6GNTN

D2.1 USE CASES DEFINITION

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Abstract	This deliverable characterizes the most relevant use cases for the non-terrestrial network components of 6G, to be investigated throughout the 6G-NTN project. The proposed scenarios illustrate how the targeted fully integrated terrestrial / non-terrestrial 6G infrastructure will support high-performance services for users across various vertical stakeholders (including automotive, maritime, public safety & defense, smart cities, energy), and considering a wide range of terminals (e.g., mass market smartphones, highly compact vehicle/drone mounted devices, or on-board fixed/mobile platforms with larger form factors).

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PU	*Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)*	✓
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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

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OTHER: Software, technical diagram, algorithms, models, etc.

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EXECUTIVE SUMMARY

D2.1 is an early deliverable of the 6G-NTN project, whose primary objective is to identify and describe relevant use cases and user stories, under a selection of vertical and consumer contexts. More precisely, the considered set of use cases notably relates to automotive, maritime, energy, drone, public protection and disaster relief as well as direct-to-handheld consumer market. With this carefully crafted set, the intention is manifold, as reported below.

First, to illustrate the novel 6G-NTN concepts and technologies that will allow the full integration between non-terrestrial communications (including drone-mounted Base Stations, High Altitude Platforms, vLEO, LEO, MEO and GEO) and the next generation of terrestrial 6G cellular networks. In that regard, the deliverable summarizes the innovation potentials that will be explored within the 6G-NTN project and explains how each use case exhibits those innovation potentials, with the important objective to provide structuring inputs to many tasks in the technical work packages of the 6G-NTN project, as is explained in this document.

Moreover, the list of use cases was elaborated with the objective to select realistic, viable and credible scenarios in which current and mid-term technologies, such as 5G NTN and 5G-Advanced NTN, would find their limitations in supporting the features exhibited by this deliverable use cases. Regular interactions with our External Advisory Board, gathering expert representatives of the different targeted vertical industry sectors, allowed orienting the use cases towards this goal.

In this context, all of the considered use case descriptions not only provide the expected user story flows, but also all considerations of requirements and usage constraints that were identified during the elaboration of this deliverable. Naturally, such requirements and constraints will need to be further analyzed, sanitized, assessed and when relevant, quantified in the two subsequent WP2 deliverables D2.2 and D2.3 that respectively deal with the user and technical requirements of the 6G-NTN project. We anticipate that this deliverable will provide early inputs to these activities, as well as several other closely-related tasks in the other work packages, namely WP3, WP4 and WP5.

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ABBREVIATIONS

3GPP	3rd Generation Partnership Project
5GC	5G Core network
AI	Artificial Intelligence
BS	Base Station
BVLoS	Beyond Visual Line-of-Sight
BWP	Bandwidth Part
C2	Command and Control
C2CSP	C2 Link communication service provider
CoW	Cell on Wheels
CP	Cyclic Prefix
C-SWaP	Cost Size Weight and Power
CT	Core Network and Terminals
E2E	End-to-end
EAB	External Advisory Board
ECC	Electronic Communication Committee
EASA	European Union Aviation Safety Agency
ECC	Electronic Communication Committee
FR	First Responder
GEO	Geostationary Earth Orbit
gNB	Next-generation Nobe-B
GNSS	Global Navigation Satellite Systems
GSO	Geostationary Orbit
HAP	High Altitude Platform
HD	High Definition
HV	Host Vehicle
IoT	Internet of Things
ISL	Inter-Satellite Link
INL	Inter-Node Link
LEO	Low Earth Orbit
LIDAR	Light Detection and Ranging
LoS	Line of Sight
M2M	Machine-to-Machine
MC	Multi-Connectivity
MC data	Mission Critical data
MC PTT	Mission Critical Push-to-Talk
MC video	Mission Critical Video
MFCN	Mobile/Fixed Communications Networks
MEO	Medium Earth Orbit
MNO	Mobile Network Operator
NASA	National Aeronautics and Space Administration
NGSO	Non-geostationary orbit
NLoS	Non Line-of-Sight
NR	New Radio
NTN	Non-Terrestrial Network
OOBE	Out-of-Band Emission
PAPR	Peak-to-Average Power Ratio
PHEM	Pre-Hospital Emergency Medicine
PPDR	Public Protection and Disaster Relief
PTT	Push-To-Talk
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
Rel	Release
RF	Radio Frequency
RIC	Radio Intelligent Controller
SAR	Search and Rescue
SD	Standard Definition
SI	Study Item
SNO	Satellite Network Operator
SON	Self-Organizing Networks
TN	Terrestrial Network
TR	Technical Report
TS	Technical Specification
UAM	Urban Air Mobility
UAV	Uncrewed Aerial Vehicle
UAV-C	UAV controller
UC	Use Case
UE	User Equipment
USSP	U-Space Service Provider
vLEO	Very Low Earth Orbit
VLoS	Visual Line-of-Sight
VNF	Virtualized Network Function
VR	Virtual reality
VTOL	Vertical Take-Off and Landing
WI	Work Item
WPAN	Wireless Personal Area Network
WP	Work Package

1 INTRODUCTION

The increasing digitization and technological progress are transforming the way industry develops and delivers new products and services, as well as the way we live, work and learn. This drives the demand for advanced Non-Terrestrial Network (NTN) components that is effectively and smoothly unified with future 6G terrestrial networks (TN), to provide very high throughput and low latency connectivity towards new services, to enhance the flexibility and agility to face market evolutions and adapt to customers' demand, to deliver scalable and resilient solutions, while reducing costs and energy consumption. Identifying the representative use cases and scenarios is a first step to consolidate the service requirements and to characterize the user terminal installation and operational constraints, as well as pricing and business model aspects for an economically viable, affordable and sustainable approach.

1.1 SCOPE AND OBJECTIVES

This deliverable is part of WP2 for the definition of use cases and the identification of requirements to be considered throughout the 6G-NTN project. WP2 aims to build common references, guidelines, and terminology for future work, including definitions, requirements, as well as technical, business, and regulatory assumptions.

The main objective of this deliverable is to propose a first set of use cases able to illustrate the usage of the 6G NTN technology for different market segments, *e.g.*, Automotive, Public Safety & Defense, Maritime, Aeronautics & Drones, Media & Entertainment and Utilities/Energy/IoT. This set does not claim to be exhaustive and the proposed use cases should be considered as non-limiting examples of the enhanced existing applications and the new services that could be offered by the unified NTN/TN infrastructure. Then, these use cases will be used as a baseline for in-depth requirement analysis. To this end, they are characterized by the benefits they provide to end-users, compared to State-of-the-Art solutions, and by their relation to 6G non-terrestrial networks.

These use case scenarios do not focus on the technological aspects, but rather on the high-level functional and non-functional ones, firstly reflecting the end-users' concerns. Note that the objective of this deliverable is not to harmonize or align such requirements and usage constraints. This will be fulfilled in other tasks of WP2, in particular T2.2 and T2.3.

As concluding remarks for this deliverable, the identified use cases are positioned regarding the project technical objectives and potential innovations, to be developed in other work packages, namely WP3, WP4, and WP5.

1.2 RELATION TO OTHER WORK PACKAGES IN 6G-NTN

The relation of this task to the rest of the 6G-NTN project is illustrated in Figure 1:. First, Task 2.1 aims to initiate the analysis to be provided in the other tasks of WP2, that is:

- T2.2 on User requirements,
- T2.3 on Service and Technical requirements,
- T2.4 on Market and Business models,
- T2.5 on Policies and Regulation.

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To do so, the use cases descriptions include discussions on these different aspects and highlight the main specificities of the targeted market segments, which should be considered in the integration of 6G-NTN technology into existing and future terrestrial networks.

Second, this deliverable proposes use cases illustrating the 6G-NTN components which will be investigated throughout the project, in WP3 on architecture, WP4 on radio aspects and on WP5 on end-to-end (E2E) services. This objective is covered in the conclusion, where the selected use cases are linked to the innovation potentials envisaged by the 6G-NTN project.

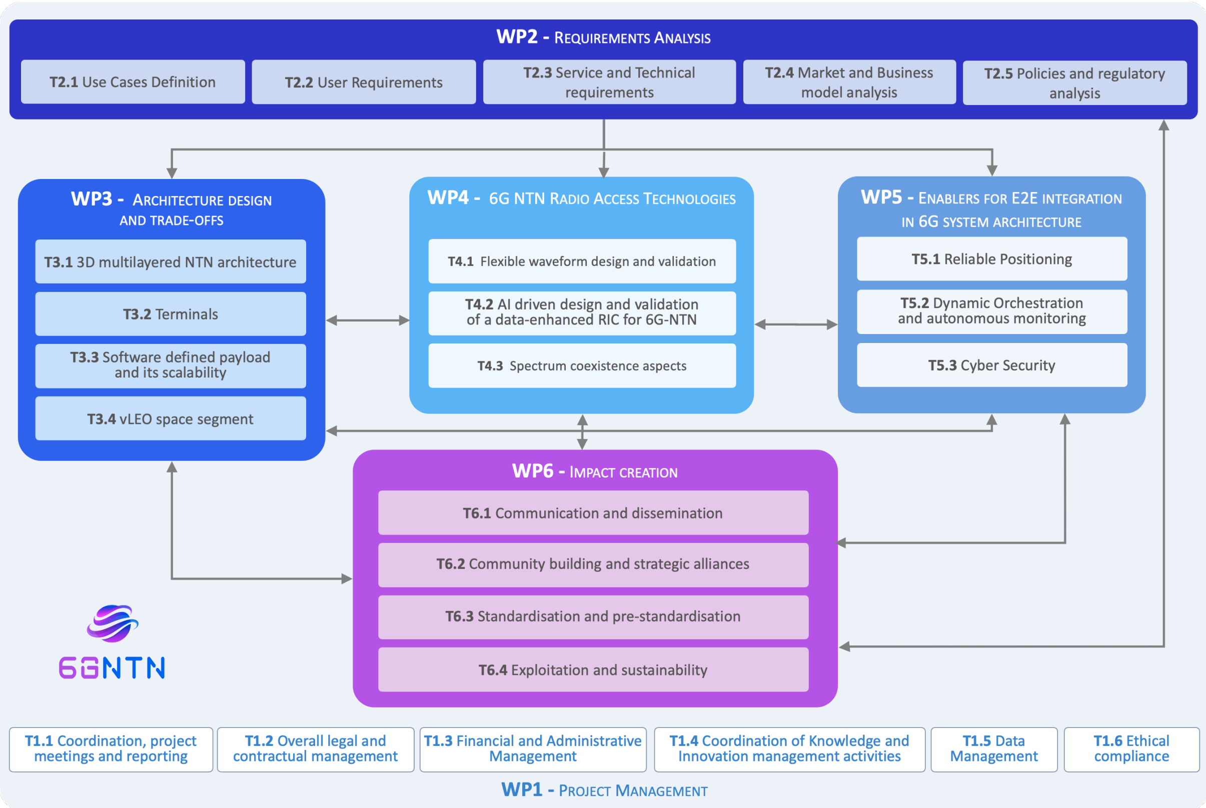

FIGURE 1: 6G-NTN WORK ORGANIZATION

1.3 STRUCTURE OF THE DOCUMENT

This deliverable is structured as follows.

Section 2 provides the general context of 6G NTN technologies and restates the main objectives of this project, as well as foreseen innovation potentials, which are considered to assess the relevance of the proposed use cases. It also overviews the main use cases that have been considered in 3GPP so far and explains their limits with respect to the project.

Section 3 gives an overview of the seven use cases selected for the project and presents the working sessions with the External Advisory Board (EAB) and the considered methodology.

Sections 4 to 10 describe these use cases, which cover the Maritime, Aeronautics & Drones, Public Safety & Defense, and Automotive sectors, and as well as the Consumer market.

Finally, Section 11 concludes this deliverable and highlights which of the objectives of the 6G-NTN project are illustrated by each use case. This is summarized in Table 4:.

2 FROM 5G TO 6G NON-TERRESTRIAL NETWORKS

The evolution of 5G into beyond 5G (5G-Advanced) and 6G networks aims at responding to the increasing need of our society for ubiquitous and continuous connectivity services in all areas of our life: from education to finance, from politics to health, from entertainment to environment protection. It is generally understood that the terrestrial network alone cannot provide the flexibility, scalability, adaptability, and coverage required to meet the above requirements, and the integration of the NTN component is a key enabler.

In this section, we first review the main technical evolution and roadmap adopted by 3GPP, from Release 15 to Release 18. Then, we discuss the potential next steps, as envisaged within the 6G-NTN project, and present its main objectives and foreseen innovation potentials. Finally, we explain why the main use cases considered so far within 3GPP do not fully cover our targets and only partially illustrate the NTN components of 6G.

2.1 EVOLUTION OF NTN TECHNOLOGIES IN 3GPP

As soon as Release 14, 3GPP recognized the added value of the NTN, and particularly satellite communication networks, but existing standards were not ready to include such new technologies and adaptations were needed, [1].

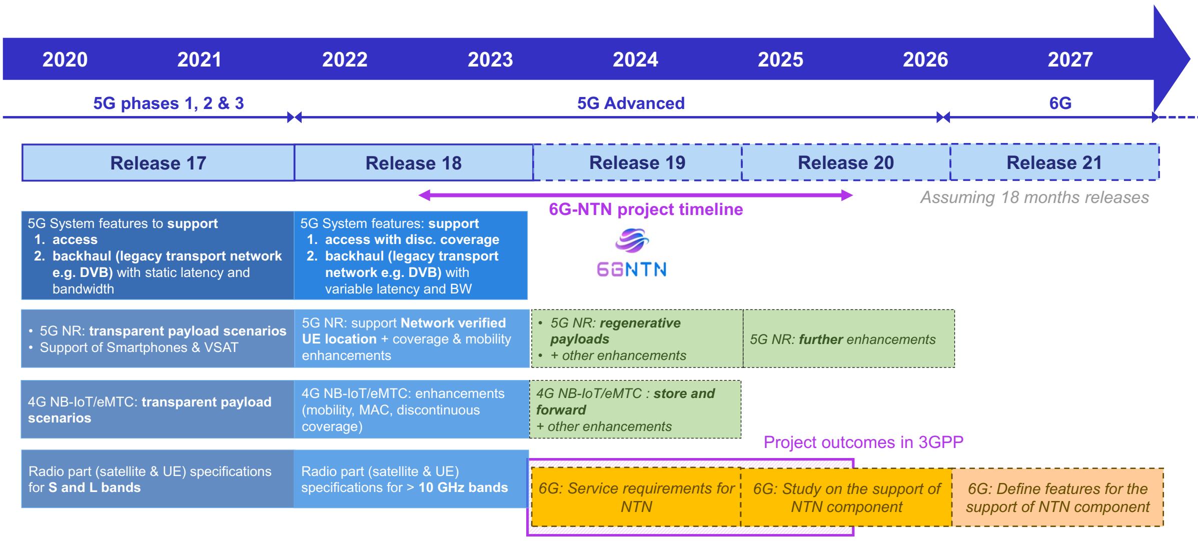

FIGURE 2: TIMELINE OF LAST 3GPP RELEASES

3GPP R-15: Starting with Release 15 in 2017, 3GPP has initiated several Study Items (SI) and related Work Items (WI) to address the inclusion of technology enablers in the New Radio (NR) standard to support NTN. The objectives of this work, documented in 3GPP TR 38.811, [2], were to select a few reference deployment scenarios of NTN, to agree on key parameters such as architecture, orbital altitude, frequency bands, etc., and to develop NTN channel models based on the terrestrial 3GPP channel models.

3GPP R-16: Then, 3GPP continued with a follow-up Rel-16 study on solutions for adapting NR to support NTN. The main objective was to identify a minimum set of necessary features/adaptations enabling NR support for NTN (with a priority on satellite access). This included architecture, higher-layer protocols, and physical layer aspects. The objectives were the consolidation of potential impacts on the physical layer and definition of related solutions,

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considering S-band and Ka-band for simulation. The outcome of the study is documented in 3GPP TR 38.821, [3].

3GPP R-17: A new work item was then started on NTNs in NR Rel-17, to specify necessary enhancements for Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) based NTNs while also targeting implicit support for High Altitude Platforms (HAPs) and air-to-ground networks. This involves the physical layer aspects, protocols, and architecture as well as the radio resource management, Radio Frequency (RF) requirements, and frequency bands to be used. Meanwhile in 2018, SA2 initiated a study on architecture aspects for using satellite access in 5G. The conclusion of the study, documented in TR 23.737, [4], was that the 5G Core network (5GC), with small enhancements as described above, is well prepared to support NR NTN access as well as satellite backhaul. In 2019, SA5 started in TR 28.808, [5], a study on management and orchestration aspects with integrated satellite components in a 5G network. It concluded that the concepts of self-organizing networks (SON) for 5G would need to be enhanced to support mobile non-terrestrial gNBs. Then, the Core Networks and Terminals (CT) working groups in 3GPP defined the core network protocols, as well as the protocol between the User Equipment (UE) and the core network.

