	Jitter UL	Latency
Fixed	900Mbps	35Mbps	900Mbps	35Mbps	0.017	0.7	13ms
Satellite	72Mbps	14Mbps	75Mbps	14Mbps	0.111	2.8	150ms

Table 30 summarizes the throughput measurements obtained. For comparison, the throughput values using a fixed backhaul based on fiber optic, are also included.

Note that the satellite link has a maximum capacity of 75 Mbps for downlink (DL) and 15 Mbps for uplink (UL).

Another known limitation is the 1Gbps maximum capacity of the Mini PC interface, which limits the maximum DL throughput for both UDP and TCP in the fixed backhaul.

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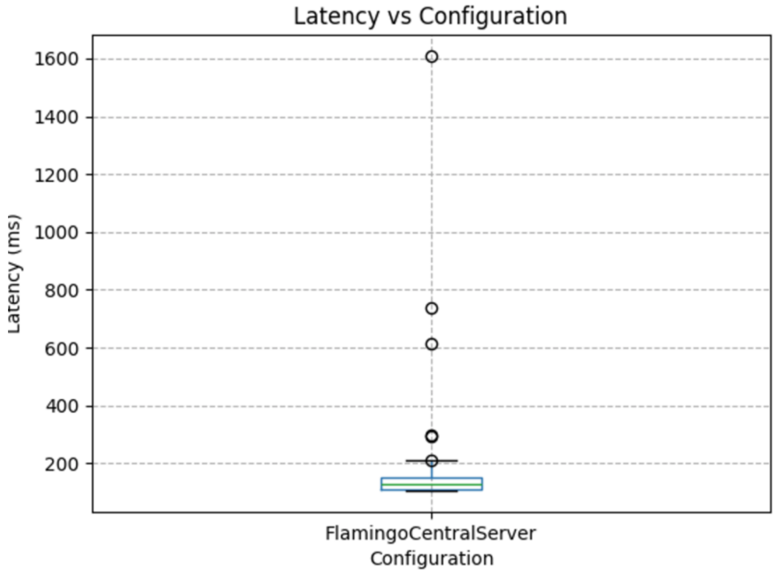

Figure 45 - Boxplot with RTT test results (Use Case 1 – NTN as backhaul)

Figure 45 illustrates the boxplot statistical analysis of RTT latency for Use Case 1, based on 100 ping tests, revealing a median value of 161 ms.

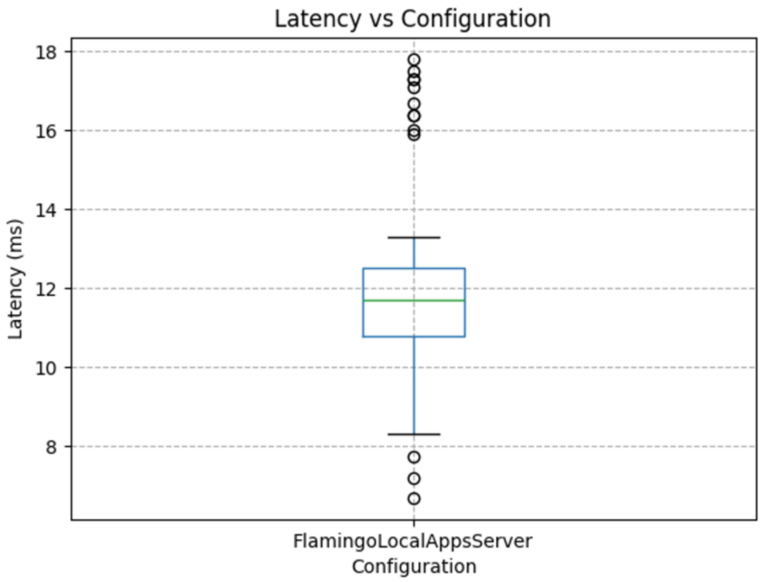

Figure 46 - Boxplot with RTT test results (Use Case 1 – Fiber optic fixed backhaul)

As a reference, Figure 46 shows the boxplot statistical analysis of RTT latency using fixed backhaul, based on 100 ping tests, revealing a median value of 11.5 ms.

In summary, the results from this Use Case 1 shows the successful E2E network establishment and effectiveness of the NTN as backhaul, replacing the fixed backhaul based on fiber optic. Both the throughput and latency (RTT based) results evaluated the performance of the satellite link provided with the Inster FoldSat LEO terminal.

3.2 Use case 2 – NTN as backup backhaul

The objective of this second use case was to enable the E2E connectivity and verify the backhaul switching (fixed vs satellite). Also in this case, the satellite backhaul is established through the Inster terminal.

