6G-INTEGRATION-01-E16: Analysis report regarding needs and requirements for implementing the NPI-NTN

6G-INTEGRATION

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Document editor	Jaime Garcia (Ericsson)
Receiver	Daniel Segovia (UC3M; 6G-INTEGRATION Principal Investigator)
Contributors	Jaime Garcia, Ruben Cerezo, Diego San Cristobal, Marc Mollà, Manuel Lorenzo, Fernando Beltrán (Ericsson)
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Executive Summary

This document contains the requirements for the subproject 6G-INTEGRATION-01 to develop a portable gNB using a Non-Terrestrial Network (NTN) as backhaul or as radio multi-access point, building a Public Network Integrated Non-Public Network (PNI-NPN).

The project will investigate and develop the following use cases: (i) NTN as backhaul, (ii) NTN as backup backhaul, and (ii) Multiaccess with NTN (ATSSS).

The development of these use cases must fulfill common requirements (general requirements) and other specifics for each use case. This document contains detailed explanation of both.

Last part of the document is the project roadmap and the risk analysis.

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Resumen ejecutivo

Este documento continue los requisitos del subproyecto 6G-INTEGRATION-01 para desarrollar un gNB portátil utilizando una Red No Terrestre (NTN) como backhaul o como punto de acceso de radio multiacceso, construyendo una Red Pública Integrada con Red No Pública (PNI-NPN).

El proyecto investigará y desarrollará los siguientes casos de uso: (i) NTN como backhaul, (ii) NTN como backhaul de respaldo, y (iii) Multiacceso con NTN (ATSSS).

El desarrollo de estos casos de uso debe cumplir con requisitos comunes (requisitos generales) y otros específicos para cada caso de uso. Este documento contiene una explicación detallada de ambos.

La última parte del documento es la hoja de ruta del proyecto y el análisis de riesgos.

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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
HAP	High Altitude Platform
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
TCP	Transport Control Protocol

UE	User Equipment
UDM	Unified Data Management
UDR	Unified Data Repository
UPF	User Plane Function

1 Overview of General Concepts

The evolution towards Beyond 5G (B5G) networks, which encompass advancements beyond the current 5G technology, underscores the seamless integration of Non-Terrestrial Networks (NTN) with terrestrial infrastructures, including satellites and High Altitude Platforms (HAPs). This integration is pivotal for extending connectivity to remote areas and enhancing network capacity and coverage. The 3rd Generation Partnership Project (3GPP) has been instrumental in driving these advancements. In Release 17 (R17), 3GPP has laid down specifications for incorporating NTN elements into 5G networks, thereby facilitating the realization of B5G networks.

Moreover, Access Traffic Steering, Switching, and Splitting (ATSSS) technology will play a pivotal role in this integration process. ATSSS enables efficient traffic management by dynamically steering user traffic between different access networks (3GPP and non-3GPP) based on factors such as network congestion and quality of service requirements.

The environment where the tests will be conducted is a NPN Non-Public Network in the 5tonic [10] laboratory, within the framework of the IMDEA Networks Institute [9].

In the following sections, we will discuss the NTN segment, highlighting its fundamental capabilities, explore the integration of NTN into a 3GPP R17 network with its reference architecture, and finally, examine the integration of 3GPP and non-3GPP accesses into 5G networks using the ATSSS technology.

1.1 NTN Segment

Non-Terrestrial Networks (NTN) encompass satellites and High Altitude Platforms (HAPs). Satellites operate in various orbits such as Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Orbit (GEO). These satellites are vital for providing wide-area coverage, particularly in remote and underserved regions. They facilitate a variety of applications, including broadband internet and IoT connectivity, offering a global reach that terrestrial networks cannot match.

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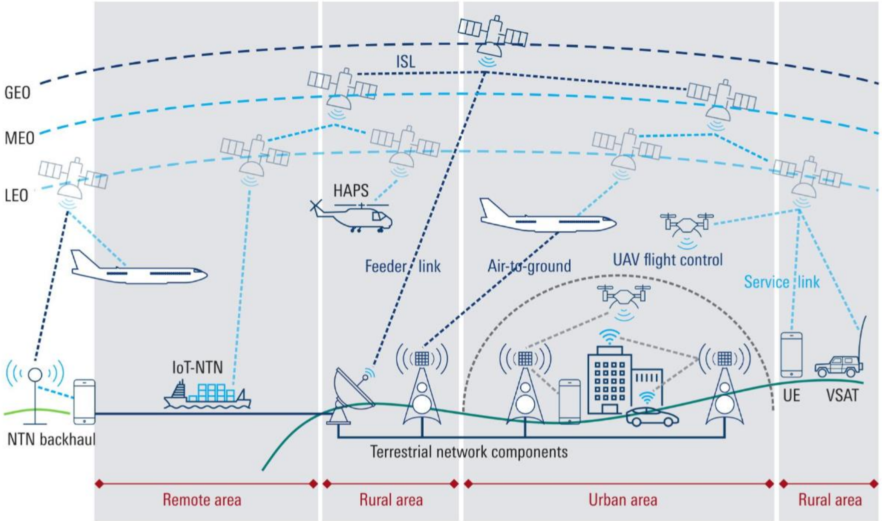

Figure 1 Non-Terrestrial Network General Scheme [5]

HAPs, situated in the stratosphere, provide high-capacity, localized coverage. These platforms act as relay stations, enhancing telecommunications by providing stable connections that complement satellite coverage. HAPs are especially beneficial in disaster recovery scenarios and for strengthening network resilience in areas with difficult terrain or sparse infrastructure.