3GPP R-18: As Rel-17 work is considered completed in March 2022, Rel-18 is now moving into focus. Looking ahead, the NTN stakeholders have discussed the Rel-18 items and are continuing to work on a further list of enhancements for both NR NTN and IoT NTN. Plans are also underway to further define the enablers for NR based satellite access in bands over 10 GHz to serve fixed and moving platforms and building-mounted devices. The goal of these efforts is to further optimize satellite access performance, address new bands with their specific regulatory requirements, and support new capabilities and services as 5G continues evolving.

Proposals for future work: Despite the fast enhancements of new capabilities for NTN systems within 3GPP standards, some key features have not yet been included.

First of all, regenerative payload is not covered by Rel-18 SIs and WIs. Compared to transparent mode, the regenerative mode brings better spectral efficiency on the service link and much lower bandwidth on the feeder link. Such architecture is also needed to support very dense LEO satellite deployment. For the moment, 3GPP has decided to focus on transparent mode only, to keep the minimum modification needed on the ground.

Other proposals, not included yet in current releases, cover

- Support of UE without Global Navigation Satellite System (GNSS) capabilities (to provide a high accuracy clock and positioning service),
- Enhanced beam management and Bandwidth Part (BWP) association (to mitigate inter-beam interference),
- New waveform (to reduce the Peak-to-Average Power Ratio, PAPR, and, thereby, loss in power efficiency and throughput),
- NTN-TN spectrum sharing, especially for mass-market smartphones,
- Management of discontinuous coverage, due to sparse constellation,
- High performance handheld devices,
- On-board edge computing (space processing capabilities requires regenerative NTN).

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2.2 MOVING TOWARDS NEW HORIZONS

The ambition of the 6G-NTN project is to go one step further, towards the full integration of NTN components into the future 6G infrastructure as illustrated in Figure 3:, and to meet the vertical industry's requirements and consumer market expectations, in terms of global coverage, increased resiliency, enhanced performance and improved sustainability. But to achieve such ambition, innovative technical, regulatory, and standardization enablers need to be researched and developed.

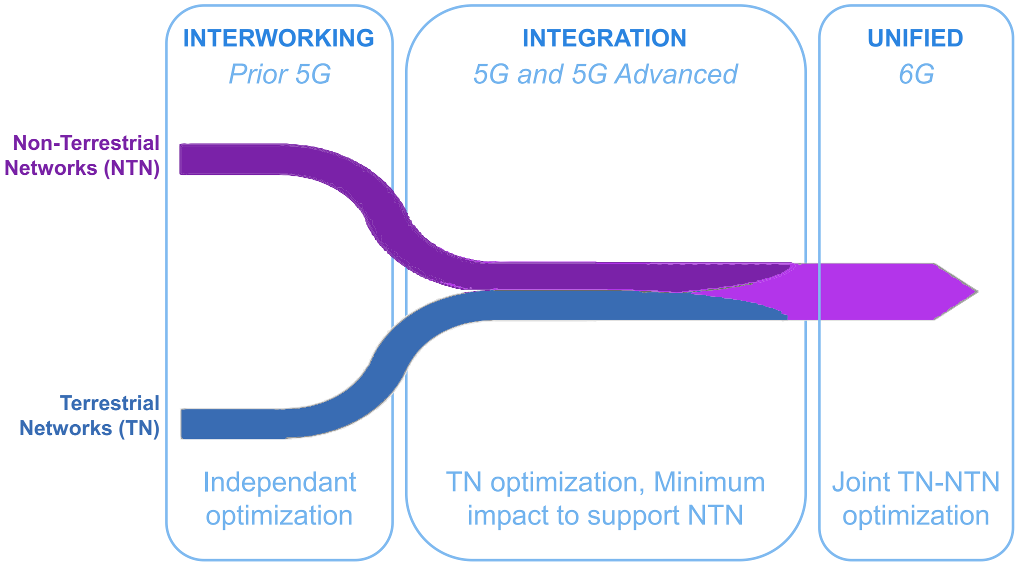

FIGURE 3: INTERACTION BETWEEN TN AND NTN BEFORE AND BEYOND 5G [6]

This deliverable aims to select the use cases which can best illustrate such enablers. They have been identified as the key objectives and innovation potentials of the 6G-NTN project. They are restated in the following for the benefit of the reader.

2.2.1 Objectives of the 6G-NTN project

This subsection restates the project's key objectives that will be considered in Section 11 to assess the relevance of the proposed use cases. First of all, this document partly responds to Objective 1, which targets the identification of the services and operational requirements for the 6G NTN components. Use cases are evaluated based on Objectives 2 to 10.

➲ **Objective #2:** *Designing a 3D TN / NTN network*

This unified 3D network is defined as a multi-dimensional and multi-layered infrastructure, composed of terrestrial nodes, air-borne flying nodes and space-borne nodes, possibly interconnected by means of wireless and optical links. Note that air-borne flying nodes encompass both HAPs and aerial base stations, for example on board of a low-altitude drone. This is illustrated in Figure 4:.

➲ **Objective #3:** *Designing compact terminals*

The size, cost and energy consumption of existing NTN terminals pose severe constraints and significantly limit their usage for some vertical industries and for the consumer market. The second objective of this project is thus to design new compact terminals, with low C-SWaP (Cost Size Weight and Power) and adequate performance, particularly targeting handheld devices as well as vehicle or drone mounted terminals able to operate simultaneously with both TN and NTN access in the considered sub-6GHz and mmWave bands.

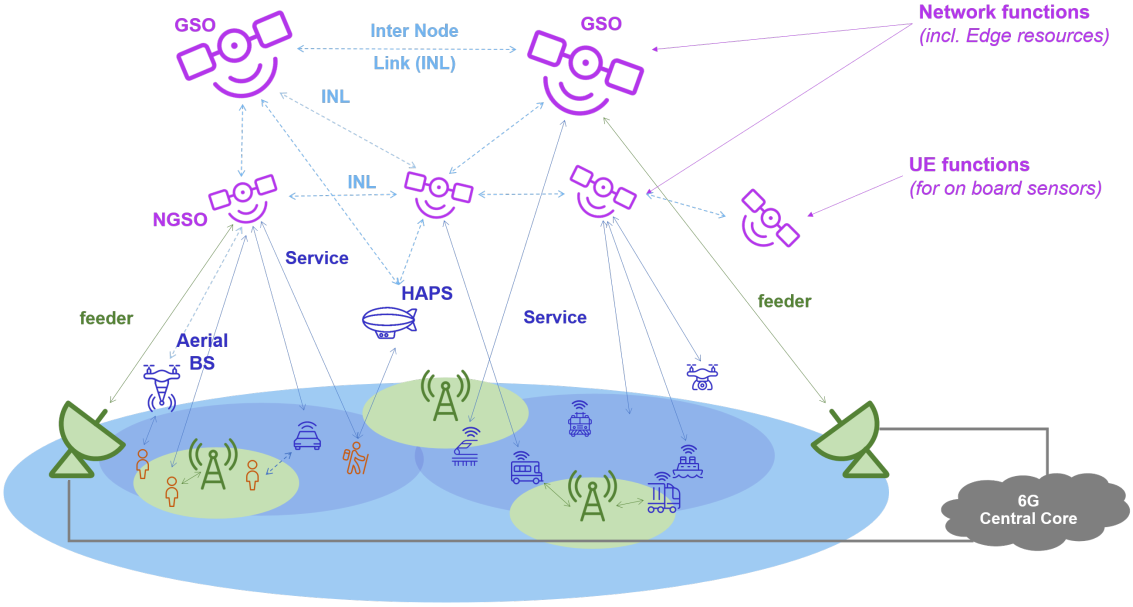

FIGURE 4: 6G-NTN VISION FOR A 3D FULLY INTEGRATED NETWORK

- **Objective #4:** *Flexible software-defined payload*

Currently, satellite platforms and payloads are dedicated to their space missions and designed according to the satellite's orbit and envisioned operations. The new software defined payload to be investigated will be built upon generic hardware and software building blocks, to optimize the platform and payload resources' usage, in a multi-mission approach.

- **Objective #5:** *Flexible waveform*

This new waveform shall take into account the usage conditions associated to the different targeted terminals, the considered frequency bands and the different access technologies of the 3D network. In addition, this waveform shall be designed GNSS-free operations, i.e., UE without any GNSS service capability on a temporary or permanent basis.

- **Objective #6:** *AI-enhanced Radio Intelligent Controller (RIC)*

Which can account for both large-scale temporal (hours) and low-scale (less than a minute) traffic variations to optimize resource utilization in a dynamic 3D multi-dimensional and multi-layered infrastructure, considering the geographical spread of satellite gateways and novel space segment computational capabilities.

- **Objective #7:** *VNF orchestration*

The objective is here to develop a novel 6G Edge and Core architectures natively integrating TN and NTN components by considering the capabilities of regenerative payloads to host Virtual Network Functions (VNF) and edge services, leveraging lightweight micro-service orchestrators.

- **Objective #8:** *Reliable and accurate positioning*

The location of a UE is an essential feature for the support of regulated services (*i.e.*, emergency calls, lawful intercept, public warning service and charging and tariff notifications). The location services need to be improved not only in their accuracy to enable a larger range of applications, but also in terms of reliability in two aspects: integrity and authenticity.

➲ **Objective #9:** *Spectrum usage optimization*

Novel spectrum regulations are envisaged for future 6G-NTN, implying that new challenges need to be addressed in terms of interference management, coexistence and possibly sharing scenarios.

➲ **Objective #10:** *Standardization and regulation*

The 6G-NTN project also aims to ensure effective exploitation of the project's outcomes, by creating synergies with relevant working groups and initiatives at European, national, and international level, including standardization- and policy-driven efforts. Open standardized platforms can ensure competitive markets.

2.2.2 Innovation potentials to be explored within the 6G-NTN project

Additional innovation potentials can be directly derived from the key objectives described above. They are listed below and will be used as well in Section 11, to assess the relevance of the proposed use cases.

➲ **Innovation potential #1:** *Performance enhancement*

Compared to 5G-NTN, a significant performance enhancement is expected for 6G-NTN, in terms of latency, rate, number of devices to be managed, etc. Such enhancement will enable new services, which remains unachievable so far, and should be offered to any type of 6G-NTN terminal.

➲ **Innovation potential #2:** *Ubiquitous connectivity and Resiliency*

Reinforce the resilience of the 6G system, provide ubiquitous coverage and global service continuity for a wide range of QoS requirements. Network outages could be addressed in a less-than-a-minute resource updates.

➲ **Innovation potential #3:** *Seamless connectivity in Mobility*

Contrary to 5G-NTN, the terminal in connected mode should be able to seamlessly and transparently switch from TN to NTN, from NTN to TN, or from NTN to NTN. Such feature is, for example, needed for cross-border scenarios.

➲ **Innovation potential #4:** *Light indoors and in-vehicles conditions*

The current NTN component allows outdoor usage only, the technologies to be developed within the 6G-NTN should enable light indoors and in-vehicle communications, with ~20 dB Building Penetration Loss.

➲ **Innovation potential #5:** *Solutions as-a-Service*

Virtualized capabilities orchestrated under cloud computing techniques enable near-instantaneous network functions deployment and thus, permit Network as a Service or Infrastructure as a service.

➲ **Innovation potential #6:** *Space Edge Computing*

Space Edge Computing is becoming a key resource to enable latency-sensitive services. Computation can be located closer to data sources, especially in remote and hard-to-reach locations. Note that space edge components could be located at any non-terrestrial layer, satellite, HAP or Aerial BS.

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- **Innovation potential #7:** *Fast adaptation to traffic variations*

The high dynamicity and re-configurability will allow the network to absorb traffic variations, at both large scale and small scale.

2.3 AN OVERVIEW OF 3GPP USE CASES

Three main categories of use cases for satellite-based NTN have been identified by 3GPP: Service Continuity, Service Ubiquity and Service Scalability. Since early releases, NTN communication services have mostly targeted:

- **Coverage extension:** for users located in areas that cannot be covered by terrestrial 5G networks (underserved rural areas, isolated/remote areas, on board aircrafts or vessels), or for passengers on board moving platforms (*e.g.*, passengers on vehicles-aircraft, ships, high speed trains, bus). In Rel-14 and Rel-15, the satellite service generally consists of a broadband connectivity between the core network and a cell (or home access point) located in this isolated / underserved area or mounted on board of the moving platform. Later releases have also included use cases for the vertical markets, such as agriculture, mining, forestry, for voice communication, video monitoring, and remote control in uncovered or under-covered areas.
- **Disaster communication:** targeting public safety authorities and first responders, NTN can offer secondary / backup connection for network resilience. This includes movable, temporarily deployable and tactical base stations for Public Protection and Disaster Relief (PPDR), to ensure capacity and/ or coverage over remote areas or where TN is down. However, this secondary or backup connection generally comes with highly degraded performance and the time to roam between TN and state-of-the art NTN may also be quite significant (several minutes). Both should be improved in future releases.
- **Broadcasting:** for broadcasting or delay-tolerant services, satellite access is usually more efficient. Such use cases have been proposed since Rel-15. This constitutes the first steps towards multi-connectivity, in the sense that delay-sensitive traffic is routed over shorter latency links, while less delay-sensitive traffic is routed over satellite. Rel-17 suggested to add the broadcasting of 5G mobile edge applications (*e.g.*, mobile gaming), where application content needs to be available in many different edge locations.
- **Internet of Things:** for Machine-to-Machine (M2M) or Internet of Things (IoT) devices, the satellite service can reinforce reliability and availability, especially for critical communications, including future railway/maritime/aeronautical communications. In general, there are two architectures of IoT NTN. In the gateway-based access, small satellite gateways collect data from terrestrial IoT devices in the covered area. These gateways have a cost, a limited coverage, and a constraint on the maximum number of attached devices. In direct access IoT NTN, the IoT devices are connected to the satellites directly. In this case, there is no gateway cost, therefore it adapts well to the cases in which the devices are scattered on large-scale areas. However, this architecture requires adapted protocols and devices in terms of cost and energy, which is still quite challenging. Such scenarios are ongoing since Rel-15.
- **Global roaming:** use cases targeting TN / NTN roaming services have been introduced mostly in Rel-16 and Rel-17, where they focused on applications like tracking and tracing of containers. In particular, this need is illustrated by a container, stored in a harbor (with terrestrial coverage) and then transported on a ship in the middle of an ocean.

Such use cases are documented in TR 22.891 (Rel-14), [10], TR 38.811 (Rel-15), [2], TR 22.822 (Rel-16), [11], and TR 21.917 (Rel-17), [12]. The analysis of such use cases led to the formulation of service requirements that were then included in the overall service requirements specification for the 5G System. Such requirements cover both NTN Radio Access Network (RAN) based satellite access for access and backhaul, as well as the possibility to use satellite radio technology not developed by 3GPP.

The 6G-NTN project covers such categories of NTN communication services as well, but with novel perspectives.

Satellite backhaul vs direct to device: Most of the 3GPP use cases are based on satellite backhaul scenarios, with a backhaul between a core network and a fixed base station or/ moving base station (deployed on a train for example or for PPDR use cases, as part of Disaster communications described above). Part of them cover direct satellite access, for broadcast service, IoT devices, and mission critical access in disaster situations, but with limited scope and service capabilities (reduced performance). On the contrary, the 6G NTN project will put particular emphasis on the satellite direct to device connectivity use cases, which are relevant for both B5G and 6G systems. New use cases are expected to illustrate the foreseen evolutions towards compact handheld devices able to achieve enhanced performance and provided with wider service capabilities.

Three categories are targeted: the consumer market (addressed in particular in UC5), the enterprise market (covered by UC2 and UC3 for drone-mounted devices and by UC6 for Automotive), and finally, the Global Government sector (addressed in UC1 for Maritime and in UC4 for Public Safety & Defense). For this latter category in particular, NTN terminals are usually challenging, in terms of performance, cost and availability on the market. Hence, direct-to-device communications should target harmonization of requirements and technologies, towards high interoperability. If widely adopted, such standards could reduce the total cost of ownership and foster the emergence of a new ecosystem.

Enhanced multi-connectivity: 3GPP has laid the foundation for Multi-Connectivity (MC), where NTN communication services are considered as backup solutions or for routing of delay-tolerant traffic. The 6G-NTN project aims to go one step further by considering true service versatility in a 3D multi-layered and multi-dimensional network infrastructure, where it is possible to adjust the service requirements (*e.g.*, in terms of latency reliability, bandwidth, connectivity density) to the targeted capabilities of available links (from drone-mounted BS and HAPS, to vLEO / LEO / MEO / GEO). Such important feature is reflected at different scales in all proposed UC.

Mobility is crucial: The 6G-NTN project will also propose novel perspectives with respect to the use of NTN terminals in mobility. 3GPP has so far mostly been targeting static use cases, NTN /TN switching in idle mode and global roaming. The use cases proposed in this deliverable aim to leverage the new capabilities envisaged in this project, relaxing the assumptions that running services may not be continued while in mobility and that UEs are equipped with GNSS. This will enable tight connection with commercial networks, far beyond isolated connectivity bubbles with satellite backhauling. Such features are illustrated for Maritime in UC1, Energy / Utilities in UC2, Smart cities in UC3 and Automotive in UC6. Furthermore, direct communication over Satellite will be addressed by UC7, to cover cases where no feeder link is available.