As can be seen in Figure 47, an IPSEC tunnel was established between the router located in "Flamingo" flight-rack and the router located in 5TONIC data center, where the 5GC is located.

The traffic across the NTN backhaul was encapsulated into the IPSEC tunnel, acting as backup backhaul. On the other hand, the fixed backhaul (operating as main backhaul) consists of a direct fiber optic interconnecting both routers mentioned.

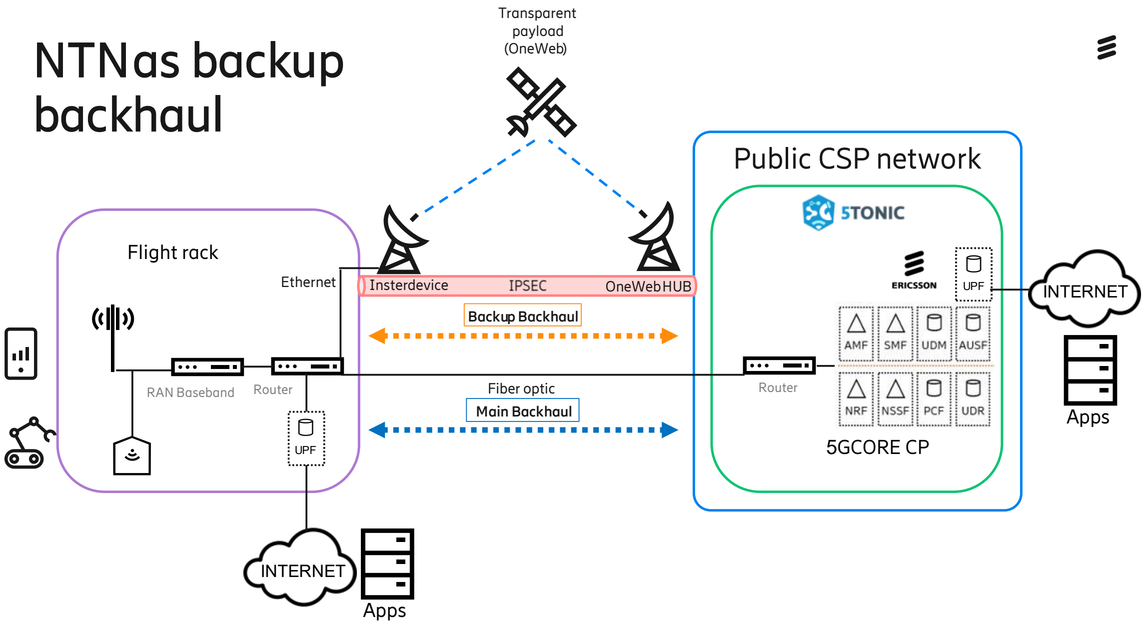

Figure 47 – Network architecture with NTN as backup backhaul (Use Case 2)

Tests were carried out using the "Flamingo" NPN local *Mini PC* (1GE interface) connected to the *Askey NUQ300M CPE*, and the applications server located in the central 5GC infrastructure.

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The following metrics were considered:

- RTT ICMP tests

The verification of line switching (fixed vs satellite) was carried out by running a continuous ping between the CPE and the central applications server.

The router in "Flamingo" flight rack was configured to have an interface in context imdea bound to port 1/1 and another interface in context sat_ipsec bound to port 1/2. Port 1/1 is connected to a fiber and port 1/2 is connected to an Ethernet that leads to the satellite device.

```
context imdea
interface oam_r6k
ip address 10.3.202.25/30

port ethernet 1/1 10ge
no shutdown
bind interface oam_r6k imdea

context sat_ipsec
interface to_sat
ip address 192.168.0.2/24

port ethernet 1/2
no shutdown
bind interface to_sat sat_ipsec
```

Besides, there were routes configured to have the traffic forwarded as a first option via the fiber interface. Only when the fiber interface was down, the backup route towards context sat_ipsec would become active.

```
ip route 0.0.0.0/0 10.3.202.26
ip route 0.0.0.0/0 context sat_ipsec distance 250
```

Originally, the active route was the one via 10.3.202.26 (which is the fiber interface)

```
Type     Network                   Next Hop         Dist      Metric     UpTime
Interface
> S      0.0.0.0/0                 10.3.202.26        1            0       6w5d
oam_r6k
```

The fiber interface was removed, which caused the backup route to become active, sending the traffic through the satellite link. The RTT values of the continuous ping that was running showed the results illustrated in Figure 48:

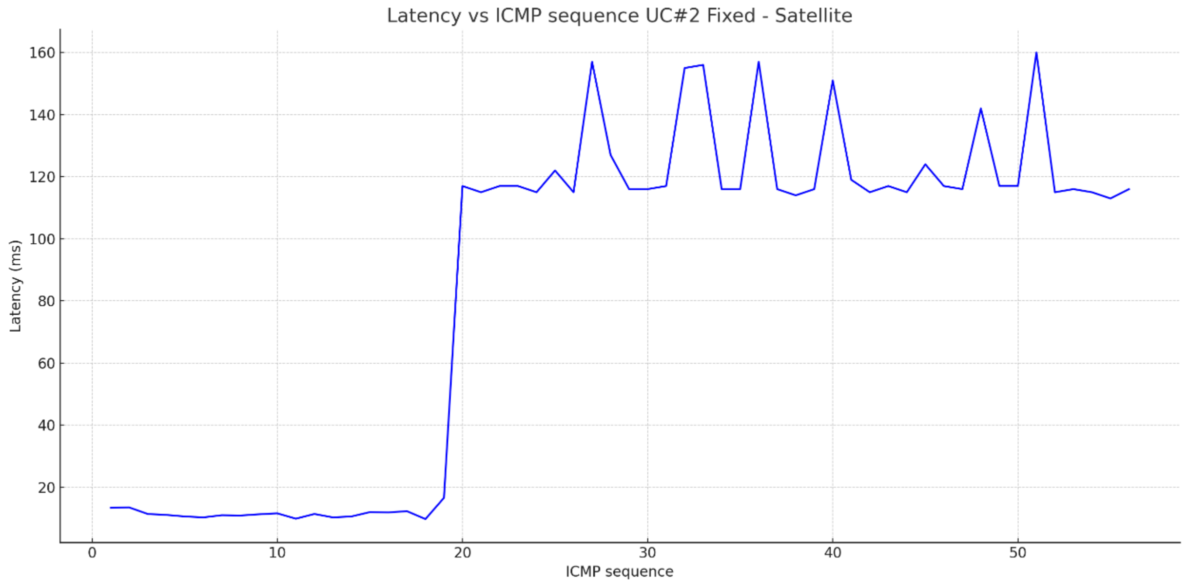

Figure 48 - Latency vs ICMP sequence (Use Case 2 - Fixed vs Satellite)

While using the fiber line, the RTT was around 10 ms. When the satellite backhaul took over, the RTT changed to around 125 ms in average. It is relevant to stress that the CPEs stayed registered in the network the whole time, thus validating that the transition was seamless for the end user.

When the fiber is connected again, the primary route becomes active again.

```
Type     Network                Next Hop         Dist      Metric     UpTime
Interface
> S      0.0.0.0/0              10.3.202.26         1            0   00:00:29
oam_r6k
```

The following Figure 49 shows the RTT values obtained for ICMP traffic during this test:

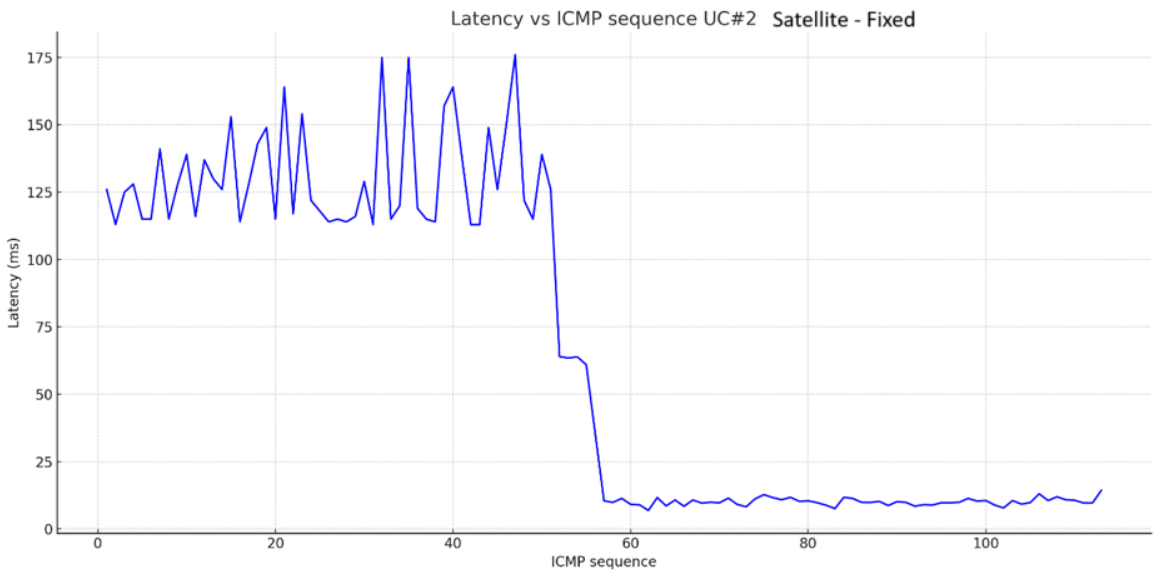

Figure 49 - Latency vs ICMP sequence (Use Case 2 - Satellite vs Fixed)

As in the previous test, the satellite link shows a RTT latency of around 125 ms, while the fixed line has a RTT latency of around 10 ms.

In summary, the results from this Use Case 2 show the successful E2E network establishment and the verification of the backhaul switching (fixed vs. satellite). As the satellite backhaul is providing on average higher RTT results compared with the fixed one, it was verified that traffic can be switched from one backhaul to another, assuring the 5G NPN system reliability.

3.3 Use case 3 – Multiaccess with NTN networks (ATSSS)

The aim of this third use case was to enable the E2E connectivity and verify the ATSSS multi-access with the NTN, to verify either the traffic going through the 5G infrastructure (3GPP access), or towards direct internet access via the satellite link (non-3GPP access).

Also in this case, the satellite access is established through the FoldSat LEO Ku OW MIL Inster terminal.

In Figure 50, it is shown the network architecture of this Use Case 3.

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ATSSS – Multi-access with NTN

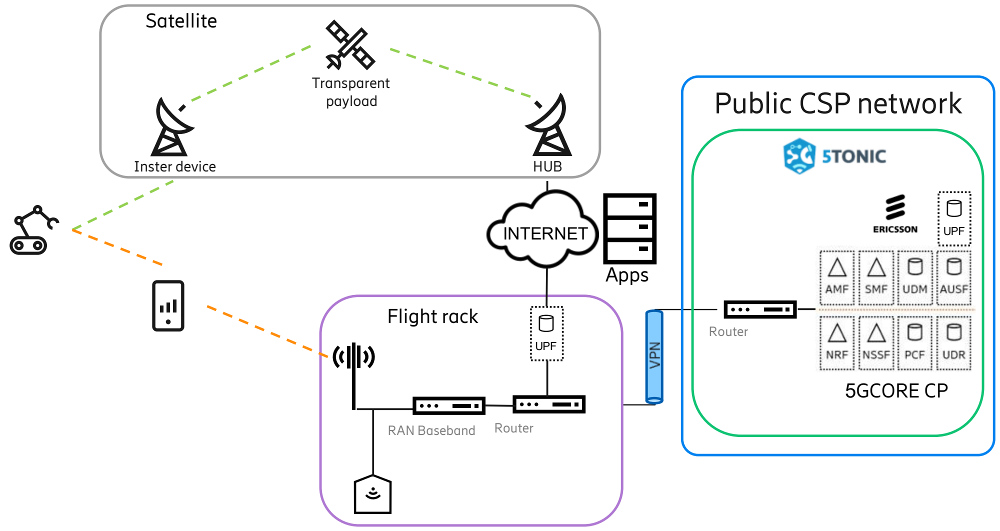

Figure 50 – Network architecture of ATSSS - Multi-access with NTN (Use Case 3)

Tests were carried out using the "Flamingo" NPN local *Mini PC* (1GE interface) connected to the *Askey NUQ300M CPE* and Google public DNS server (8.8.4.4), as the other end.

The following metrics were considered:

- RTT ICMP tests

Switching functionality of the ATSSS technology is tested as follows:

On the flight-rack local Mini PC, two routes were configured towards Google public DNS server with different priorities, therefore one of them acts as a backup for the other one. One of the routes will direct traffic through the 5G infrastructure (3GPP), while the other will provide direct internet access via the satellite link (non-3GPP). The routes configured in the Mini PC were the following:

```
8.8.4.4 via 192.168.1.1 dev enp2s0
8.8.4.4 dev enp3s0 scope link metric 210
```

For testing, a continuous ping was executed to 8.8.4.4. Originally, the traffic was hitting the primary route via enp2s0 interface of the Mini PC, which corresponds to the 3GPP access network. The RTT latency values were around 10 ms. At a certain point, the cable connected to enp2s0 interface was unplugged. As a result, the backup route became active, and the traffic started to be forwarded through the non-3GPP network. The measured RTT latency was around 70 ms while the satellite network was being used. Finally, the cable was connected again to enp2s0, the primary route became active again and the traffic was sent again through the 5G network with RTT latencies of around 1 ms.