Integrating NTN into existing network infrastructures involves overcoming several technical challenges, such as managing the high Doppler shifts and signal delays characteristic of satellite communication, ensuring continuous service during transitions between terrestrial and non-terrestrial networks, and optimizing frequency usage to prevent interference. This integration enhances the reliability and reach of network services, ensuring consistent connectivity even in the most remote and challenging environments [1] [2].

1.2 NTN into a 3GPP R17 Network

The integration of Non-Terrestrial Networks (NTN) into a 3GPP network, specifically within the context of 5G, involves several key components and objectives. 3GPP Release 17 (R17) has established specifications for incorporating NTN elements, such as satellites and High Altitude Platforms (HAPs), into the 5G infrastructure. This development aims to enhance coverage, especially in remote and underserved areas, by using satellite backhaul to connect isolated 5G segments with public 5G networks operated by Communication Service Providers (CSPs) [3][4].This integration includes user equipment (UE), the gNodeB (gNB), Non-Public Networks (NPN), and the 5G Core Network (5GC). The primary goal is to leverage the NTN segment to provide reliable and extended connectivity, which is crucial in regions lacking fixed infrastructure. For instance, NTNs can support enhanced mobile broadband (eMBB), massive Machine Type Communication (mMTC), and critical communication services in various challenging environments) [4][5].

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This integration facilitates several use cases:

1. **Enhanced Mobile Broadband**: Providing connectivity in underserved areas and to mobile platforms like aircraft and ships.
2. **IoT Connectivity**: Supporting global IoT device communication and connecting isolated IoT networks.
3. **Disaster Recovery**: Offering resilient communication solutions during natural or man-made disasters.
4. **Public Safety**: Ensuring robust communication for public safety agencies, enabling real-time coordination and response (Industry-leading technology group).

Overall, the integration of NTNs into 3GPP networks is a significant step towards achieving ubiquitous, resilient, and high-capacity 5G services, furthering the capabilities of modern communication systems and expanding the reach of 5G technology globally.

1.2.1 Reference Architecture

The provided diagram illustrates the proposed architecture for NTN backhaul.

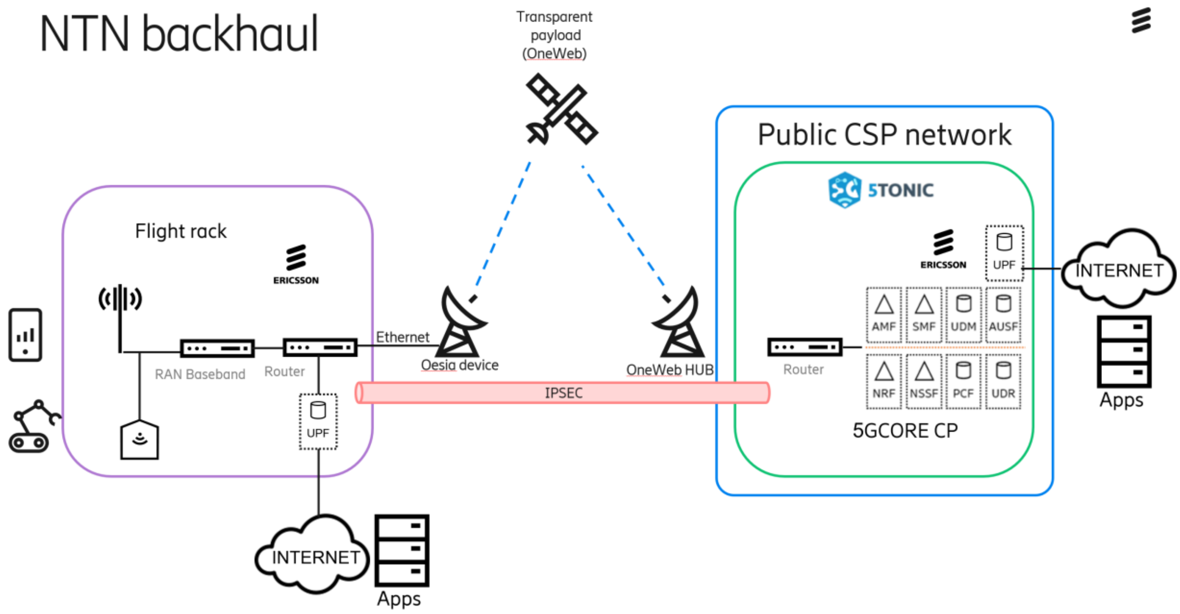

Figure 2 Non-Terrestrial Network as Backhaul

The diagram provides a visual representation of the NTN backhaul architecture, showcasing the integration of satellite communication into the 5G network as a backhaul solution. Below is an in-depth explanation of the components and their interactions within this architecture:

1.2.1.1 Key Components:

- **Flight Rack:**

RAN Baseband: This component 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 satellite communication system. It facilitates the routing of data packets to and from the RAN Baseband and establishes the IPsec tunnel for secure communication.

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.

- **Satellite Communication:**

Oesia Device: This device interfaces with the router in the flight rack. It connects to the satellite (OneWeb) using an Ethernet connection, enabling data transmission to and from the satellite.

OneWeb Satellite: Provides the transparent payload capability, acting as a relay between the Oesia Device and the OneWeb HUB.

OneWeb HUB: Receives data from the satellite and forwards it to the public CSP network.

- **Public CSP Network:**

The Public CSP Network serves as a bridge to connect users to the private 5G Core Network. It includes several critical components and functions within its 5G Core Network (5GC), which can be divided into the Control Plane (CP) and User Plane (UP).

- 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.

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- 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.

1.2.1.2 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 5Tonic site router. Flight router is connected to Oesia device and OneWeb Hub is connected to 5Tonic site router. Between Oesia device and OneWeb Hub a satellite communication is established.