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3 AN OVERVIEW OF PROPOSED USE CASES

This deliverable is first of all a collection of use cases which reflect the high diversity of background of the project contributors and External Advisory Board (EAB).

3.1 TARGETED VERTICALS

Seven use cases are proposed:

- **UC1:** Maritime Coverage for search and rescue coast guard intervention,
- **UC2:** Autonomous power line inspection using drones,
- **UC3:** Urban air mobility,
- **UC4:** Adaptation to PPDR or Temporary Events,
- **UC5:** Consumer Handheld Connectivity and Positioning in Remote Areas,
- **UC6:** Continuous Bi-directional Data Streams in High Mobility,
- **UC7:** Direct Communication over Satellites.

Note that this last use case provides a new capability for NTN communication which could be applied to many verticals. Such feature is also reflected in other use cases, in particular UC1 and UC4. Further examples are proposed in the description of UC7.

In Table 1:, these use cases are mapped to the verticals or market segments they explicitly illustrate (x) or could illustrate with minor adaptations (o). They are also linked to the three main Service Categories, defined in 3GPP TR 22.822 [11]:

- **Service Continuity**, which characterizes the opportunity for users in mobility to be provided with an access to terrestrial networks and satellite networks. Note that, in the 6G-NTN project, this notion is extended to non-terrestrial networks in general (and not only satellite) and to users which are consuming connectivity services while in mobility (*i.e.*, in connected mode and not only in idle mode).
- **Service Ubiquity**, which encompasses coverage extension and digital divide, where an area is under-served / unserved by terrestrial networks, due to temporary outage (*e.g.*, disaster) or due to economic rationales, accounting for the cost of network deployment vs. expected revenues.
- **Service Scalability**, which refers to the advantages derived from the large coverage of non-terrestrial networks, for example, for traffic off-loading, multicasting or broadcasting.

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TABLE 1: TARGETED VERTICALS AND SERVICE CATEGORY FOR THE PROPOSED USE CASES

		UC1	UC2	UC3	UC4	UC5	UC6	UC7
Targeted verticals								
1	Consumer					x		
2	Automotive			o		o	x	x
3	Public Safety & Defense	x		o	x	o		x
4	Utilities / Energy / IoT		x			o		x
5	Media and Entertainment				x			
6	Railways transportation		o	o				o
7	Maritime transportation	x				o		x
8	Aeronautic / drone sector		x	x				o
10	Road transportation / Smart cities			x		o	o	o
Service category								
1	Service Continuity	x	x	x		x	x	
2	Service Ubiquity	x		x	x	x		x
3	Service Scalability				x			

3.2 FEEDBACK FROM THE EXTERNAL ADVISORY BOARD

Acknowledgement: We would like to particularly thank the EAB for their time and consideration. The feedback they gave us, during the workshops and one-by-one meetings that have been organized since November 2022, have allowed us to significantly improve the scenarios considered in each use cases. We hope that this first set of use cases will meet their expectations.

More precisely, two general workshops have been organized, one in November 2022 and one in January 2023, during which we have presented the 6G-NTN project and brainstormed on use cases. Then, several working sessions have been organized, each dedicated to a specific market segment:

- **Public Safety & Defense:** with Kari Junttila (Erillisverkot), Antti Kaupinen (Erillisverkot), Germano Capela (NCIA) and Renaud Mellies (French Ministry of Interior), during which we have defined UC 4: Adaptation to PPDR or Temporary Events.
- **Automotive:** with Steffen Schmitz (Volkswagen), Olivier Wick (BMW) and Roland Beutler (SWR), where we have discussed UC6: Continuous Bi-directional Data Streams in High Mobility.

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- **Maritime:** with Hyounhee Koo (Synctechno), for UC1: Maritime Coverage for search and rescue coast guard intervention.
- **Consumer** with all EAB members (see Table 2:), to discussed UC5: Consumer Handheld Connectivity and Positioning in Remote Areas.

Future meetings will cover the other use cases, which could not be discussed due to the limited time allocated to Task 2.1.

TABLE 2: MEMBERS OF THE EXTERNAL ADVISORY BOARD, AT THE TIME OF WORKSHOPS, IN FEBRUARY 2023

Vertical sector	Name	Company
Automotive	Mr. Steffen Schmitz	Volkswagen Infotainment GmbH
Automotive	Mr Oliver Wick	BMW
Automotive	Dr. Khaled Hassan	Bosch
Media & Entertainment	Dr Roland Beutler	SWR
Aeronautic & drones	Mr Olivier Balard	Thales Group
Railway	Dr. Ingo Wendler	SBB
Utilities	Mr. Vincent Audebert	EDF
Maritime	Mrs Hyounhee Koo	Synctechno
Public safety	Mr Antti Kaupinen	Erillisverkot
Public safety	Mr Kari Junttila	Erillisverkot
Public safety	Mr Renaud Mellies	French Ministry of Interior
Defense	Mr Luis Bastos	NCAI
Defense	Mr Germano Capela	NCAI

3.3 METHODOLOGY FOR USE CASE DESCRIPTION

To keep consistency, each use case description is structured as follows:

- A brief introduction presents the general context of the considered use case, together with its service category (Service continuity, Service ubiquity and Service scalability), the targeted vertical(s) and references. If any, specific terminology is specified for this use case. Some comments are made if proposed scenarios could also be proposed for other verticals, with minor adaptations.
- This introduction is followed by a detailed scenario description, with illustrative figures. For some use cases, several scenarios are proposed, highlighting the broad context of this use case for 6G NTN.

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- Then, the reasons for change are explained, *i.e.*, how such use case benefits from the awaited 6G TN / NTN complementarity. This section aims to target the required enablers and assess why this UC is best suited to illustrate the objectives of the 6G-NTN project.
- Finally, each use case is described in terms of practical constraints, usage, operational risks and specific regulations (*e.g.*, spectrum or device manufacturing, if any or known). The objective of this section is to initiate discussions for the other tasks of WP2, as well as for WP3, 4 and 5. To this end, families of requirements have been identified and each use case is characterized with respect to those families. They cover:
    - **Service capabilities:** which may include, for example, the type of service (Voice, Data, Video, etc.), high-level traffic characteristics (downlink / uplink, continuous / intermittent, etc.), heterogeneity of communication, etc. For some use cases, details could be given on expected performance (throughput, latency, availability, etc.). This description will be pursued within Task 2.3.
    - **Positioning and Timing services:** if specific services are required.
    - **Terminal features:** *e.g.*, type of NTN device (smartphone, vehicle-mounted, etc.), size and weight constraints, installation, power consumption, etc.
    - **Device density:** to be served by the 6G NTN components.
    - **Mobility pattern & velocity:** to highlight if a device is expected to be static, or moving. Cross-border scenarios are highlighted here.
    - **Environment specificities:** to describe specific radio propagation constraints or challenges to be overcome (for example, open seas or altitude).
    - **Coexistence scenarios:** in relation to any specific spectrum regulation to be considered for the use case. Deep analysis will be provided within Task 4.3.
    - **Policies and regulatory constraints:** specific to the considered UC, if known.

Note that this last section serves as a baseline for scenario description but, due to the different degree of maturity of the selected use cases, not all of this information could be detailed for each use case.

4 UC1: MARITIME COVERAGE FOR SEARCH AND RESCUE COAST GUARD INTERVENTION

For many years, there have been continuous attempts to improve the means given to the Search and Rescue (SAR) teams to intervene quickly in case of distress. The primary goals of Search and Rescue technologies are to alert and locate the people or assets in distress for the SAR team to focus on their "Rescue" role. Having a reliable way to communicate with the SAR team in case of an emergency is key to accelerate the response and effectiveness of the rescue team.

In this use case, we focus on the maritime emergencies, where the overall coordination of the stakeholders such as coast guards, militaries and civil protection agencies is necessary, and this can be obtained by combining the communication capabilities of TN and NTN.

However, we can mention that this use case could be also applicable in many other cases such as in case of a rescue in the inaccessible mountains and other areas not covered by TN (Amazonian forests, deserts, avalanche regions, floods, etc.

- **Service category:** Service continuity, Service ubiquity.
- **Targeted vertical:** Maritime, Public Safety.
- **References:** [8], [9], [11], [13]-[20]

Specific terminology:

- **SAR:** Search and Rescue
- **Uncrewed Aerial Vehicle (UAV):** This is an aerial drone.
- **Sidelink:** Device-to-device communication

4.1 DESCRIPTION OF THE PROPOSED SCENARIO

A ship at large has a serious issue, and the Coast Guard must intervene urgently and perform a SAR mission on a site. The ship and people on board who requested to be rescued should be able to provide their accurate position regardless of whether there is any network infrastructure around the ships or not. Furthermore, the crew on the Coast Guard ship and helicopter needs to have seamless communication with the Coast Guard headquarters at shore, which in turn need to have full situational awareness. This will be obtained by terrestrial communication (ships within the coverage of the cellular network) and, when it is not available, the connection switches seamlessly to NTN communication. This is also complemented using drones by offering better coverage, on-demand network deployment, and high mobility capabilities. The following scenarios are considered.

Scenario 1: Coast Guard Intervention with Terrestrial Coverage

1. A ship leaves from the port of Piraeus and, after a few days at the Mediterranean Sea, the ship approaches the port of Valencia when a serious issue happens.
2. The crew on the ship uses UEs with subscriptions to terrestrial operator A in the port of Piraeus. However, terrestrial operator A has roaming contracts with most terrestrial

operators worldwide. Therefore, when the ship approaches the port of Valencia and there is indication of the terrestrial network, the UEs select terrestrial operator B.

3. The crew on the ship to be rescued provide their accurate position using the 6G terrestrial network.

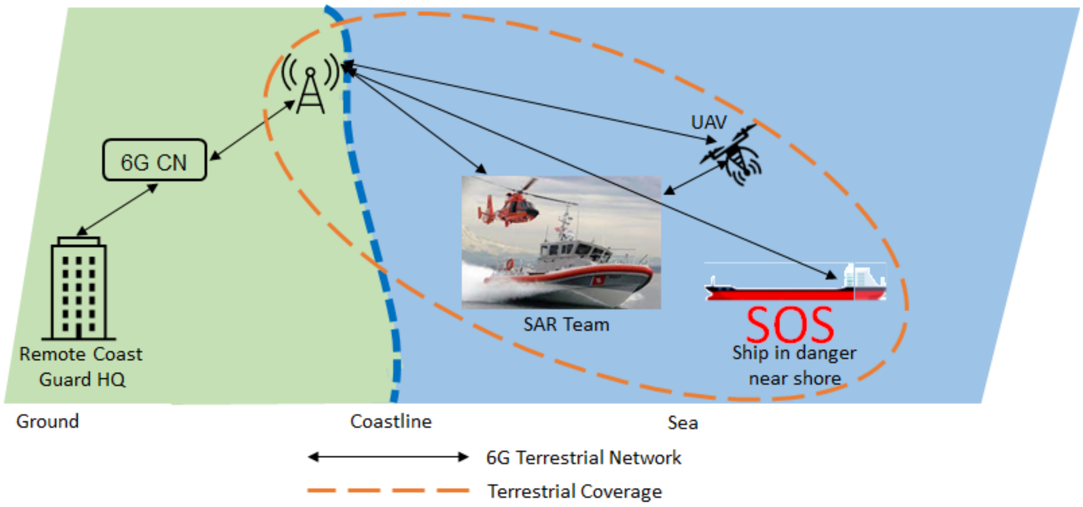

FIGURE 5: COAST GUARD OPERATION: OPERATION WITH TERRESTRIAL COVERAGE

4. The Coast Guard (boats, helicopters and drones), knowing the accurate position of the people to be rescued, must intervene urgently and perform a SAR mission on the ship.
5. The Coast Guard ship, helicopter, and drones approach the ship, and they are all in the coverage of terrestrial operator B.
6. The crew on the Coast Guard ship and helicopter uses UEs with subscriptions to terrestrial operator B. The same applies for the drones, which send high-definition video and pictures in real-time to the other actors in the mission.
7. The SAR team needs to have seamless communication with the Coast Guard Headquarters at shore. The people at the headquarters use UEs with subscriptions to terrestrial operator B. The 6G terrestrial network is used to provide the following communication services:
    a. Voice services, including 3GPP MCPTT (Mission Critical Push-to-Talk), within the SAR Teams, between SAR teams and headquarters and between the Ship crew and the SAR teams or headquarters.
    b. Video surveillance, including 3GPP MC (Mission Critical) video: high-definition video transmission with very low communication latency.
    c. Continuous data, including 3GPP MC data, upload for data analytics at the Coast Guard Headquarters: high uplink data volume.
    d. Support information from the Coast Guard Headquarters to the SAR team on site: high downlink data volume.
    e. Sensor data, including 3GPP MC data, collection by drones and communication of position data, etc.: medium/low data rate, no restriction on communication latency.
    f. The C2 (Command and Control) of the drones.

Scenario 2: Coast Guard Intervention without TN Coverage and with only NTN coverage

This scenario, illustrated in Figure 6:, foresees to connect the UE terminals ("UE Boat", "UE Helicopter", "UE Drone") to the NTN component in a reliable manner, even if these are far out at sea and may not be connected to a TN network and if the feeder link to the NTN network may not be directly accessible. The NTN networks should be able to accept the connectivity and establish a connection between all the UE actors using only the NTN component.

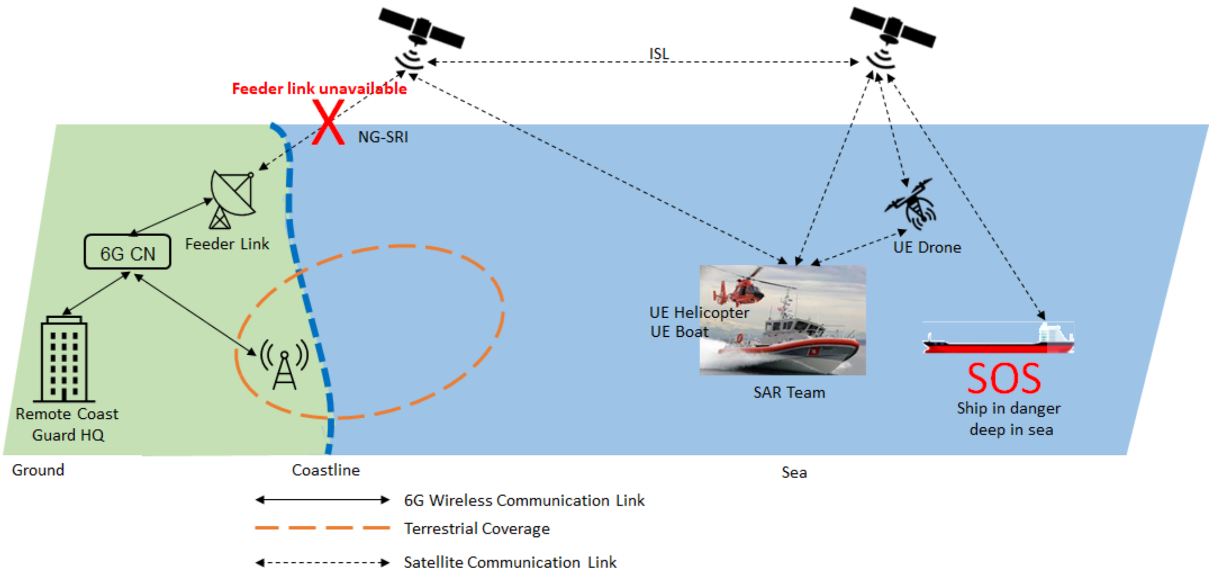

FIGURE 6: COAST GUARD OPERATION: OPERATION WITHOUT NTN FEEDER LINK. REMOTE LARGE AREA FROM COAST WHERE A SEARCH OPERATION IS CONDUCTED WHERE DIRECT SATELLITE ACCESS IS ESSENTIAL FOR THE SUCCESS OF THIS SCENARIO

1. A ship leaves from the port of Piraeus, and in the middle of the trip at the Mediterranean Sea, a serious issue happens.
2. The crew on the ship uses UEs with subscriptions to terrestrial operator A in the port of Piraeus. However, terrestrial operator A has roaming contracts with most terrestrial operators worldwide.
3. Furthermore, as the ship travels in areas where there is no terrestrial coverage, the UEs of the crew are also equipped with NTN access capabilities, even when the feeder link is unavailable.
4. TN operator A recognizes the importance of worldwide roaming and, therefore, has also established roaming agreements with NTN operators such an NTN operator A.
5. The crew on the ship to be rescued provides its accurate position via NTN without requiring a feeder link connectivity.
6. The Coast Guard (boats and helicopters) closest to the ship, knowing the accurate position of the people to be rescued, must intervene urgently and perform a SAR mission on the ship.
7. The Coast Guard ship and helicopter approach the ship, and all are without terrestrial coverage.
8. The crew on the Coast Guard ship and helicopter uses UEs with subscriptions to terrestrial operator B. The UEs are also equipped with NTN access capabilities, even when the feeder link is unavailable. Terrestrial operator B has established roaming agreements with NTN operators such as NTN operator A.
9. Furthermore, the crew manually flies drones for monitoring the area and sending high-definition video and pictures in real-time to the other actors in the mission.