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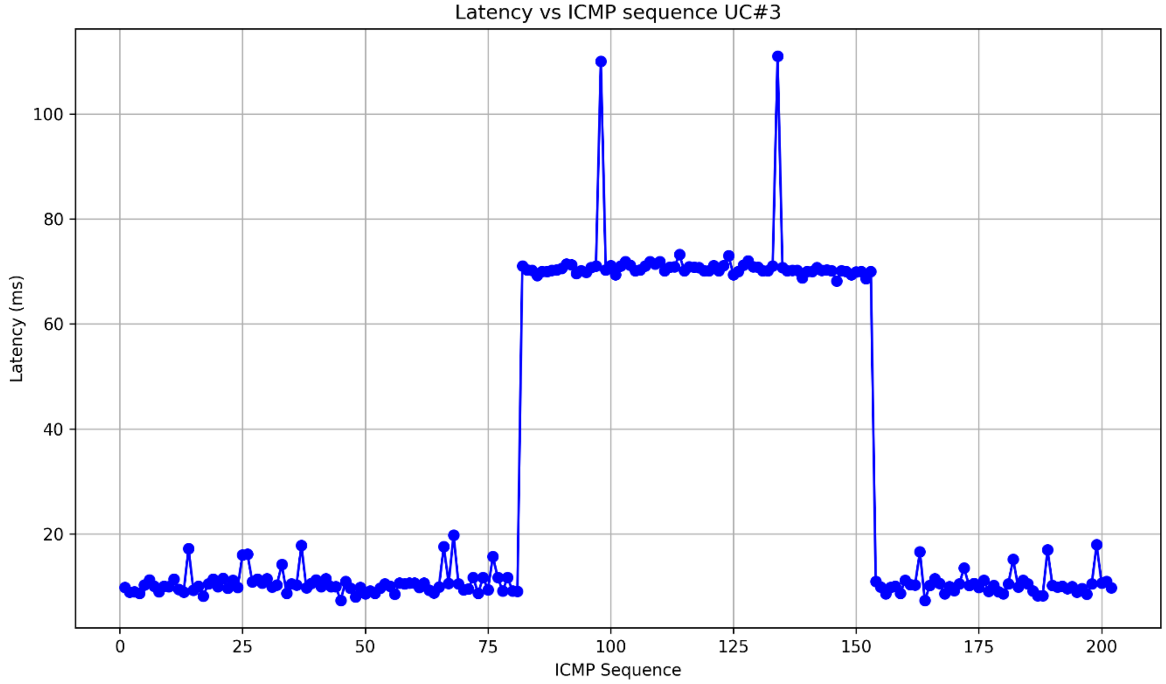

Figure 51 – Latency vs ICMP sequence (Use Case 3 - ATSSS switching)

In Figure 51, it can be observed how the switch between the fixed and satellite lines occurs around sequence 80, while the switch from satellite to fixed takes place around sequence 155.

It is needed to mention that in the way the test was done, when recovering the Mini PC interface, it needs to come up again and request an IP to the CPE via DHCP. This takes time and causes one of the packets to peak up to around 1 s of RTT. Anyhow, there is no packet loss and the usual values of 10 ms are recovered quickly. That value was removed from the graph to be able to depict more clearly the rest of the values, but it is reflected in the test logs below:

```
64 bytes from 8.8.4.4: icmp_seq=152 ttl=115 time=70.0 ms
64 bytes from 8.8.4.4: icmp_seq=153 ttl=115 time=68.6 ms
64 bytes from 8.8.4.4: icmp_seq=154 ttl=115 time=70.0 ms
64 bytes from 8.8.4.4: icmp_seq=155 ttl=111 time=1011 ms
64 bytes from 8.8.4.4: icmp_seq=156 ttl=111 time=9.94 ms
64 bytes from 8.8.4.4: icmp_seq=157 ttl=111 time=8.62 ms
64 bytes from 8.8.4.4: icmp_seq=158 ttl=111 time=9.83 ms
```

In conclusion, the results from this test show that the switching functionality of the ATSSS technology was verified, optimizing traffic management by dynamically routing data between 3GPP (5G infrastructure) and non-3GPP networks (the satellite link).

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SECRETARÍA DE ESTADO DE TELECOMUNICACIONES E INFRAESTRUCTURAS DIGITALES
Plan de Recuperación, Transformación y Resiliencia
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