Data packets are transmitted from the router to the Oesia Device, then relayed by the satellite to the OneWeb HUB.

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

The OneWeb HUB 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.

- **Service Continuity and Coverage:**

The NTN backhaul enables the integration of non-public network segments with public 5G networks, ensuring coverage in remote or underserved areas where fixed infrastructure (e.g., fiber optics) is not available.

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This setup provides seamless connectivity, allowing users in remote areas to access 5G services reliably.

1.3 ATSSS into 5G Networks – Integration of 3gpp and non-3gpp Accesses

1.3.1 Basics and Objectives of ATSSS

ATSSS is a critical technology in the 5G ecosystem designed to enhance flexibility and efficiency in network traffic management. It enables the integration and optimization of different types of access, both 3GPP (like 5G mobile networks) and non-3GPP (such as WiFi), to provide more robust and efficient connectivity [6].

1.3.2 Components and Architecture of ATSSS

- **Key Elements**:
  - User Equipment (UE): User devices that support connections to multiple types of networks.
  - 5G Core Network (5GC): Manages and coordinates connections, ensuring service continuity through various functions like UPF and SMF.
  - Policy Control Function (PCF): Defines and applies traffic policies to efficiently manage the use of different accesses.

- **Specific Mechanisms:**
  - Steering: Selecting the best network route based on link quality and other parameters.
  - Switching: Changing between links without interrupting the connection, enhancing service resilience.
  - Splitting: Simultaneous use of multiple links to improve transmission capacity and connection robustness.

1.3.3 Implementation and Complementary Technologies

- **MultiPath TCP (MPTCP):**
  - MPTCP allows a single TCP flow to use multiple paths to transmit data, optimizing bandwidth use and increasing resilience against link failures .

- **ATSSS-LL (Lower Layer):**
  - Manages traffic at the data link layer for applications that do not use MPTCP, providing an additional layer of traffic control and optimization .

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➢ **Traffic Management Policies:**

- Network policies are defined to prioritize and manage traffic based on criteria such as latency, available bandwidth, and Quality of Service (QoS). These policies enable dynamic adaptation to changing network conditions.

1.3.4 Benefits of ATSSS in 5G Networks

➢ **Improved Service Quality:**

- ATSSS enhances user experience by optimally managing network resources and providing more stable and high-quality connectivity.

➢ **Resilience and Continuity:**

- The ability to switch between different access types without interruptions ensures greater robustness and service continuity, even in network failure scenarios.

➢ **Resource Utilization Efficiency:**

- By allowing the simultaneous use of multiple links, ATSSS maximizes the use of network resources, preventing congestion and improving overall system efficiency.

1.3.5 Challenges and Considerations for Implementation

➢ **Complexity of Integration:**

- Integrating multiple access types and managing mobility between them presents significant technical challenges. Coordinating different technologies and configuring complex policies are crucial aspects to consider.

➢ **Standards and Compatibility:**

- Adhering to technical specifications and standards defined by organizations like 3GPP is essential to ensure network interoperability and efficiency.

➢ **Continuous Evolution:**

- The 5G and ATSSS technologies are continuously evolving, requiring ongoing updates with the latest innovations and advancements to fully leverage their capabilities.

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2 Use cases

Next, we will explore three specific use cases that illustrate practical applications of integrating Non-Terrestrial Networks (NTN).

The testing environment will be set up using the 5Tonic laboratory and the satellite service provided by Oesia.

2.1 Use case 1: NTN as backhaul

2.1.1 Objective

The objective of this use case is to demonstrate the capability of a 5G network to efficiently utilize its services when a non-terrestrial network (NTN) backhaul based on satellites is used instead of a fiber optic connection. This use case tests the resilience and flexibility of the 5G infrastructure when integrated with satellite backhaul solutions, such as those provided by OneWeb, ensuring continuity of service in areas where fiber optics are not feasible.

2.1.2 Scenario

In this scenario, a user device connects to a 5G network that uses a combination of terrestrial and satellite infrastructure. The 5G network is configured to use a NTN backhaul provided by OneWeb, which enables communication between the Radio Access Network (RAN) and the 5G core network through secure satellite links. Additionally, an IPSec tunnel will be established between the RAN and the Core through the NTN network, providing enhanced security, data integrity, and authentication.

2.1.3 Setup

The setup is described in the following points:

- User device is connected to 5G SA network.
- Flight rack is connected to Oesia device through an ethernet connection
- OneWeb hub connects to 5G Core.
- Flight rack establishes an IpSec tunnel against 5G Core through NTN (transparent payload)

The following picture represents the proposed setup:

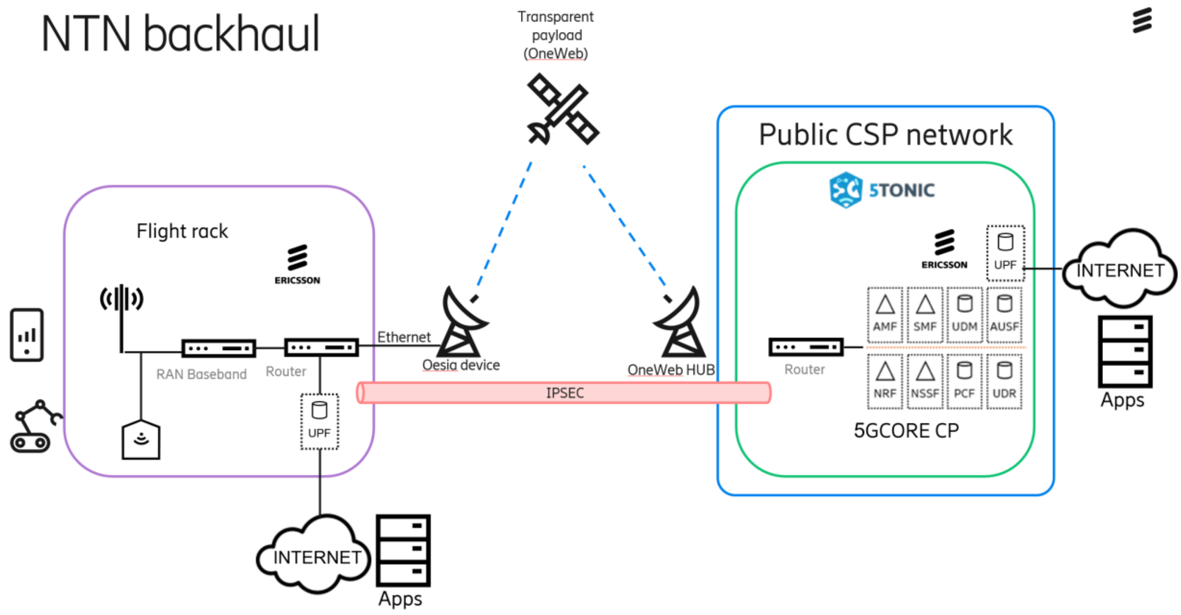

Figure 3 Use Case NTN as backhaul

2.1.4 Experimentation

The following tests can be conducted:

- **Throughput UL/DL**: Measure the upload and download throughput at the network edge and core to compare performance.
- **Latency**: Evaluate network latency to ensure that satellite backhaul integration does not introduce significant delays.
- **Slicing (eMBB/URLLC)**: Conduct network slicing tests for enhanced mobile broadband (eMBB) and ultra-reliable low-latency communications (URLLC).
- **Satellite Bandwidth Consumption**: Evaluate satellite bandwidth usage to ensure that the NTN backhaul can support the expected data load without becoming saturated.

2.2 Use case 2: NTN as backup backhaul

2.2.1 Objective

This use case aims to demonstrate that a 5G network can maintain its services and performance by using a satellite-based non-terrestrial network (NTN) backhaul as a backup to a fiber optic connection. It is crucial to verify that the 5G network behaves consistently, even when the fiber optic line is disrupted due to natural disasters or other interruptions, necessitating the NTN backhaul to take over.

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2.2.2 Scenario

A 5G network is engineered to sustain its services and performance by employing both fiber optic and satellite-based non-terrestrial network (NTN) backhaul infrastructure. While the primary connection relies on a fiber optic backhaul, the network is designed to seamlessly switch to a satellite backhaul provided by OneWeb in the event of disruptions, such as natural disasters or other interruptions. This setup guarantees uninterrupted communication between the Radio Access Network (RAN) and the 5G core network via secure satellite links.

The prerequisite for this use case is that user executes the Use Case 1 successfully.

2.2.3 Setup

The setup is described in the following points:

- User device is connected to 5G SA network.
- Flight rack router is connected to Oesia device through an ethernet connection
- Flight rack router is connected to backhaul optic fiber
- OneWeb hub connects to 5G Core router
- Optic fiber is connected to 5G Core router

The following picture represents the proposed setup:

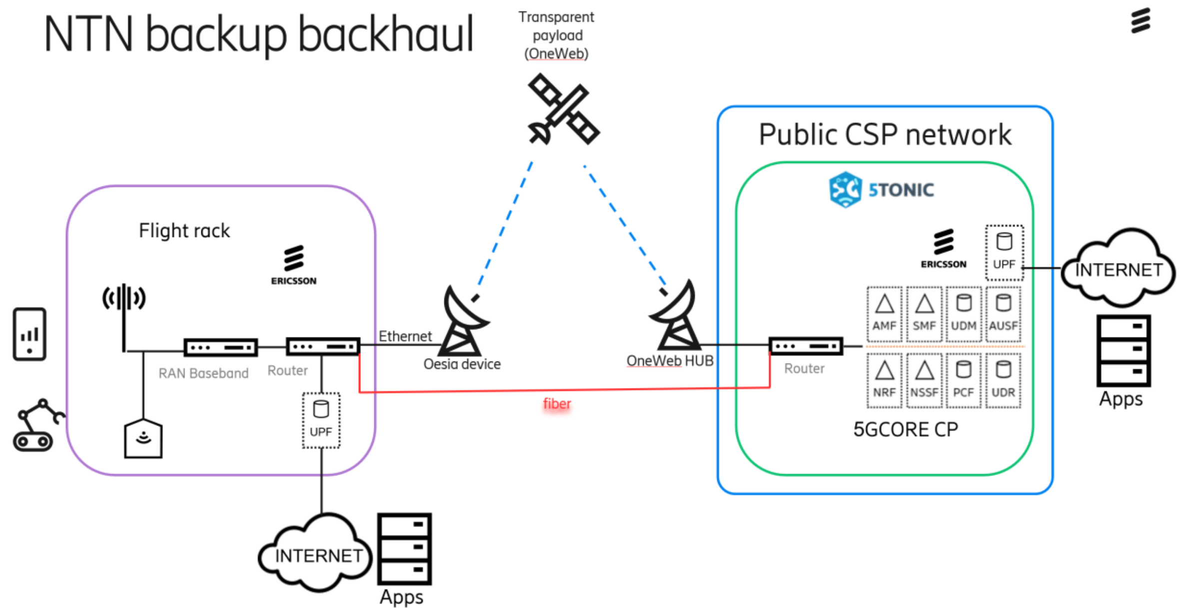

Figure 4 Non-Terrestrial Network as Backup Backhaul

2.2.4 Experimentation

The following tests can be conducted:

- **Automatic Switching**: Test the network's ability to switch from fiber optic to satellite backhaul when disruptions are detected.
- **Performance**: Measure throughput UL/DL, latency, and slicing tests at the network edge and core to compare performance between fiber optic and satellite backhaul.