10. The SAR team needs to have seamless communication with the Coast Guard Headquarters at shore. The people at the headquarters use UEs with subscriptions on the terrestrial operator B. The UEs are also equipped with NTN access capabilities, even when the feeder link is unavailable. The terrestrial operator B has established roaming agreements with NTN network operators such an NTN operator A.
11. Therefore, the SAR team on site and the Coast Guard Headquarters at shore have direct NTN communication without a feeder link. They may be served by the same NTN, or they may be served by different NTN that are connected via Inter-Satellite Links (ISL). Examples of the included communication services are:
    a. Voice services, including 3GPP MCPTT, within the SAR Teams, between SAR teams and headquarters and between the Ship crew and the SAR teams or headquarters.
    b. Video surveillance, including 3GPP MC video: high-definition video transmission with low communication latency (LEO satellites).
    c. Continuous data, including 3GPP MC data, upload for data analytics at the Coast Guard Headquarters: high uplink data volume.
    d. Support information from the Coast Guard Headquarters to the SAR team on site: high downlink data volume.
    e. Sensor data, including 3GPP MC data, collection by drones and communication of position data, etc.: medium/low data rate, no restriction on NTN communication latency.
    f. The C2 (Command and Control) of the drones.

Scenario 3: Coast Guard Intervention with Multi-link Support for Reliable Roaming

This scenario is the combination of Scenario 1 and Scenario 2, in which the UE terminals at sea can roam into the High Seas or into other countries so that we should assume that the operational area may reach into other countries or into the High Seas. During the operation, the services operated by the Coast Guard should transition reliably between coastal TN connectivity to NTN connectivity. The transition needs to be without interruption and without any service degradation, even if the UE terminals go far out at sea or move into the vicinity of other countries coastal areas. This is illustrated in Figure 7:.

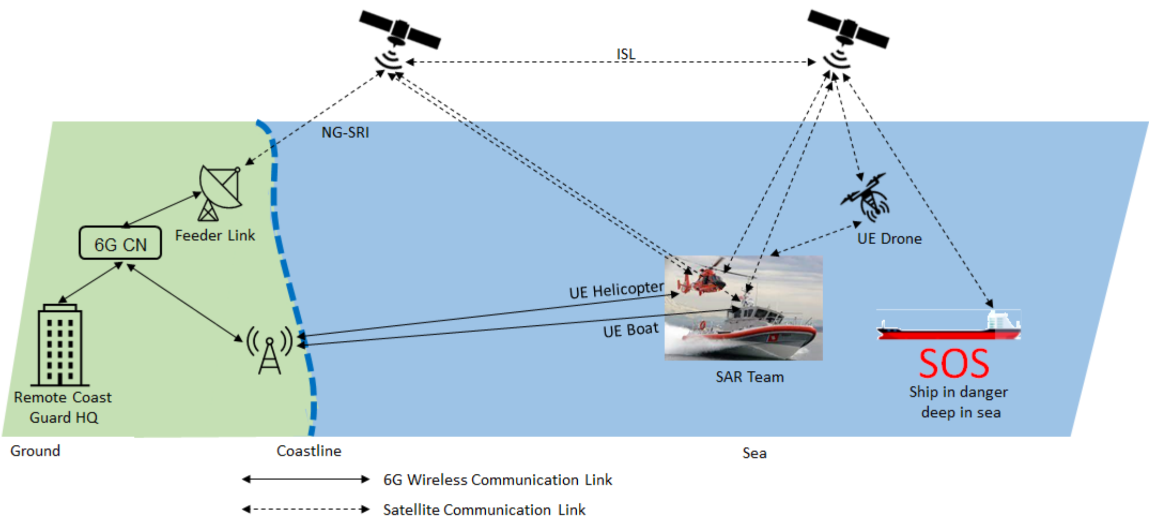

FIGURE 7: COAST GUARD OPERATION WITH MULTI-LINK SUPPORT FOR RELIABLE ROAMING IN DIFFERENT COUNTRY AND REGULATORY ENVIRONMENTS

Scenario 4: Coast Guard Intervention with Seamless Handover to Different Feeder Links for NTN Network Connection

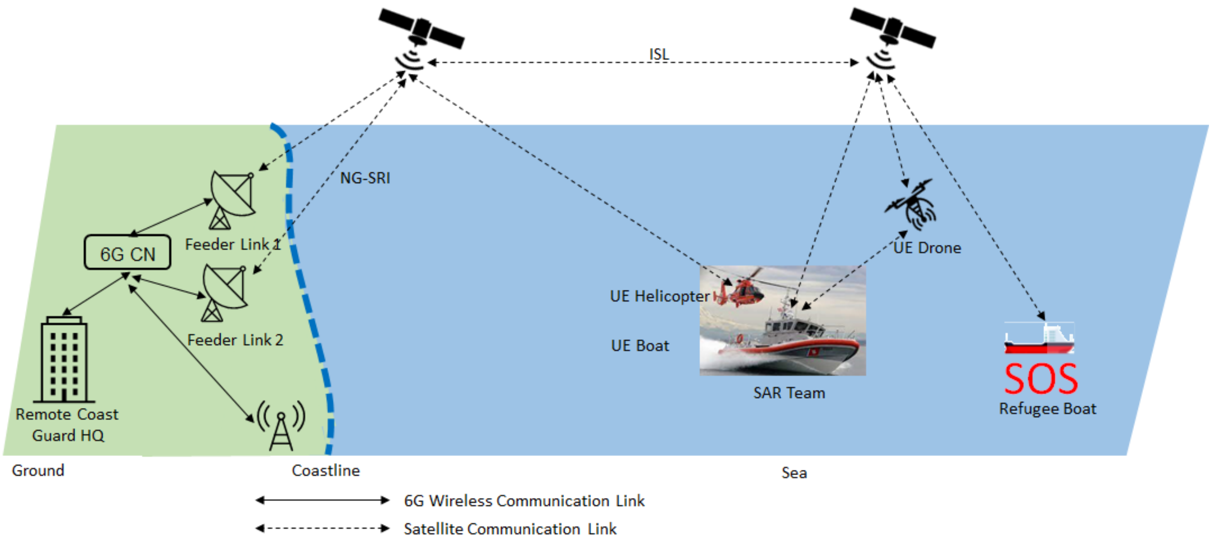

FIGURE 8: COAST GUARD OPERATION WITH SEAMLESS HANDOVER TO DIFFERENT FEEDER LINKS FOR NTN NETWORK CONNECTION WITH SERVICE CONTINUITY WHILE CHANGING THE FEEDER LINKS.

This scenario foresees the seamless roaming of the NTN service between different feeder links while maintaining the connectivity to the UE equipment and the required Quality of Service levels. This is illustrated in Figure 8:, while the scenario description for seamless feeder link handover in sea border area is as follows:

1. The Coast Guard operates for border control in a remote area close to High Sea and other countries sea borders.
2. In this area, the TN coverage is present but unreliable and the NTN network is used for the operations of the coastguard.
3. A refugee boat appears on the distance and the Coast Guard needs to intervene beyond its normal operational planned range.
4. It uses its search and rescue equipment and the NTN provided seamless coverage beyond borders to approach the rescue ship fast with a drone to inspect the situation.
5. The roaming into another country requires a feeder link change of the NTN network. This is executed without connection loss in a seamless manner to ensure that the important search and rescue missions can continue without interruption of communication links.

Finally, in all the previous described scenarios, with some modifications, the UAVs can be also used for extending the coverage covering the blind spots of satellite.

4.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The benefits and key enablers envisaged by the 6G-NTN project for this use case cover:

- **[Enabler #1]** As mentioned earlier, in this use case, it is very critical to have accurate positioning of the vessels and the people on board who requested to be rescued when any accident happens during the navigation at sea, regardless of whether there is any network infrastructure around the vessels or not. Furthermore, the accurate positioning of the actors within the SAR team (Ships, Helicopter, Drones) will allow the Coast Guard headquarters to have full view of the situation details. In this context, sidelink positioning (a core topology of 5G) is important to be supported between vessels in order to obtain more precise positioning information when any vessel accident happens at sea. However, currently ongoing 3GPP works on NR sidelink enhancements, including sidelink positioning, need to be continuously enhanced to provide more optimized performance to maritime communication environments where much longer distance needs to be supported, earth curvature also needs to be considered, and other potential impacts from antenna heights and the sea surface wave along with vessel movement need to be analyzed. These enhancements will be addressed by 6G.

- **[Enabler #2]** In addition, for these critical life missions the reliability and continuity of service as well as the low latency, are necessary. Despite the recent advancements in wireless communications on land, offering reliable, low latency and high-speed data rates for maritime communication remains challenging. Terrestrial base stations cannot be installed far offshore and in oceans, and hence, regular mobile phones cannot be connected to terrestrial cellular broadband networks when far offshore (the maximum reach is between 20 and 25 km from shore in many countries). For these reasons, satellites are a crucial pillar in maritime communications. Satellites are essential in providing connectivity in unconnected oceans; however, user mobile devices operating on terrestrial networks cannot directly connect to satellites. The current NTN solutions up to 3GPP Rel-18 require a feeder link to connect the satellite with the ground network, *e.g.*, to facilitate the E2E link setup between two communication UEs, which results at this moment in high cost, high latency, and limited available bandwidth.
- **[Enabler #3]** Since 6G NTN is expected to provide a ubiquitous coverage to complement the TN coverage, it is critical to support direct communication over satellite(s), even when and/or where a feeder link is unavailable. Therefore, connecting UEs, such as 6G ones, directly to an NTN can be possible, but we need to rely on emerging LEO satellite constellations orbiting a few hundred kilometers from Earth, as they can satisfy the low latency requirement. Moreover, in this case there are several challenges to be addressed, such as the high Doppler effects. In this context, a new dynamic network paradigm is desired for wide-band ubiquitous coverage in the coming 6G era, where multi-connectivity and link diversity need to be supported. This can be obtained with the integration of UAVs to complement terrestrial and satellite networks bridging the 5G/6G divide between those sailing on-board and users on land.
- **[Enabler #4]** Last but not least, privacy and security are very important aspects of the SAR missions and, hence, 3GPP public safety services, including mission-critical push-to-talk, mission-critical data, and mission-critical video should be supported; therefore, the 6G network should be able to fulfil all the mission critical requirements.

Final, we can say that a novel network architecture paradigm which will allow accurate positioning, low latency, high data rate, multi-connectivity, direct connectivity over satellite, privacy and security is essential for the SAR mission and this is envisioned to be supported by 6G-NTN networks.

4.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

Service capabilities: The following service capabilities should be included (see also Table 3:):

1. Real-time reliable voice (including 3GPP MCPTT) connection between all UE terminals and with the Coast Guard Headquarters.
2. Real-time reliable video (including 3GPP MC video) data collection and partial processing of data with edge computing capabilities to detect and identify specific

scenarios (*e.g.*, person in the water, lifeboat, refugee boat, any potential coastal threats, etc.). Drones should be able to transmit in real-time high-definition pictures and videos captured by embedded cameras.

3. Sensor data (including 3GPP MC data) collection by drones and communication of position data, etc.

TABLE 3: SERVICE CAPABILITIES FOR THE SCENARIOS ENVISAGED IN COAST GUARD INTERVENTION

Service	Throughput and Reliability	Latency
Voice connectivity between UE in Coast Guard Intervention	Extremely reliable, even under challenging weather (>99.9% p.a.)	Low
Video links between UE in intervention scenario	High data rates, real-time data transmission, highly reliable transmission of data (>99.9%)	Very low
Sensor data collection	Medium/Low data rate, real-time sensor data collection and processing	Not constraining

Positioning and Timing Services: The accurate positioning of the actors within the SAR team (Ships, Helicopter, Drones) allows the Coast Guard Headquarters to have a full view of the situation details. Furthermore, the accurate position of vessels and people on board who requested to be rescued when any accident happens during the navigation at sea is essential.

Device density: Few drones are expected to fly at the same time over a given area. Furthermore, the crew of the Coast Guard ships and helicopters will be involved in the SAR mission.

Type of terminal: Drones, vessel-mounted, and smartphones.

Coverage range: More than 99% of the coast and sea will be covered with the collaboration of NTN, and TN.

Mobility pattern & Velocity: The Coast Guard Intervention is foreseen to operate in Coastal areas of any country, possibly in the immediate neighborhood of other countries and possibly extended into the high sea areas. This implies possible roaming between different countries, between different regulatory regimes, and to the high seas with no TN coverage. The connectivity may also be only possible with NTN network segment components.

Environment specificities: Reliable coverage and connectivity should be provided in open sea even under bad weather conditions**.**

Coexistence scenarios: The intended scenario foresees the requirement to consider this scenario in coexistence with others.

Policies and regulatory constraints: The ability to deliver the services described in this use case is impacted by the current regulatory environment at both international (ITU-R Radio Regulations) and national (domestic licensing rules) levels. Emissions from terminals on the move (maritime mobile or aeronautical mobile) communicating with a mobile base station on the ground are typically licensed as terrestrial mobile services following domestic rules and expected to be in alignment with the frequency allocation as outlined in the ITU-R Radio Regulations. For the same terminals on the move (maritime mobile or aeronautical mobile) communicating with a space station are limited to operate in certain frequency ranges allocated to mobile satellite service and subject to international and/or domestic rules to protect terrestrial services in the same frequency ranges. In the case of maritime services, certain countries impose limitations to control the power flux density measured at the coast. Based on current spectrum allocations at international level, the frequencies of the C and Q/V bands may not be immediately available to deliver this use case and modifications at the international level will be necessary.

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5 UC2: AUTONOMOUS POWER LINE INSPECTION USING DRONES

Aerial drones have become an essential tool for many companies wanting to inspect infrastructure, monitor industrial sites, or create 3D models for digital twins. But the connectivity services that are available today hardly offer seamless connectivity for drones in mobility over remote areas, thus limiting the growth of this new market. This use case illustrates the related challenges, through the example of long-range power line inspection. However, it could be easily transposed to other verticals, such as Oil / Gas (pipeline inspection), Railways or Road transportation (road infrastructure inspection).

Power line inspection has been historically relying on helicopters for data collection along some tens of thousands of kilometers, and on technicians, climbing on electric pylons, scaffolding or cranes for in-depth monitoring. This method shows very limited performance, it is highly time-consuming, it has high impact on carbon emissions, and it presents high risks for technicians. Drones have thus been considered as an attractive alternative to increase the frequency of routine inspections, to facilitate troubleshooting, reveal any anomaly and potential faults or defects (such as bird's nests, lightning strikes, rust/corrosion, and damaged bolts), and address them in a timely manner. At the same time, drone surveillance can monitor damage to power lines caused by natural disasters or storms, to get a first evaluation of the situation, better organize repairs, and ensure safe operations for technicians.

However, current drone services typically operate in Visual Line of Sight (VLoS), i.e., a human pilot stays in the vicinity of its drone during the whole flight. This has two major drawbacks. First, without remote control, the drone operations are limited by the pilot's ability to travel along the power lines or to be on site after a natural disaster. Second, there is no backhaul connection to a cloud, such that there is no data offloading. Large amounts of data must be stored onboard and then, at the end of the mission, be manually transferred and post-processed.

- **Service category:** Service Continuity.
- **Targeted vertical:** Aeronautic & Drone, Utilities / Energy / IoT.
- **References:** [21] - [23]

Specific terminology:

- **Uncrewed Aerial Vehicle (UAV):** Also known as aerial drone.
- **UAV controller (UAV-C):** The drone's pilot / telepilot.
- **Visual Line-of-Sight (VLoS):** When the pilot is connected to her / his drone using direct communication. In this case, he /she needs to stay in the vicinity of the drone.
- **Beyond Visual Line-of-Sight (BVLoS):** When the pilot is connected to his / her drone through a network infrastructure. In this case, he / she remotely controls the drone.
- **Vertiport:** a fixed or transportable "drone airport". While in standby in the vertiport, the drone recharges the batteries and waits till the next mission.

5.1 DESCRIPTION OF THE PROPOSED SCENARIO

We consider a fully autonomous UAV to monitor the safety, reliability, and integrity of wires, electrical substation, and other power generation assets. The UAV operates in Beyond VLoS

(BVLoS), *i.e.* it is controlled from a remote control center instead of an on-site pilot, and transmits the captured images and videos to a cloud for (near) real-time analysis and decision making. For this use case, illustrated in Figure 9:, two scenarios are considered: one for routine inspection and one for manual inspection, in case an anomaly is detected.

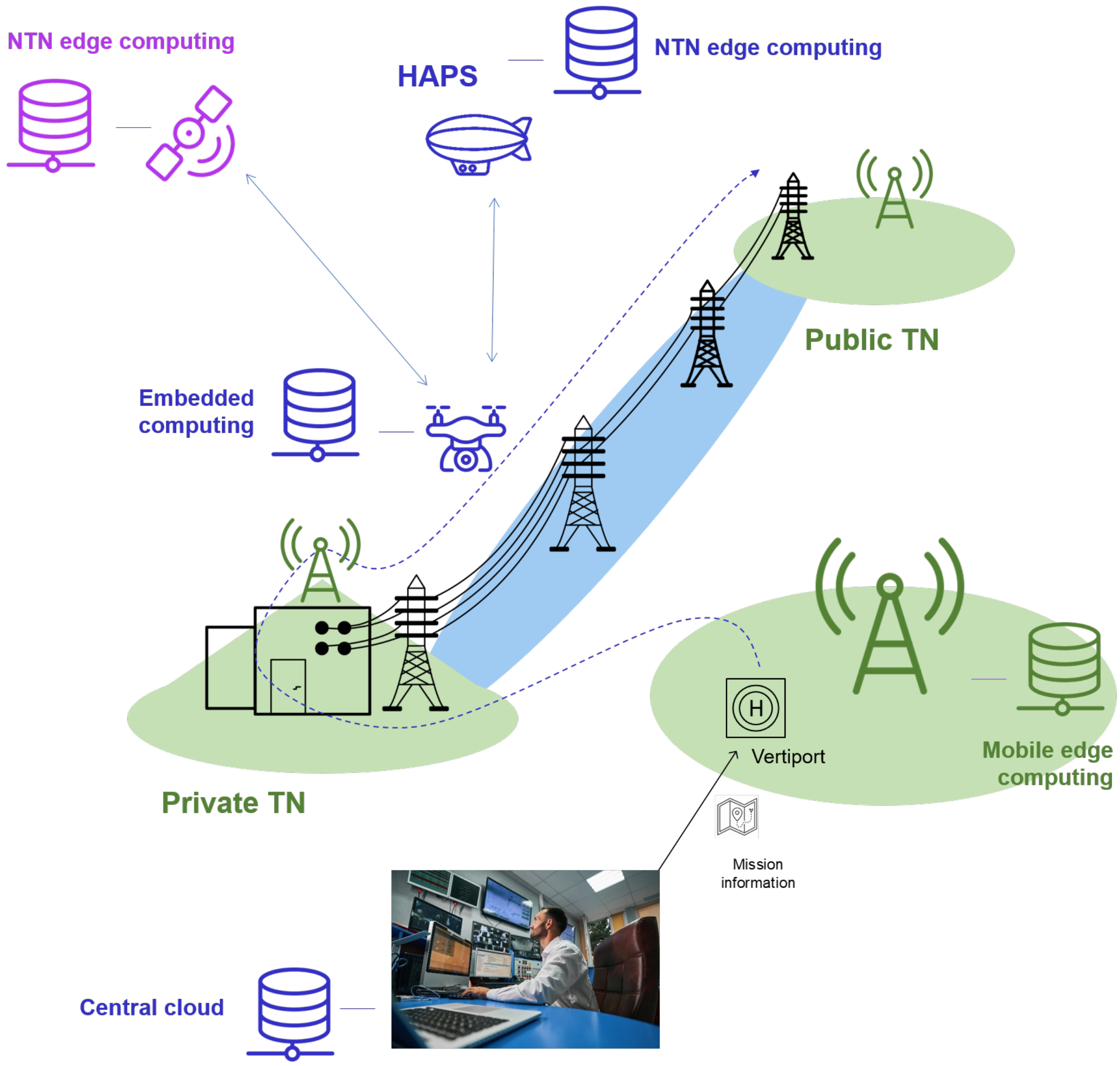

FIGURE 9: AUTONOMOUS POWER LINE INSPECTION USING DRONES

Scenario 1: Routine inspection

1. The UAV is stored in a vertiport and receives information and flight authorization for a new mission.
2. It takes offs and autonomously goes by power lines where it enters in routine inspection mode.
3. In this mode, the UAV follows a predefined trajectory and captures pictures and videos, which are processed partially by embedded Artificial Intelligence (AI) and partially by servers located at edge and / or central cloud. The right balance depends on the available bandwidth, experienced latency, service criticality, and drone battery status.

4. In case an anomaly is detected, an alert is triggered and the drone enters in manual flying mode (Scenario 2).
5. At the end of its mission, the UAV goes back to its vertiport, recharges batteries and waits for its next mission.

Scenario 2: Manual inspection

1. In case an anomaly is detected, a human pilot remotely takes control of the drone to make necessary verifications (additional pictures, zoom-in, etc.) and resolve any issue. If needed, maintenance operations are programmed.
2. When manual inspection is over, the drone re-enters in routine inspection mode or flies back to the vertiport.

In addition to services related to power line inspection, the UAV is permanently tracked and monitored by the UAV-C located in a remote control center.

5.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The benefits and key enablers envisaged by the 6G-NTN project for this use case cover:

- **[Enabler #1]** As investigated in [21] the low latency and high throughput capabilities of next-generation terrestrial networks would enable such use case. Nevertheless, high-voltage transmission lines and transformers are generally located in rural zones, far from cities and inhabited areas, such that the TN infrastructure does not always match the power grid distribution. Today, if out of terrestrial coverage, the UAV remains isolated from the servers and the collected data should be either processed offline or onboard, with no possibility for alert triggering and manual flight mode. Furthermore, embedding sophisticated data processing would imply high battery drainage, as well as costly drones.
- **[Enabler #2]** The drone should be able to seamlessly and transparently handoff between terrestrial and non-terrestrial networks, while transmitting data (*i.e.,* in connected mode). The drone may be covered by either public terrestrial networks or private ones (*e.g.,* around electrical substations, at take-off and landing). The remote control station and grid operator's cloud are expected to be on private infrastructure.
- **[Enabler #3]** This use case requires compact NTN terminals, to be mounted on drones.
- **[Enabler #4]** Reliable positioning using 6G-NTN technologies could complement legacy GNSS positioning techniques and offer higher resilience with respect to drone navigation.
- **[Enabler #5]** This use case would highly benefit from automated deployment of network services, for guaranteed quality of service, and flexible orchestration of edge computing components to optimize data processing offloading.

5.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

The following constraints can be considered for this use case.

Service capabilities: As in [21], the UAV is equipped with one Light Detection and Ranging (LIDAR), for collision avoidance, one LIDAR for infrastructure inspection, one camera for 4k video streaming and one sensitive camera for night image processing. This traffic is mostly uplink and may reach up to 200 Mbps.

Service Latency: AI data processing is quite sensitive to delay and throughput variations, in particular at a TN / NTN handover, and to potential connection loss. To compensate for the reduced throughput and increased latency induced by NTN communications, a drone may embed part of AI processing, but at the cost of increased battery consumption, lower integration to other workflows (*e.g.*, digital twin) and much larger initial investment for each aircraft. Optimization of the edge & cloud offloading capabilities would be of high interest.

Positioning and Timing Services: A very tight control of the drone 3D location is needed for both the routine inspection and the manual flight modes. An erroneous positioning could cause the drone to get too close to power lines, with a high risk of electric arcs to the drone.

Device density: Only a few drones are expected to fly at the same time over a given area. Note that, high-voltage power lines are often geographically isolated such that very little traffic is expected in the close vicinity.

Type of terminal: Drone designs are evolving quite quickly to enhance endurance, speed, and payload capability (up to several kilos). Four types can be envisaged: 1) multi-rotors drones, which generally have a shorter battery lifetime but can fly in stationary mode; 2) long-range fixed-wing drones with much lower power consumption but without stationary flight mode; 3) vertical take-off and landing (VTOL) and hybrid drones, with increased flight mode versatility; and 4) platforms embedded in airships. In all cases, current NTN terminals may represent a non-negligible weight and volume, implying more stringent operational constrains (increased distance to power lines, maneuverability, flight authorization harder to obtain, etc.). Next, the integration of an NTN-terminal within a drone will be constrained by aerodynamics and should account for the inclination of the drone while moving, turning, taking off or landing (roll and pitch up to 180°, yaw of 360°, possibly at high velocity). The material used for manufacturing (*e.g.*, carbon fiber, composite material), as well as the proximity of rotors and battery, may affect the GNSS capabilities, as well as antenna / waveform properties.

Coverage range: Power line inspection missions are expected to cover hundreds of kilometers per day.

Mobility pattern & Velocity: The UAV considered for this use case flies at a maximum velocity of 70 km/h, along linear trajectory (generally known in advance) with a relatively constant height from the ground. In the manual flying mode, the drone is expected to move at a lower velocity, but with a much wider motion range (turning around electrical pylons, going up and down, etc.). No cross-border scenario is envisaged for this Use Case.

Environment specificities: This use case is outdoor but specific environmental constraints exist due to the proximity of power lines or electrical transformers and to the altitude (the drone's flight height altitude is up to 120 m).

First, drones require electromagnetic shielding, which can affect the antenna radiation properties, and the ambient electromagnetic field may disrupt the positioning system, such that using redundant localization systems is seen as essential.

Second, airspace is a new radio environment for terrestrial networks. When in the air, a drone is no longer affected by the attenuation resulting from trees or buildings, but it may receive interference from distant sources. In addition, cellular networks are designed for terrestrial use. Antennas are tilted down toward the ground, with vertical side lobe power limitations. The resulting effect on aerial coverage is generally negligible over rural areas but may affect the TN / NTN handover probability over urban zones ("ping pong effect"). Radio propagation models for aerial LTE coverage have been proposed in 3GPP TR 36.777 (Release 15) [23].

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Coexistence scenarios: In November 2022, the ECC (Electronic Communication Committee) adopted [22], also referred to as Decision 22-07150. This decision provides harmonized technical conditions for the usage of aerial UE for communications in the following MFCN harmonized bands: 703-733 MHz, 832-862 MHz, 880-915 MHz, 1710-1785 MHz, 1920-1980 MHz, 2500-2570 MHz and 2570-2620 MHz. Such conditions have been translated into new Out-Of-Band Emissions (OOBE) limits for aerial UEs and no-transmit zones (*i.e.*, 3D airspace volumes where a drone is not allowed to use some frequency bands). Such decision raises several challenges to be addressed with respect to coexistence scenarios in C-band and the new waveform to be designed.

Policies and regulatory constraints: Drones are submitted to specific airspace regulation and conditions for flight authorization primarily depend on its weight and size. Smaller antenna design is thus a key asset for this use case. In addition, providing the drone with ubiquitous & always-on connectivity can greatly ease procedures to get authorized to fly.

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6 UC3: URBAN AIR MOBILITY

Urban Air Mobility (UAM) has been defined by EASA (European Union Aviation Safety Agency) as “a new safe, secure and more sustainable air transportation system for passengers and cargo in urban environments” and by NASA, as “safe and efficient air traffic operations in a metropolitan area for manned and unmanned aircraft systems.” This new concept spans intra-city, suburban, and inter-city passenger transport and package/cargo deliveries, and both manned and unmanned aircrafts, i.e., remotely piloted or with a pilot on board, integrated into multimodal transportation systems. It promises faster and more sustainable low emission journeys, smarter use of urban infrastructure and reduced congestion within cities.

Urban Air Mobility is envisaged for goods delivery for citizens and businesses (e.g., between warehouses, distribution hubs, or directly to the customer), for urgent medical delivery (to overcome ground congestion), for emergency situations (to transport first responders) and later on, for on-demand, highly automated, passenger transportation (to complement other options such as subways and buses with scheduled operations or on-demand door-to-door).

The use case proposed in this section raises unique challenges. Compared to other scenarios, it is less about high performance data transmission than about UE management over some airspace volume, for example over aerial corridors. While some of the related services are already supported by 5G (and even 4G) terrestrial networks, only a multi-layer fully integrated 6G-NTN architecture will be able to:

1. Open high-altitude airspaces to drones (from ground to aircrafts cruising altitude, with no terrestrial coverage);
2. Ensure sufficient network resilience and fulfill the aviation’s requirements for air & ground risk mitigation, at a national scale;
3. Accommodate a huge diversity of drones within a unified and interoperable traffic management system, for both manned and unmanned aircrafts.

To meet such goals and to prove that 6G-NTN is safe enough to support future UAM services, new technical requirements need to be defined, in alignment with U-Space services. As detailed by EASA, the U-space is a set of new services towards the full digitalization and automation of air traffic control and management, to support safe, efficient, and secure access to airspace for large numbers of drones.

- **Service category:** Service continuity, Service Ubiquity.
- **Targeted vertical:** Aeronautic & Drone, Road Transportation / Smart Cities, Public Safety
- **References:** [23] - [27]

Specific terminology:

- **EASA:** European Union Aviation Safety Agency
- **C2-Link:** The C2-Link is the data link between the uncrewed aircraft and the (potentially remote) control station which permits the safe and secure management of flights within a shared airspace.
- **C2CSP:** C2 Link communication service provider

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- **U-Space:** It is a set of new services to support safe, efficient and secure access to airspace for large numbers of drones. It is based on a Service-Oriented architecture, where open, interoperable and standard based interfaces are offered to the various stakeholders of the drone ecosystem.
- **USSP:** U-Space Service Provider
- **Drone operator:** EASA has defined the drone operator as any person or organization, "who owns or rents one or more registered drones". The pilot is the one who "is actually flies the drone, without necessarily owning or renting the drone".

6.1 DESCRIPTION OF THE PROPOSED SCENARIO

Providing connectivity services for the so-called C2-Link (C2 for Command and Control) is critical for drone operations in general, and for BVLoS missions in particular. A 6G-NTN architecture shall thus provide specific services to be recognized as C2CSP (C2 Link communication service provider) and be used for UAV communications. Some ongoing studies seek to leverage 3GPP cellular network mechanisms to support UAV operations and propose a C2CSP model, but so far, NTN are not yet covered. The three scenarios proposed in the following cover part of such C2CSP services, they are respectively illustrated in Figure 10:, Figure 11: and Figure 12:.

Scenario 1: On-demand creation of aerial corridors for last-mile delivery (pre-flight service)

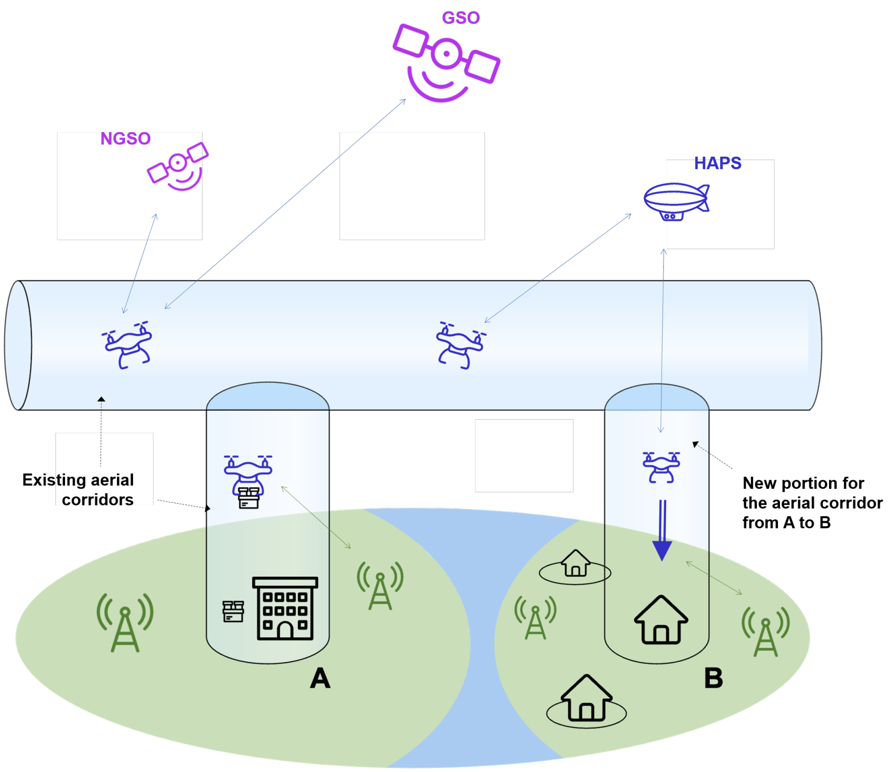

FIGURE 10: ON-DEMAND CREATION OF AERIAL CORRIDORS FOR LAST-MILE DELIVERY

1. A goods delivery is scheduled following an online order and a cargo UAV needs to fly from a warehouse A to a customer B. A request for flight authorization is automatically generated and sent to the U-Space system and 6G-NTN system (see Figure 10:).

2. To get flight authorization, a sufficient quality of service must be provided within the overall corridor, at any time of the flight. The planned trajectory starts within a pre-existing aerial corridor, shared with other drone operators, but a new portion needs to be created to reach B.

3. Due to specific airspace restriction in the vicinity of B, the cargo UAV needs to fly at an altitude sufficiently high to leave the TN coverage. The 6G-NTN system thus plans a TN / NTN handover to guarantee connectivity.

4. Once the trajectory is planned and the flight authorized, dedicated resources are automatically set up on the TN / NTN infrastructure covering this corridor.

As in [16], the network shall provide additional information to execute pre-flight preparation (e.g. flight recommendation, based on network capacity and QoS information over both TN and NTN, for the different orbits). Such service implies highly interoperable interfaces for network function exposure and data exchange between the network operator(s) and the U-Space service provider, as presented in [17]. In the case of a multi-layer 6G-NTN architecture, such service also raises novel challenges related to business model.