2.3 Use case 3: Multiaccess with NTN networks (ATSSS)

2.3.1 Objective

This use case investigates the integration of Non-Terrestrial Networks (NTN) within a 3GPP, non-3GPP multi-access environment (ATSSS) to enhance the reliability of Beyond 5G (B5G) networks.

2.3.2 Scenario

It examines how an NTN network can support and complement terrestrial 5G infrastructure, providing connectivity and increased robustness. The focus is on leveraging ATSSS to enable

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efficient traffic steering, switching, and splitting between terrestrial 5G access and satellite-based non-3GPP access. This ensures continuous service availability and consistent performance, even in scenarios where terrestrial networks are disrupted or unavailable.

The prerequisite for this use case is that NPN portable system was integrated with the 5TONIC network.

2.3.3 Setup

The setup is described in the following points:

- User device is connected to 5G SA network and non-3gpp Oesia device.
- Flight rack router is connected to 5G Core by VPN
- OneWeb hub connects to internet
- ATSSS manages the access

The following picture represents the proposed setup:

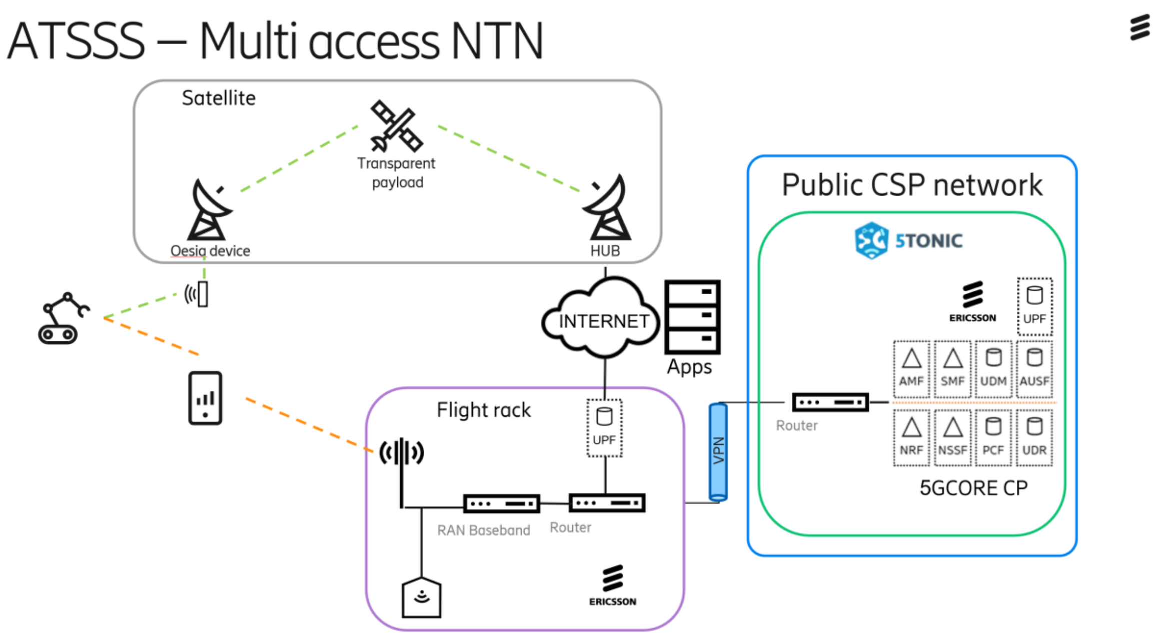

Figure 5 Multiaccess with Non-Terrestrial Network

2.3.4 Experimentation

The following tests can be conducted:

- **Connectivity**: Verify that the device can independently and simultaneously connect to 3GPP and non-3GPP networks. Establish connections to both 5G and WiFi networks, ensuring that the device authenticates and maintains connections in both cases.

- **Steering**: Evaluate the system's ability to dynamically select the optimal link based on parameters such as link quality, network load, and QoS policies. Simulate various network conditions and monitor how the system redirects traffic between 3GPP and non-3GPP accesses.

- **Switching**: Verify that the system can switch from one access to another without interrupting the active connection. Force a link drop and observe how the system switches to an alternate link without session loss.

- **Traffic Splitting**: Evaluate the system's ability to efficiently split traffic between multiple links. Initiate multiple data flows and ensure that traffic is appropriately distributed among the available accesses.

- **Performance**: Measure throughput UL/DL and latency for each type of access, both individually and combined.

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3 Requirements analysis

Requirements have been exposed and described in 2 areas:

- "General" that define the requirements that needs to be accomplished to implement initial system and will be the base for all use cases.

- "Based on use cases" that describe the specific requirements that needs to be complied to achieved different use cases.

3.1 General

This section describes general requirements that are the base of the PNI-NTN implementation and will be the system base for the whole project.

3.1.1 Requirement-G-01 NPN Portable System

The 1st requirement to develop a NTN as a backhaul is the implementation based in a Non-Public Network (NPN) Portable System that is connected to 5TONIC network. This solution scenario is known as "Shared Radio access network and control plane" within "NPN network in conjunction with public network" as described in [7].

NPN Portable system requires the following elements:

- **Flight rack**: A portable container used as RACK for installation of Physical Twin elements.
- **Radio Access Network (RAN) Elements:**

  - Monitor terminal: User Equipment (UE) or Customer Premises Equipment (CPE) used to monitor the network End-to-End (E2E).
  - Radio Equipment and Antenna: Radio access point of the NPN Portable System.
  - 5G Node B (gNB): Base Station that processes the Radio signal of the NPN Portable System.
  - IP RAN: Router used in transport network between RAN and CORE elements.

- **CORE Network Elements:**
  - User Plane Function (UPF) handles the payload traffic from the NPN Portable System.

This architecture is 3GPP R17 compliant and could also be updated with the latest software available.

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3.1.2 Requirement-G-02 NTN System

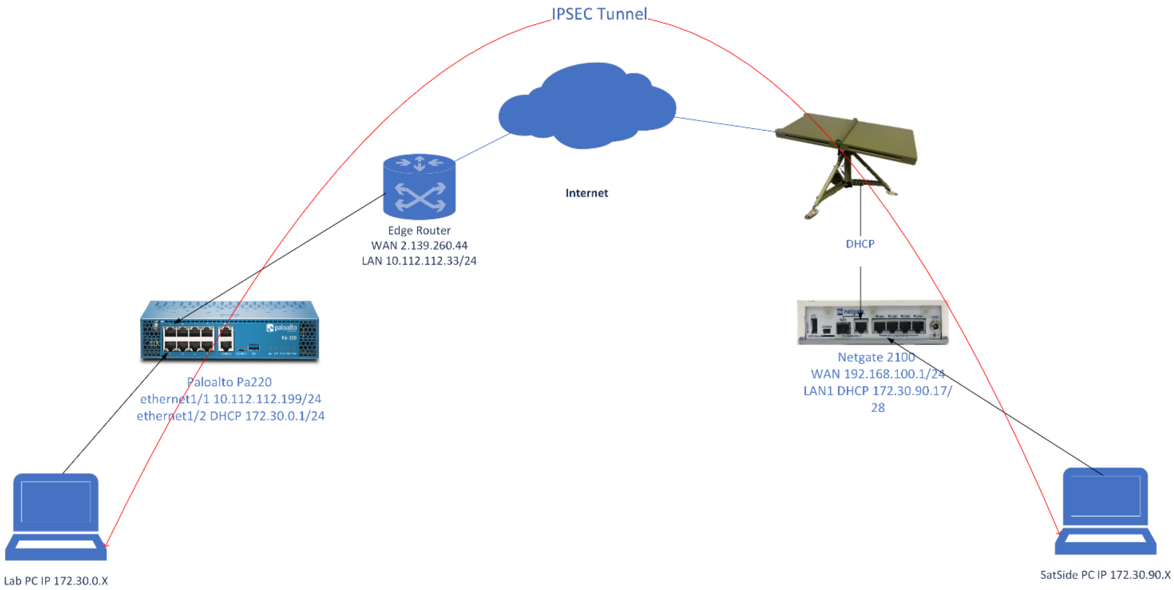

Figure 6 Configuration NTN System

Here is the detailed configuration of the NTN system. Satellite equipment is provided by Oesia and connectivity to the internet will be achieved through a third party, which in this case is OneWeb.

- Interfaces of the Palo Alto PA-220 (Fixed Site Firewall)

ethernet1/1 (WAN)

- **IP:** Dedicated fixed IP for the tunnel interface
- **Connection:** Connected to the Edge Router.
- **Function:** Acts as the outbound interface to the edge router.
- **Static IP Address:** 10.112.112.199/24.
- **IPsec Compatibility:** Must support IPsec tunnel establishment.
- **QoS:** Capability to handle QoS to prioritize IPsec tunnel traffic.
- **Firewall Policies:** Configuration of firewall policies to allow IPsec traffic.
- **High Availability:** Support for failover and redundancy.

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- **Monitoring and Alerts:** Capability to monitor the IPsec tunnel status and generate alerts in case of failures.

ethernet1/2 (LAN)

- **IP:** Range of private addresses we use.
- **Connection:** Connected to the local network where the lab PC is located.
- **Function:** Acts as the local network interface for internal network traffic.
- **Network Segmentation:** Capability to segment and control internal traffic.
- **Security:** Implementation of security policies to protect the local network.
- **Monitoring:** Capability to monitor internal traffic and detect threats.

➢ Interfaces of the Edge Router

WAN

- **IP:** Public IP address.
- **Connection:** Connected to the Internet.
- **Function:** Provides Internet connectivity and allows the establishment of the IPsec tunnel.
- **IPsec Support:** Must support the establishment and management of IPsec tunnels.
- **NAT:** Capability to perform NAT (Network Address Translation) if necessary.
- **Adequate Bandwidth:** Sufficient bandwidth to handle IPsec tunnel traffic and other network activities.
- **Bandwidth Capacity:** Compatible with FTTH speeds (possibly 1 Gbps symmetrical or similar).

LAN

- **IP:** Addresses distributed by the router.
- **Connection:** Connected to the Palo Alto PA-220 firewall.
- **Function:** Acts as the link between the firewall and the external network.
- **Static IP Address:** 10.112.112.33/24.
- **Routing:** Capability to route traffic between the LAN and WAN.

➢ Interfaces of the Netgate 2100 (Satellite Terminal Firewall)

WAN

- **IP:** Dynamically assigned by the satellite terminal. Dynamic public satellite address.
- **Connection:** Connected to the satellite terminal.
- **Function:** Provides connectivity to the satellite terminal.
- **IPsec Compatibility:** Support for the establishment and management of IPsec tunnels.
- **QoS:** Capability to handle QoS to prioritize IPsec tunnel traffic.
- **Same requirements as the previous firewall.**

LAN1

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- **IP:** Range of private addresses we use.
- **Connection:** Connected to the local network where the satellite site PC is located.
- **Function:** Acts as the local network interface for internal network traffic.
- **DHCP Configuration:** Assign IPs in the corresponding range.
- **Network Segmentation:** Capability to segment and control internal traffic.
- **Security:** Implementation of security policies to protect the local network.
- **Monitoring:** Capability to monitor internal traffic and detect threats.
- **Satellite Link Optimization:** Maximize the efficient use of the satellite link, especially considering the asymmetry (200 Mbps download and 30 Mbps upload).