Scenario 2: Anti-collision and autonomous deconfliction (in-flight service)

Even if flight trajectories are planned to prevent any collision, they are rarely perfectly executed. Deviation in time or distance, or unplanned events, may lead to a risk of collision. Geo-awareness and real-time observation of drone traffic is thus required.

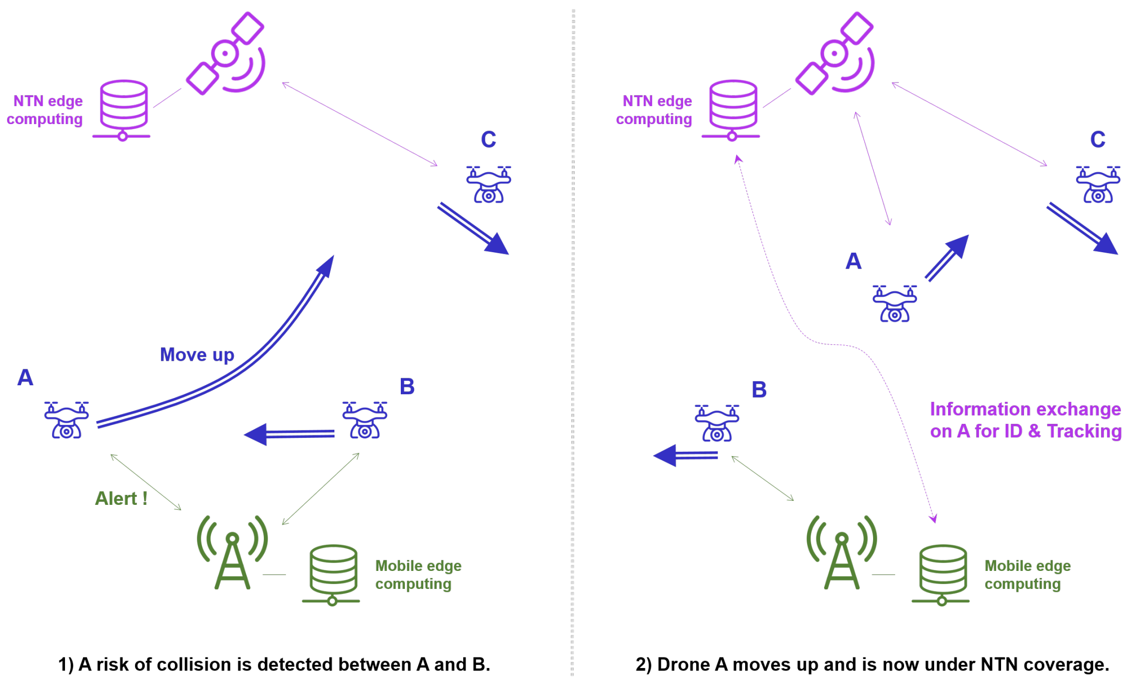

FIGURE 11: ANTI-COLLISION AND AUTONOMOUS DECONFLICTION

1. Three drones, A, B and C, are flying over a given area and transmit to the U-Space system their identification, telemetry, and accurate positioning in real-time. A and B are provided with TN / NTN capabilities and currently using terrestrial connectivity. C has only NTN capabilities and is flying at a higher altitude.

2. Positioning information is processed by algorithms for conflict detection and resolution: if a conflict is detected, an alternative trajectory is proposed to all concerned UAVs. As B is flying with high velocity, low latency processing is needed for a timely deconfliction strategy. Distributed computing is envisaged for this scenario. Since A and B are in close vicinity, they are processed by a function deployed in the same mobile edge computing server, for faster conflict resolution. Data from C is processed within a space edge computing server. Both servers communicate (at lower rate) to ensure that A / B does not risk to collide with C.

3. A risk of collision is detected between A and B. Hence, A receives a trajectory modification and flies up, thereby leaving terrestrial coverage. Seamless handover is thus operated from TN to NTN, with continuity of the Identification & tracking service. Location information from A is now processed together with C.

Scenario 3: Emergency situation management (in-flight service)

1. Due to an accident on a road (see Figure 12:), a given airspace (in red) must be closed to UAV operations and a helicopter with first responders needs to cross an aerial corridor (in yellow).

2. The TN / NTN infrastructure is notified and an alert is sent, in broadcast or multi-cast, to all drones which may cross the closed airspace or targeted corridor. These drones receive a new trajectory over another aerial corridor (in blue).

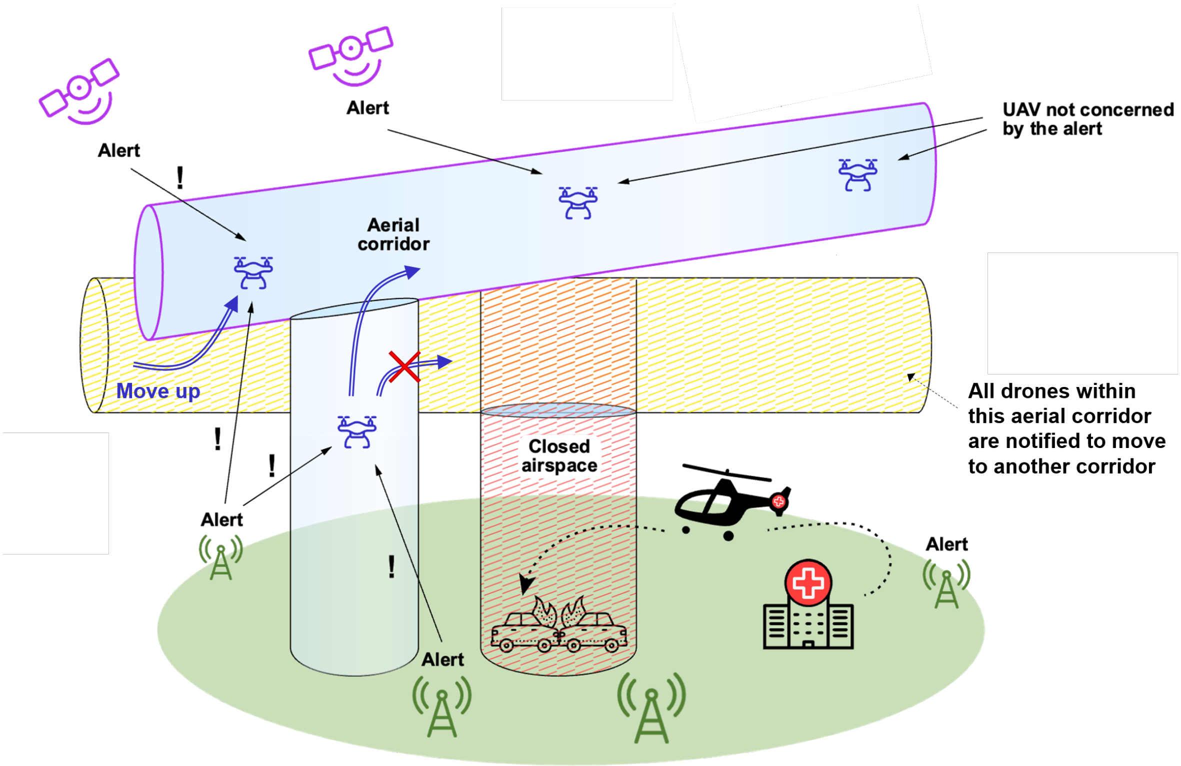

FIGURE 12: EMERGENCY SITUATION MANAGEMENT

6.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The benefits and key enablers envisaged by the 6G-NTN project for this use case cover the following aspects.

- **[Enabler #1]** The drones should be able to seamlessly and transparently handoff between terrestrial and non-terrestrial networks, while transmitting data (*i.e.*, in connected mode) and maintaining the continuity of U-Space services, in particular Identification & Tracking.
- **[Enabler #2]** Reliable positioning using 6G-NTN technologies would complement legacy GNSS positioning techniques and offer higher resilience with respect to drone navigation.
- **[Enabler #3]** This use case would highly benefit from automated deployment of network services, for guaranteed quality of service, and flexible orchestration of edge computing components. In particular for Scenario 2, computing components should "geographically" follow the drones and dynamically migrate as close as possible to them.
- **[Enabler #4]** High interoperability of network service exposure and coverage information exchange between the different layers of the 3D architecture (from terrestrial to vLEO / LEO / MEO / GEO) and the U-Space system is critical for this use case, towards unified UAV traffic management.

6.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

The following constraints can be considered for this use case.

Service capabilities: Urban Air Mobility includes:

- Low-rate data communication services, for traffic information, aircraft monitoring and potentially emergency management. This covers air-to-air and air-to-ground links, both uplink and downlink.
- Uplink video streaming may be needed, *e.g.,* for remote piloting.
- AI & Onboard computing
- Edge services for low-latency drone traffic tracking and deconfliction, including AI-based mobility & anti-collision management for aerial users.
- Broadcast / multicast communications can be envisaged for alerts and notifications.

Positioning and Timing Services: A very tight control of the drone 3D location is needed to ensure airspace safety.

Device density: Compared to Autonomous Power Line inspection, a much higher number of drones are expected to fly simultaneously over a given area. In [26] Low, Medium and High UAM traffic densities have been defined, depending on either temporal or distance spacing between drones.

Type of terminal: Urban Air Mobility will encompass a wide range of drones, with various size, weight, battery lifetime, velocity, and flight altitude, from small drones, carrying medical samples of less than 1 kg to large aerial vessels for passenger transportation. This implies that a unified air traffic management should accommodate different levels of autonomy in drone operations (VLoS or BVLoS, partially or fully autonomous) and different connectivity capabilities (TN-only, NTN-only, both TN / NTN, other wireless technologies), to ensure airspace safety for all.

Coverage range: This use case operates at the scale of a city and potential of a region, for inter-city mobility along aerial corridors.

Mobility pattern & Velocity: Drones are expected to fly at a maximum velocity of 100km/h, generally along trajectories planned some days or some hours in advance, mainly within aerial corridors, with a relatively constant height from the ground.

Environment specificities: Currently, the maximum height for drone operations is set to 120m, to physically separate airspaces for manned and unmanned aircrafts and simplify traffic management. However, future airspaces will be integrated and interoperable, implying that UAM is expected to operate at much higher flight altitudes, from ground up to manned aircraft cruising altitudes. In this case, new interference scenarios may occur between aerial and terrestrial users, and the need to switch between TN and NTN will be much greater, especially when the drone is changing altitude, at take-off and at landing. Contrary to Autonomous Power Line Inspection, this UC is expected to largely operate over urban areas, and potentially with less favorable weather conditions (rain, clouds, wind).

Coexistence scenarios, Policies and regulatory constraints: Same as Power line inspection as main landscape. Specific rulemaking is under preparation by airspace regulatory bodies.

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7 UC4: ADAPTATION TO PPDR OR TEMPORARY EVENTS

6G NTN offers the opportunity to revise the way organizations from Public Safety and various other Verticals provision their network connectivity to make sure they can serve anywhere, anytime, reliable and efficient communications to respond to Public Protection and Disaster Relief (PPDR) events as well as temporary planned events, in which the user traffic demand is expected to surge at some point in time, and exceed the capacity offered by the default terrestrial infrastructure.

It is worth noting that some commonalities in terms of objectives can be found with use case UC1 previously described in Section 4, in which the four scenarios describe how coast guards can indeed serve anywhere, anytime, reliable and efficient communications to support their operations. However, whereas UC1 focuses on maritime scenarios where no TN impairment is considered, the following use case UC4 focuses on scenarios where an efficient combination of TN and NTN is required when TN is progressively repaired.

- **Service category:** Service ubiquity, Service scalability.
- **Targeted vertical:** Public Safety and Defense, Media & Entertainment.
- **References:** [28], [29]

Specific terminology:

- **First responders (FR):** the term generally refers to the public safety teams which oversee the response in case of an emergency situation. In this context, it both applies to teams from Public Safety (e.g., police, fire and rescue, ambulance/ Pre-Hospital Emergency Medicine (PHEM), SAR) or Defense (e.g., military teams). When an unexpected event such as a man-made or a natural disaster occurs, these teams are not immediately (at time t0) on site. Therefore, one of their objectives is to quickly reach the site and rapidly benefit from adapted means of communicating.
- **Event organizers:** in case of a planned event (e.g., a stadium event, an outdoor sport event or a concert in a temporary or remote area) for which the expected user traffic is anticipated to exceed the existing network capacity, if any. In that case, one objective of these stakeholders is to secure an additional and temporary network capacity in proportion of the anticipated user traffic during the considered planned event.
- **Greater public:** in case of both planned or unexpected events, the end users who are present on site during the event are expected to access the network, e.g., to give a situational report or request for help in case of a disaster, or to have an Internet session involving multimedia traffic linked with the nature of the event (e.g., in case of a concert or a sporting event), and so on.

7.1 DESCRIPTION OF THE PROPOSED SCENARIOS

Two scenarios are described hereafter to outline the importance of network support for the rapid and adapted deployment of PPDR operations.

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Scenario 1: Support FR communications

1. An unplanned event (e.g., a natural or a man-made disaster) occurs at time T_0, thereby requiring the rapid intervention of FR. It is assumed that in the wake of this event, the TN infrastructure on the designated area is temporarily damaged, as illustrated in Figure 13:.
2. A FR team happens to be present on site at T_0, and these FR users are able to use their cellular equipment immediately (e.g., smartphones, dedicated equipment with a cellular backhaul to the Internet and to the FR headquarters, etc.).
3. At time $T_0+T_{reconfSoftware}$, to support an adequate Quality of Experience (QoE), dedicated resource has been automatically set up on the NTN infrastructure covering the site for this purpose as soon as the event has been notified to the NTN infrastructure. As a result, FR users can access their dedicated services (e.g., interpersonal services like PTT, situational awareness applications, etc.) with a first level of QoS, consistent with the given number of users and dedicated resource allocated by the NTN network for this purpose.
4. Figure 14: shows that other FR teams progressively arrive on the scene of the event and require complementary resource and communications equipment. Therefore, at $T_0+T_{reconfHardware}$, additional NTN nodes (e.g., drones or HAPS) are deployed on site, seamlessly coexisting with, and complementing the existing NTN segment. With this deployment, all FR teams are able to access their dedicated services with a nominal second level of QoS, consistent with the total number of FR users and the performance offered by the NTN network augmented with additional NTN nodes.
5. While the FR teams conduct their missions (e.g., related to providing care to the victims and securing the assets), the terrestrial infrastructures are progressively restored. The 6G NTN is, by design, able to coexist (including in terms of the adequate frequency spectrum on which either network segment operates) with this progressive restoration. In addition, the equipment from the FR teams can switch from NTN to TN segment transparently, while their users keep their existing communication sessions, as shown by Figure 15:.