Attached is also the tunnel configuration as it is created in the setup:

IKE (Internet Key Exchange) Configuration:

- **IKE Version:** IKEv2.
- **Authentication Method:** Pre-shared keys (PSK).
- **Encryption Algorithm:** AES-256-CBC.
- **Hash Algorithm:** SHA-256.
- **Diffie-Hellman Group:** Group 14.
- **Lifetime:** 8 hours.

IPsec Configuration:

- **IPsec Protocol:** ESP (Encapsulating Security Payload).
- **Encryption Algorithm:** AES-256-CBC.
- **Integrity Algorithm:** SHA-256.
- **Perfect Forward Secrecy (PFS):** Enabled, Group 2.
- **Lifetime:** 1 hour.

Tunnel Mode:

- **Tunnel Mode:** Encrypts the entire IP packet, commonly used for site-to-site VPNs.

Endpoints Configuration:

- **Local and Remote IP Addresses:** 172.30.0.X and 172.30.90.X.
- **Peer Address:** Dynamic.

NAT Traversal (NAT-T):

- **Enable NAT-T:** Allows IPsec to work across devices that perform Network Address Translation (NAT).
- **UDP Encapsulation Ports:** UDP port 4500.

Keep-Alive and Dead Peer Detection:

- **Keep-Alive:** Regular checks to ensure the tunnel is still active.

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- **Dead Peer Detection (DPD):** Enabled.

3.1.3 Requirement-G-03: Probes in different parts of network

Test and validations need as requirement the implementation of measure tools and we will used Software probes. The software probe is a component that extracts KPIs from the end-user traffic with the granularity of flow for IP traffic as it was defined in [8]. A flow is identified by a tuple of origin IP address, destination IP address, origin Port, destination Port, type of protocol.

The software probe needs to be deployed in an independent system that receives a copy of the application traffic, using port mirroring in different interfaces of the network:

- Interface N3: To access the traffic between RAN and UPF.
- Interface N6: To access the traffic between UPF and Application.

3.1.4 Requirement-G-04: Availability of advanced 5G terminals

The CPEs must support the 5G network functionalities required for this project. To determine the level of interoperability with the 5G network, Ericsson regularly conducts tests with manufacturers. Additionally, these terminals will need to support both 3GPP and non-3GPP access technologies.

3.1.5 Requirement-G-05: Traffic generation tools

Tools are required to generate traffic with the aim of simulating user traffic in order to check system performance in various use cases.

3.2 Based on use cases

This section contains singular requirements for each use case. To check and implement the activities of these requirements, general ones must be fulfilled.

3.2.1 Requirement-UC-01

To fulfill the backhaul connectivity between the flight rack and 5Tonic, an IPSec tunnel is configured. The flight rack router is managed by Ericsson. The 5Tonic site router is managed by IMDEA networks.

The flight rack end is configured as initiator of the tunnel, because the Oesia device has a dynamic IP, thus it is not known from the other end. The flight rack router is configured to request the IPSec tunnel to the IMDEA public IP 193.145.14.195. The 5Tonic end is configured as receptor of the tunnel. The encryption algorithms and pre shared key have been agreed by router administrators to establish the tunnel.

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3.2.2 Requirement-UC-02

In this case, the intention is to have a fiber connectivity link as the main path for the traffic, and to have a satellite link as a backup path. For that purpose, at the flight rack router, two routes towards the 5GCore IP range on the other end are defined. When there are multiple routes towards the same destination, the one with the lower administrative distance is preferred. Thus, the route that sends the packets via the satellite link must have a higher administrative distance than the one that uses the fiber link. The route via satellite is configured with an administrative distance value of 210. On the router at 5Tonic end, two routes towards the flight rack IP range are configured in the same way.

3.2.3 Requirement-UC-03

Devices must support concurrent connections to both 3GPP and non-3GPP networks.

ATSSS must work with 5G Core (5GC) components like UPF, SMF, and PCF.

Support for protocols that allow data transmission over multiple paths as MCTCP.

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4 Risk analysis

Below, the detected risks are detailed, and possible mitigation actions are described.

4.1.1 R01: Hardware supply chain

Currently, hardware equipment is having delayed delivery times, typically between 6 and 18 months, impacting specially networking equipment. Ericsson takes this situation into account when planning installations at 5Tonic. To mitigate this issue, Ericsson has a certain stock of equipment that can be used temporarily while the final ordered products arrive.

4.1.2 R02: Test device

The test device must be equipped with the capability to connect with the CPE supporting the requisite 5G network functionalities for this project, as well as with the non-3GPP device installed to facilitate the ATSSS functionality within the Core.

4.1.3 R03: NTN technology

For the use cases' experimentation defined in this proposal, Ericsson assumes that an expert NTN contractor will provide UC3M with both the NTN devices necessary for communication and the network itself, whether real or through emulation/simulation.

The study of different satellite communication aspects (doppler shift, beam management, mobility management…) will be managed by the NTN contractor.

4.1.4 R04: Non-3GPP wireless link and ATSSS integration

Adding a non-3GPP wireless link alternative using Access Traffic Steering, Switching, and Splitting (ATSSS) from the Core network improves service resilience and availability but this integration can address several risks:

- Interference and Spectrum Congestion:
  - Non-3GPP wireless links can suffer from interference, especially in dense urban environments.
  - Utilize dynamic spectrum management technologies and adaptive channel selection to minimize interference.
- Latency and Bandwidth:
  - Variability in latency and bandwidth of non-3GPP wireless links could affect service quality.
  - Implement ATSSS to dynamically redirect traffic and balance the load between links, optimizing real-time performance.

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- Security and Cybersecurity:

  - Non-3GPP links can be more vulnerable to attacks due to the open nature of some wireless technologies.
  - Implement robust security measures such as advanced encryption and strong authentication, and continuously monitor traffic.

- Compatibility and Standards:

  - Integration of non-3GPP links may present compatibility issues with the 5G core network.
  - Use ATSSS, which is designed to facilitate the integration of different types of access, ensuring compatibility and smooth operation.

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5 Roadmap

The plan will be focused on adapting the laboratory environment and the integration of the use cases and the demos execution. The original project plan was included in the proposal delivered by Ericsson during the public bidding process. However, as the project starting date has been finally established in January 2024, the following figure reflects the plan adapted to such modification:

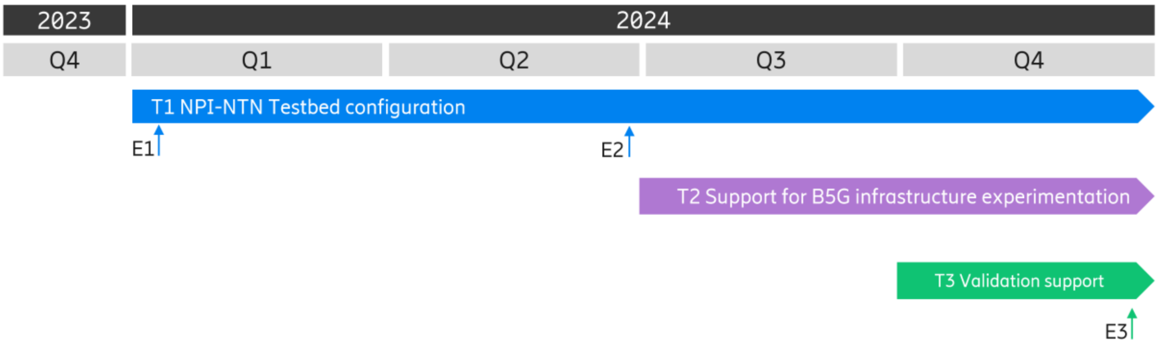

Figure 7 Project Plan

Task 1: Configuration of a test laboratory in version Rel. 17 (January 2024 – December 2024)

This activity includes the analysis, evolution, and integration of functionalities defined in Release 17 in the 5Tonic laboratory to support the integration of non-terrestrial networks. The focus for the selection of functionalities will be the use cases described:

- NTN as backhaul
- NTN as backup hackhaul
- Multiaccess with NTN networks (ATSSS)

For the integration tests, Ericsson will provide 5Tonic with a real non-public network environment, consisting of a portable system that includes the 5G radio access network (antenna and gNB) as well as the user plane (UPF). In the case of multiaccess, Ericsson proposes the use of the ATSSS (Access Traffic Steering, Switching and Splitting) architecture for the integration and demonstration of a multi-access solution using 5G NR and NTN, in order to provide a system with high reliability.

During the year, the work for this task will be focused first on the acquisition of the equipment. Then, such equipment will be installed, configured and integrated in the laboratory environment. Additionally, the 5G RAN and Core software will be regularly upgraded with the new official software released by Ericsson. Along with the new software releases comes the possibility to activate certain new features. Before activating new features, a feasibility analysis must be done to make sure it is feasible technically (it is aligned with the laboratory environment conditions and with the goals of the project) and timewise (it can be done within the lifetime of the project).

Task 2: Support for experimentation (June 2024 – December 2024)

During this phase, Ericsson will provide support for the experimentation of the thee use cases.

Task 3: Support for validation (October 2024 – December 2024)

During this phase, Ericsson will provide support for the experimentation and validation of the there use cases. This task has the following deliverable:

• 6G-INTEGRATION-01-E17 Integration testing report. (December 2024)

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6 Works Cited

[1] "Evolution of Non-Terrestrial Networks From 5G to 6G: A Survey (ieee.org)" Retrieved from: https://arxiv.org/abs/2103.09156

[2] "Non-Terrestrial Network Advantages, Challenges, and Applications" Retrieved from: https://arxiv.org/abs/2103.09156

[3] "Non-Terrestrial Networks (NTN) (3gpp.org)" Retrieved from: https://www.3gpp.org/technologies/ntn-overview

[4] "5G from Space: An Overview of 3GPP Non-Terrestrial Networks" Retrieved from: https://arxiv.org/abs/2103.09156

[5] "Connecting the world with 5G NTN" Retrieved from: https://arxiv.org/abs/2103.09156

[6] "ATSSS in 5G networks" Retrieved from: https://arxiv.org/abs/2103.09156

[7] 5G-ACIA "5G-ACIA 5G Non-Public Networks for Industrial Scenarios" https://5g-acia.org/wp-content/uploads/5G-ACIA_5G_Non-Public_Networks_for_Industrial_Scenarios_09-2021.pdf

[8] "Terminology for Benchmarking Network-layer Traffic Control Mechanisms" RFC 4689 RFC 4689 - Terminology for Benchmarking Network-layer Traffic Control Mechanisms (ietf.org)

[9] "About IMDEA Networks" Retrieved from: https://networks.imdea.org/about-imdea-networks/

[10] "About 5Tonic" Retrieved from: https://www.5tonic.org/

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