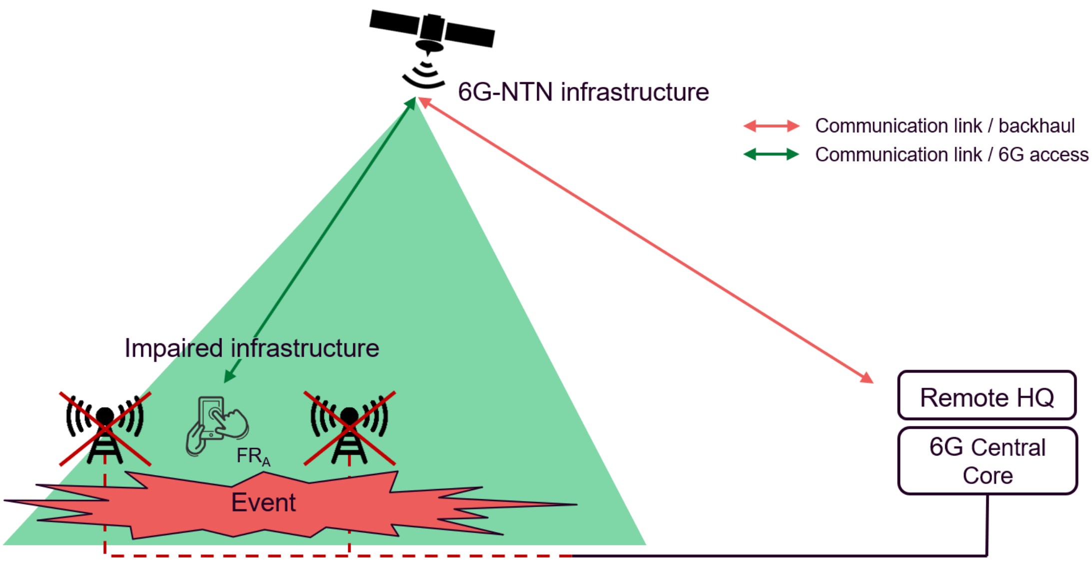

FIGURE 13: IN THE WAKE OF A DISASTER (STEP 1) FIRST RESPONDERS (FR_A) MAY IMMEDIATELY USE THEIR CELLULAR EQUIPMENT (FR1) VIA 6G NTN ACCESS (STEP 2)

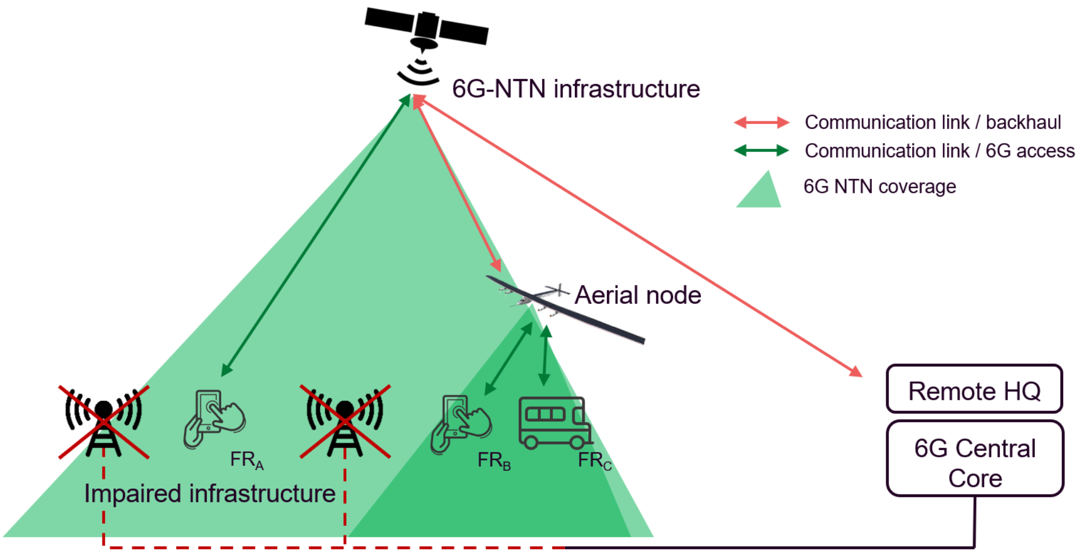

FIGURE 14: FRB AND FRC TEAMS PROGRESSIVELY ARRIVE ON THE SCENE OF THE EVENT AND REQUIRE COMPLEMENTARY NETWORK RESOURCE (STEP 4)

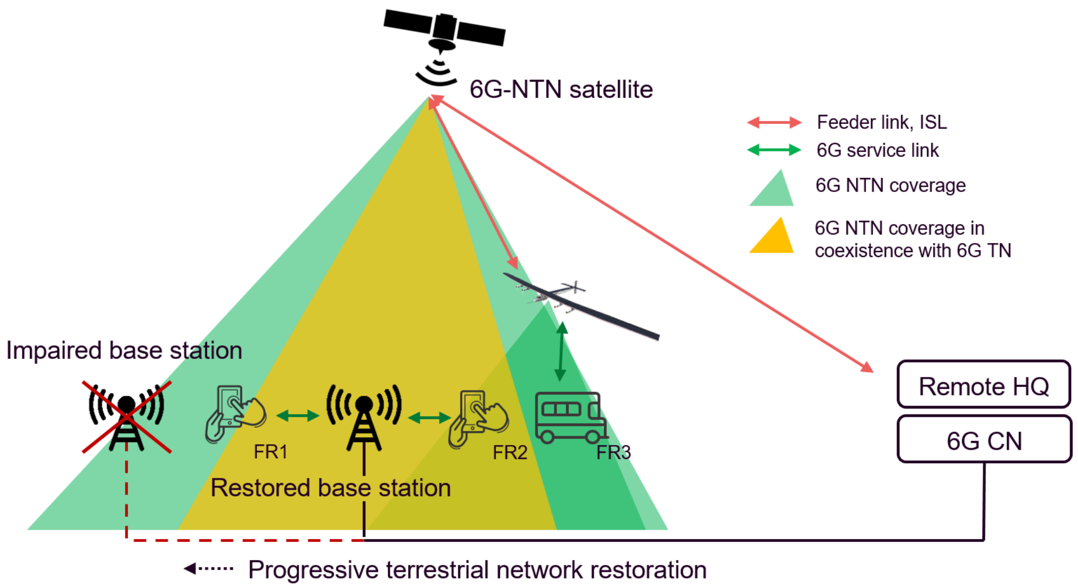

FIGURE 15: IN THE SUBSEQUENT PHASES OF THE EVENT RESPONSE, THE 6G NTN SEGMENT NEEDS TO COEXIST WITH THE RESTORED TERRESTRIAL INFRASTRUCTURE (STEP 5)

Scenario 2: Support the greater public communications

1. An unplanned event (e.g., a natural or a man-made disaster) occurs at time T_0, and it is assumed that in the wake of this event, the terrestrial infrastructure on the designated area is temporarily damaged.
2. Immediately at T_0, and until the TN is restored, the users from the greater public are able to notify their situation with their regular smartphones, which are able to transparently use the NTN connectivity.

3. At time $T_0+T_{reconfSoftware}$, those users are provided information on the event, and are able to easily interact with emergency services and deployed FR teams to provide situational awareness and ask for help, thanks to dedicated components which have been automatically set up on the NTN infrastructure within the area of the considered event.

When the terrestrial infrastructure is progressively restored, the smartphones from those users can transparently switch from NTN to TN segment, without the users losing their existing communication sessions.

7.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

In case of either planned or unexpected events, the responsible stakeholders (e.g., respectively the planned event organizers and the unexpected event FR) need to secure communications for all relevant users. Traditionally, these communications cannot entirely (or at all) be supported by the TN on site, either because the user traffic is anticipated to exceed what the existing network can deliver, or because this network has been temporarily damaged or shut off during the considered event. As a result, FR and event organizers traditionally plan, as a part of their own preparedness phases, the rapid deployment of their own means of communications to replace or complement the existing TN on site, if any. Such rapidly deployable equipment may encompass transportable base stations and cellular equipment such as Cells on Wheels (CoWs), aerial equipment such as drones, tethered balloons, High Altitude Platform Stations (HAPS) and satellite terminals, and so on. This traditional approach regarding the deployment of additional network capacity burden the organization or response teams with tasks such as provisioning the equipment and staff to operate this connectivity service with the desired quality of communications and deployment times [29].

It is envisioned that the 6G-NTN project will significantly alleviate such tasks and, in general, facilitate the corresponding concepts of operations, thanks to the combination of two intrinsic breakthroughs:

- **[Enabler #1]** First, the additional performance increase ambitioned with 6G networks will allow leveraging event organizers and FR-based use cases and push forward the level of service they ambition. Several 6G-oriented research projects have started investigating the benefits of 6G advances to further support public safety use cases [28].
- **[Enabler #2]** Secondly, the benefits offered by NTN in terms of service ubiquity and complementarity with respect to TNs will support the ability of accessing cellular connectivity, even when the TNs on site are damaged or unable to provide the necessary capacity.

The 6G-NTN project, leveraging on both 6G and NTN advances, will allow the extension of traditional public safety in many regards:

- **[Enabler #3]** Shorten the deployments for public safety connectivity, and even target near-instantaneous connectivity to support a first level of public safety communications, which can be further improved in subsequent temporary deployment phases with dedicated or additional equipment support.
- **[Enabler #4]** Enforce seamless connectivity when transitioning from TN and NTN segments and vice-versa, allowing an increased, consistent, and adapted QoE for all users (e.g., FR, event organizers and the greater public) of the communications system during the various phases associated with the occurrence of the planned or unexpected event.

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- **[Enabler #5]** Offer means of rapid and automated deployments of service components dedicated to handling the many phases in the wake of the occurrence of a planned or an unexpected event. With these new abilities, the 6G NTN network can rapidly bring on site customized services for the relevant users, e.g., components to support PPDR push-to-talk (PTT), situational awareness of the teams and greater public on site, collect and process data from deployed sensors and forward the processed data to headquarter or teams deployed on site, and so on. In addition, thanks to a deployment as close as possible to the event occurrence, latencies should be further decreased (e.g., for interpersonal services such as PTT between team members deployed on site) and QoE for the users on site improved.

In the following subsection, we describe how those enablers will support this use case through several scenarios in which user stories help understanding how the 6G-NTN architecture (and the aforementioned enablers) will support public safety and planned event operations.

7.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

In the context of this use case, the following usage requirements have been delineated:

Service capabilities: depending on the type of user (greater public, type of FR user), the service capability requirements may greatly vary. It is expected that text-based conversational and situational services will be needed for all users, as well as some form of voice support (including PTT for FR users). In addition, the use of video will trigger higher bandwidth needs (e.g., for remote health monitoring in case of a disaster medical assistance team requiring a tele-monitoring outside the disaster area).

Service availability: the communications shall be available for all types of considered users, and during all the phases of both user stories.

Experienced quality of communications: both user stories refer to differentiated QoE for the considered users. This notably refers to the two levels of QoS for the FR users described in steps 3 and 4 of the first user scenario. This also refers to the level of QoS experienced by the greater public in all steps of the second user scenario.

Network coverage: the 6G-NTN coverage should be scalable with the extent of the event and of the temporarily dysfunctional TN.

Network equipment: both user stories allowed identify some preliminary requirements regarding computational power, time of deployment $T_{reconfSoftware}$ as mentioned in steps 3 of both user stories, and other metrics related to softwarization and slicing.

Type of terminals: Both user stories underline the need for supporting mass-market smartphones, and in the case of FR users, there is a general need to serve all existing networked equipment traditionally used by these response teams. On that note, it is envisioned that the standardized architecture of the integrated 6G NTN / TN networks should allow network equipment interoperability and help avoid vendor locking effects. For the FR-specific devices, the existence of a unified network access technology should favor the emergence of a larger market of standardized terminals, thereby able to circumvent vendor-locking effect, reduce costs thanks to volume effects, and so on. Finally, it is worth noting that, as usual with the FR device market, there is a high requirement on privacy and security, and the 6G-NTN should offer security features at least consistent with what FR users experience today on their dedicated proprietary terminals.

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Usage: to be able to easily assess the intended usage (and performance) of the 6G-NTN connectivity, there is a need to express requirements related to the data rates (per type of user and terminals) and to the number of estimated users per surface unit.

Coexistence of NTN-TN networks: this use case has illustrated the need for a coexistence between the TN and NTN 6G networks, including the question of spectrum on which either segment is operated. This is especially important in times of scenario transitions: for instance, during the initial phases, when the event area in which the existing TN is only partially impaired, which implies that both types of networks will need to coexist in adjacent areas. Likewise, as described in step 5 of this use case first scenario, when the terrestrial infrastructure is progressively restored, the 6G-NTN footprint will need to seamlessly coexist with the dynamic pattern of terrestrial access network which is being restored. Finally, this subject of coexistence may also involve all additional NTN nodes that may be dynamically brought on the considered event area, as illustrated by step 4 of the use case first scenario.

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8 UC5: CONSUMER HANDHELD CONNECTIVITY AND POSITIONING IN REMOTE AREAS

Direct-to-handheld communications refers to the ability of a NTN infrastructure node (e.g. a communications satellite) to be able to serve consumer ground devices such as smartphones. In many direct-to-handheld NTN infrastructure designs, one of the prominent objectives is to minimize the modifications made on the smartphones themselves, ideally leaving the hardware and antenna design mostly untouched. These constraints on the ground user equipment have an obvious impact on such links since NTN infrastructure nodes will need to deal with faint signals from terrestrial smartphones. As a result, current direct-to-handheld designs struggle with many challenges regarding link capacity and the ability (or lack thereof) to serve consumer smartphones in indoor conditions. In addition, smooth integration of these links into a global TN / NTN network, in which transitions between the terrestrial and non-terrestrial segments are transparent to the user experience, is still a challenging objective with current 5G NTN Rel.17 architectures [31].

In this regard, as part of the 6G-NTN overall ambition, one objective is the support of smooth integration of smartphones from consumer and vertical markets alike, thereby offering a significantly increased QoE to the end-user regarding the ability to experience higher data rates, transitioning from TN to NTN links and vice-versa in a more transparent way (i.e., without loss of existing user communications sessions). In addition, the 6G-NTN project intends to support the ability to serve smartphones not only in outdoor conditions, but also in light-indoor conditions.

- **Service category:** Service Continuity, Service Ubiquity.
- **Targeted vertical:** Consumer market, all verticals which may require direct-to-handheld connectivity (e.g., Public Safety and Defense, Agriculture, Maritime, Energy, Mining, etc.).
- **References:** [30], [31]

Specific terminology:

- Semi-outdoor conditions represent a GNSS-hostile outdoor environment such as an urban canyon or a wooded area, where there are not enough satellites for positioning [30].
- Light indoor conditions refer to the ability to serve users in indoor conditions, but with the constraint that users are sufficiently close to the external walls or hull of the considered structure that the corresponding added attenuation does not exceed a given threshold, for instance in the range of 15 to 20 dB.
- WPAN: Wireless Personal Area Network.
- In the subsequent user scenario, a consumer user is a subscriber of an operated network, e.g., a subscriber of an MNO offering an integrated TN / NTN connectivity following the 6G-NTN architecture.

8.1 DESCRIPTION OF THE PROPOSED SCENARIO

A consumer user has subscribed to an MNO whose network offers a 6G terrestrial connectivity able to meet this user's regular connectivity needs, since it is assumed this user regular mobility pattern forms an area which is included in the MNO's terrestrial 6G footprint. Furthermore, this MNO offers an integrated TN / NTN connectivity following the 6G-NTN architecture.

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This user has prepared a long hike during his holidays in a remote mountain chain and aims to keep his friends updated of his trek. To this end, he intends to use his favorite GNSS-based trekking app, which can notify his group of friends of his progression, by various means including sharing real-time positioning information and pictures and setting up a dedicated vocal chat for the duration of the event. In addition, this user wants to share real-time video of his progression. He considered several possibilities, including the possibility of using a drone in follow-me mode or using his smartphone to capture small video footages at times. But he opted for a continuous video feed from a WPAN (e.g., Bluetooth) front camera fastened on a helmet, to be fully free to hike on a possibly challenging terrain.

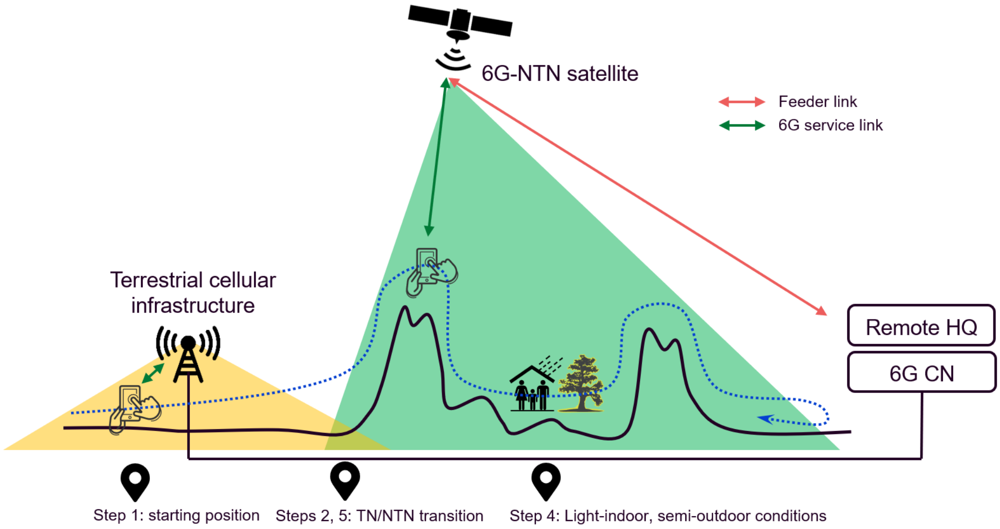

FIGURE 16: SEAMLESS SERVICE CONTINUITY FOR CONSUMER DIRECT-TO-HANDHELD

Scenario: Seamless service continuity for consumer direct-to-handheld

1. The day of his departure, this user has travelled to the starting point of his trek, as illustrated by Figure 16:, step 1. This location is still under his MNO's 6G TN coverage, and among other preparations, this user powers on his front camera, sets up the WLAN connection with his smartphone, and starts all needed apps to share with his group of friends some data, including position, messages, pictures, voice, and video.
2. The user starts his trek and soon leaves his MNO's 6G coverage. Since this MNO offers an integrated TN / NTN connectivity following the 6G-NTN architecture, the user's smartphone can seamlessly transition from a 6G TN to a 6G NTN connectivity and the user is able to keep all his applicative data flows open, without any noticeable interruption of the 6G service.
3. To deal with the lower capacity offered by the 6G NTN connectivity, some flows (e.g., the 4K video flow) may be dynamically downgraded at applicative level, but the 6G NTN link shall offer sufficient capacity to continue streaming video flow with e.g., a Standard Definition (SD) or High Definition (HD) quality.
4. During his trek, Figure 16: shows that the user crosses a challenging terrain, e.g., enters sites with obstacles such as small canyons or forest canopy. In these semi-outdoor or light-indoor conditions, 5G networks (and earlier generations) would be unable to cope with either the temporary loss of direct line-of-sight conditions or the reduced number of GNSS satellites in sight to derive the user position. In contrast, the 6G NTN is still able to serve the user in these conditions, at the expense of a decreased

performance, notably regarding the user bitrate and the precision of the position. In the case of this user, a temporary interruption of the most bitrate-demanding flows may be needed, while the text-based flows shall seamlessly be supported by the 6G NTN network in these conditions.
5. At the end of his trek, this user re-enters the area covered by his MNO's 6G TN coverage. The user's smartphone can seamlessly transition from a 6G NTN connectivity to a 6G TN connectivity. Consequently, some of the most bitrate-demanding flows may dynamically revert to their original setting (e.g., 4K video flow).

8.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The benefits brought by the 6G-NTN architecture are as follows:

- **[Enabler #1]** Current direct-to-handheld designs suffer from limited bandwidth offered to the direct-to-handheld users. Therefore, use cases are currently merely limited to text-based usage, and phone and limited data usage such as light Web browsing are still a distant objective. In contrast, 6G-NTN allows higher bitrates, opening perspectives for a wider range of usages.
- **[Enabler #2]** Transitioning from terrestrial to NTN (and vice versa) is only imperfectly supported in current direct-to-handheld solutions. It generally refers to long handover procedures in which zero-packet loss and the continuity of user experience is not addressed. In the most common cases, current generations of direct-to-handheld solutions rely mainly on roaming features to transition between the considered network segments, with a long convergence time and associated constraints which restrict the possible usage to specific use cases in which users do not need to frequently switch from terrestrial to non-terrestrial segments, and vice-versa. In contrast, 6G-NTN, thanks to an intrinsically integrated TN / NTN architecture, allows extended usages whereby users may frequently transition from both types of user segments. This allows, as will be illustrated bellow, richer and more useful user stories.
- **[Enabler #3]** To our best knowledge, all existing direct-to-handheld NTN solutions enforcing satellite connectivity are restricted to outdoor conditions, which can easily be explained by the fact that the corresponding direct-to-handheld link budgets cannot allow sufficient provision, in dB, to address any form of indoor connectivity. This naturally greatly restricts the usage of such solutions in wider conditions. In contrast, 6G-NTN ambitions to offer sufficient link budget margins to serve users in light indoor conditions, thereby enabling richer use cases in which users will be able to use their smartphones in harsher conditions.

8.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

In the context of this use case, the following usage requirements have been identified:

Service availability: the direct-to-handheld communications shall be available to the user during all the phases of both user stories.

Experienced quality of communications: the QoE for the considered users (i.e., consumer user in the illustrated scenario) is important to correctly qualify how smooth the transitions from different segments (6G terrestrial – non-terrestrial) and conditions (outdoor, semi-outdoor / light-indoor) shall be. As a results, this QoE shall be quantified via relevant metrics in the subsequent 6G-NTN requirement deliverables D2.2 and D2.3, both in outdoor and semi-outdoor / light-indoor conditions). Such metrics should include a range of average bitrates for the aforementioned communications conditions. Additionally, an estimation of the needed number of users per surface unit is also required.

Type of terminals: This user scenario underlines the need for supporting mass-market regular smartphones. Ideally, all 6G-branded smartphones should support this mode of communications and this use case. This naturally has implications in terms of antenna, operating frequencies, chipset, firmware, etc. on the considered smartphones, so that the 6G-NTN can nominally serve those terminals.

Coverage range: To fully support all types of service continuity, the 6G-NTN coverage should be scalable with all forms of coverage gaps in the terrestrial 6G network (e.g., a plurality of small gaps in a large area, or a wide area totally uncovered by the terrestrial network).

Coexistence of NTN-TN networks: this use case has also illustrated the need for a coexistence between the terrestrial and non-terrestrial 6G networks, including the question of spectrum on which either segment is operated. This is especially important in times of scenario transitions, when the consumer user transits from a terrestrial link to a 6G-NTN link, and vice versa (step 2 of the considered scenario).

9 UC6: CONTINUOUS BIDIRECTIONAL DATA STREAM IN HIGH MOBILITY

For mobile applications such as Automotive, 6G NTN is offering alternative connectivity in case terrestrial network coverage loss. The interworking between the TN and NTN network is the key to maintain connectivity for use cases demanding a continuous stream such as media content streaming and conversational content such as video conferencing. Therefore the focus of the use case is to prevent service interruption in mobile data stream scenarios by complementing TN and NTN networks.

- **Service category:** Service continuity, Service scalability.
- **Targeted vertical:** Automotive, Road transportation / Smart Cities.
- **References:** [32]

Specific terminology:

- **Host Vehicles (HV):** Host Vehicle is the Vehicle equipped with in-build TN and NTN functionality, where the passengers consume the content.
- **Service Providers:** Voice, streaming and gaming service providers
- **Communication provider:** NTN or TN operator

9.1 DESCRIPTION OF THE PROPOSED SCENARIO

The use case concerns entertainment content delivery and bi-directional interactive content such as video conferencing for passengers of a moving or stationary vehicle. It is applicable to both automated and non-automated vehicles, where in the latter the driver is restricted in the content he or she is allowed to consume. The content would be provided via vehicular built-in NTN and TN communication equipment, the further distribution of the content within the vehicle is not especially treated in the use case only the accumulation, *i.e.* handling several unicast streams in parallel by the device leading to a higher total throughput requirement is considered being of special interest for the 6G NTN communication capabilities.

Due to the unexpected occurrence of TN or NTN coverage constraints such as coverage holes or border case scenarios special focus is to be taken on service continuity when changing from NTN to TN or vice versa and seamless connectivity is considered as a special side condition for ensuring quality of experience for the end user.

For cars, up to four occupants can consume high-definition and immersive entertainment media content while the vehicle is stationary or moving. For buses and transporters up to 30 passengers can consume the same content under similar conditions. Each occupant may be interested in different content, which may include video, gaming, office work, online education, advertisement and in future even virtual reality (VR). Contextual information can be embedded in the entertainment media depending on the location of the HV.

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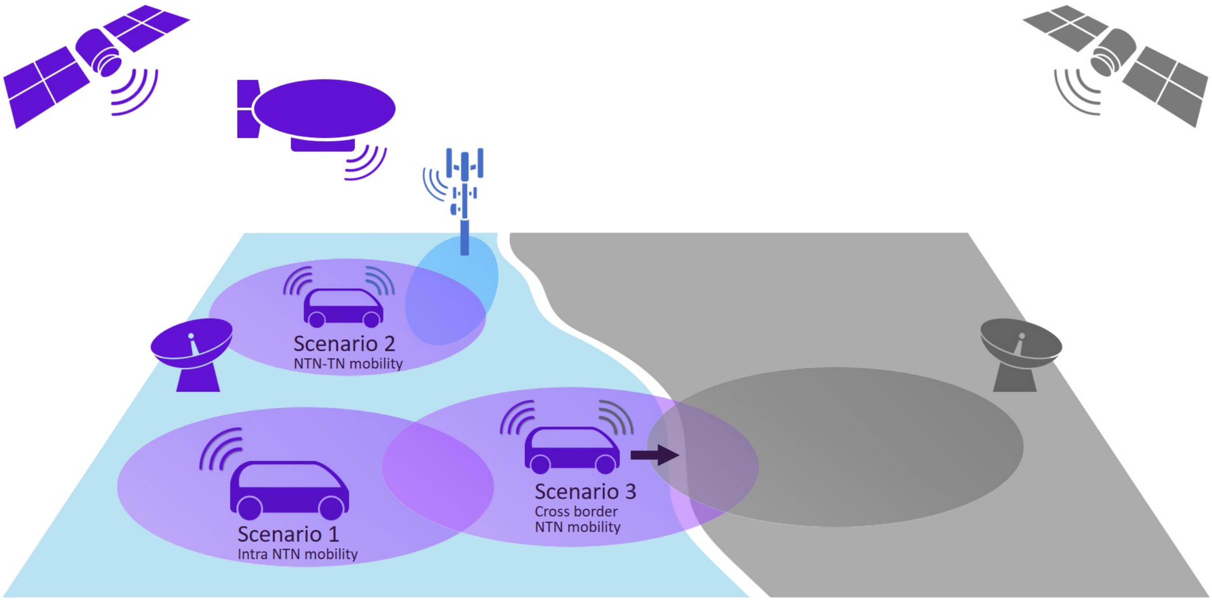

FIGURE 17: CONTINUOUS DATA STREAM IN HIGH MOBILITY

Scenario 1: NTN only usage

1. The passengers of the host vehicle want entertainment in form of high-definition content while travelling for longer periods. The vehicle is equipped at least with an NTN capable communication unit and momentarily in an NTN (only) coverage area. The HV owner has a service agreement with the communication provider.

2. A communication link via satellite 6G-NTN is established via the communication link provider to the high definition service provider. In case of multiple passengers several independent unicast links via satellite may be provided to different service providers.

3. Each passenger individually choses which HD content or bi-directional data services he or she is interested in and the service providers make the content available to the individual passengers. I.e. multiple independent data flows with different duration and QoS criteria may need to be provided.

4. During the entire travelling period the host vehicle is continuously connected to the same 6G NTN network. Due to the moving satellites and HV subsequent lossless intra 6G NTN-network handovers need to be performed.

Scenario 2: NTN - TN switching usage

1. In a modified version compared to scenario 1 the HV is equipped with an NTN and TN capable communication unit. The communication is setup via 6 NTN, TN is at least monitored in parallel and services are provided via NTN accordingly as depicted in scenario 1. During the travel period (prior step 4 of scenario 1) the HV entering an area where also TN coverage is available.

2. Due to the continuous monitoring of the terrestrial network by the communication unit of the host vehicle the presence of a suitable TN network is detected.

3. The 6G NTN network decides to handover the communication link to the terrestrial network and all links are loss less transferred. In an ideal case the transfer of the communication link between NTN and TN is seamless, having minimalist impact on the consumer applications ensuring highest QoE.

Scenario 3: NTN - NTN switching in cross border usage

1. In a modified scenario compared to scenario 1, the host vehicle may reach a boarder whilst being travelling. In case of a border scenario handovers to an NTN or TN network could be performed depending on commercial agreements and regulatory aspects.

2. As a differentiator compared to scenario 2 a NTN-NTN handover is considered. When the host vehicle passes the border, the supporting ground connection of the satellite network is changed, *i.e.* the feeder link is switched.

3. Also in case of a feeder link switch all communication links need to be loss-less maintained and switched to the new feeder link to ensure highest QoE for the high definition stream consuming passengers.

Note: The detection of the border crossing requires a certain positioning accuracy which is already present/prerequisite in today's NTN system. And hence even though 6G NTN has higher positioning accuracy and faster time for estimation this should not trigger a new requirement.

9.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The 6G NTN will significantly contribute to the stability and service continuity for such services, improving stability and continuity, increasing the user experience in areas with non-continuous TN coverage, or areas having small TN coverage holes, e.g. in rural areas. In general the service provisioning via NTN could be provided everywhere outdoor but the aforementioned scenarios for increasing service stability and continuation in conjunction with terrestrial networks seem to be most interesting.

- **[Enabler #1]** First the additional performance increase envisaged with 6G NTN in combination with suitable vehicle antennas which allow for the required throughput to address and maintain such scenarios with NTN. Antenna dimension may depend on the vehicle type whether bus/transporter or individual car and hence scale also in capability related to expected throughput needs.
- **[Enabler #2]** The shortened round trip delays ambitioned for 6G NTN allows for latency critical services such as gaming and in future even VR.
- **[Enabler #3]** Enforce handover and seamless connectivity when transitioning from terrestrial to non-terrestrial networks and vice-versa, allowing an increased quality of experience for all users even for
- **[Enabler #4]** For TN NTN Cross border mobility, whether NTN-TN or NTN-NTN mobility is considered may be subject to commercial agreements or regulatory aspects. Note: regulatory aspects impacting the user scenario or parts thereof may be considered at a later stage once the work has progressed in said area.

In the following subsection, we describe how those enablers will support this use case through several scenarios in which user stories help to understand how the 6G-NTN will allow or improve the continuity of high-definition (HD) content delivery to vehicles. The 6G NTN ambitioned throughput increase, latency improvement and mobility improvements (the aforementioned enablers) are key to improve the user experience for high definition content delivery also in areas with non-continuous TN coverage.

9.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

Usage requirements will be related to:

Service Capabilities: Availability of communications, during all the phases of the user scenarios, Quality of communications during all the phases of the user stories.

NTN–TN tight-interworking is needed to achieve the seamless mobility for highest QoE.

Coverage range: the 6G-NTN coverage should especially be available for areas without TN coverage to allow for service continuity and prevent from interruptions.

The requirements on the network equipment (and possibly on the satellite payload) to support also the multiple passenger bus scenarios needs to be evaluated accordingly, considering also adapted communication antennas for such vehicles.

Type of terminals: Vehicular mounted communication devices with suitable antennas. Antenna geometry may also depend on considered host vehicle and frequency bands being used.

In case of multi-user scenario evaluations, a reasonable service mixture concerning downlink centric services (streaming) or bi-directional with tight latency requirements (gaming) may need to be considered. In addition, also a mixture of active and inactive passengers and passengers only using low capabilities services (*e.g.* voice, chat, text).

Device density: There is also an impact by the number of vehicles in a certain coverage area and their high-definition service usage.

10 UC7: DIRECT COMMUNICATIONS OVER SATELLITES

This use case considers a scenario for two or more UEs to communicate with each other via satellite(s) directly, without requiring a feeder link connection between the satellite(s) and the ground station(s). This use case is applicable for HAPS, drones, and other NTN infrastructure components. Note by NTN infrastructure, we refer to airborne (e.g. HAPS) or space borne (e.g. satellite) vehicle for transmission. However, main technical challenges are on the satellite segment.

- **Service category:** Service Ubiquity.
- **Targeted vertical:** Automotive, Public Safety, Defense, Maritime, Energy/Utilities/IoT.
- **References:** [33]

10.1 DESCRIPTION OF THE PROPOSED SCENARIO

In areas where a terrestrial network is unavailable or during a time when the terrestrial network becomes unavailable, satellite communication can be used to provide communication services to users. However, in certain scenarios, a feeder link to connect a satellite with the ground network may not be always available. For instance, the users may locate in a remote area (e.g. over the sea) with no ground stations (e.g. gateway) available for feeder link connectivity. In another example, the ground stations may experience a power outage due to certain events, e.g. an earthquake or other natural disasters. In these cases, though a feeder link may not be available to connect the ground stations with the satellite, it is still critical and beneficial to apply a direct communication over satellite(s) for supporting communication between two or more UEs, e.g. to support an emergency service for public safety.

It is noted, due to the large coverage area of a satellite, it may provide a much higher probability to cover the located area of the two communicating UEs, comparing to a base station in the terrestrial network nowadays. In addition, inter-satellite link (ISL) between two nearby satellites can be leveraged to further enlarge the coverage area.

As an alternative to support the communication among UEs in case of no network coverage, sidelink communication can be used. However, sidelink communication is developed as a local and distributed communication system, where the communication happens between two nearby UEs and does not require a central coordination entity, such as a base station. Thus, in case the required communication range is large, e.g. up to a few hundred kilometers as considered in this use case, it is technically challenging for sidelink communication to achieve the same efficiency as the proposed direct communication over satellites:

- For instance, in order to avoid mutual interferences coming from the different transmitter UEs located at different distances from a considered receiver UE, the duration of a cyclic prefix (CP) in sidelink communication is required to be larger than the maximal signal propagation delay. For certain scenarios in the considered use case, the maximal communication range that needs to be supported between two UEs can be very large. The large communication range requirement could cause a large maximal signal propagation delay as well as the need for a very large CP duration for sidelink communication, which further decreases the communication efficiency. In comparison, in the proposed direct communication over satellites, a receiver UE may receive only the signal from a single satellite and all the local receiver UEs may receive the signal from the same satellite. Due to that, the mutual interference issue among the different links can be solved, as by the legacy NTN solutions.

- In another example, when two outdoor UEs are deployed on the ground, the radio channel of sidelink communication will be dominated by the non-line-of-sight (NLOS) propagation model, if the communication distance is large, e.g. as considered in this use case. Thus, it would cause a large signal propagation loss, which is difficult to be handled by sidelink communication. In comparison, the communication between an outdoor UE and a satellite mainly experiences a line-of-sight (LOS) propagation model. Therefore, together with the large gain that can be achieve by the satellite antenna, the proposed direct communication over satellite is supposed to be able to provide a better radio condition and a better efficiency than the sidelink communication.

It should be noted, the use case is described by using a public safety scenario as an example, but it should not restrict the use case from being extended to other scenarios/verticals, and some of the relevant scenarios are described in the following.

Scenario 1: Public Safety

1. Person A and Person B are family members. Officer C and Officer D are public safety officers executing rescue tasks. Due to some reasons, e.g. after an earthquake or the UEs are located in a remote area, a feeder link is not available for the satellite(s) serving Person A, Person B, Officer C, and Officer D.

2. Person A detects an event, e.g. an emergency event.

3. To request for an emergency help, Person A detects a public safety Officer C is reachable via the satellite communication without a feeder link.

4. Person A communicates with the public safety officer C via the direct NTN communication without a feeder link, where the communication is set up and taken place between the person and the public officer via satellite(s), without requiring a feeder link connectivity.

5. To facilitate the rescue task, public safety Officer C detects another public safety Officer D is reachable via the satellite communication without a feeder link. For example, public safety Officer D is more closed to Person A comparing to public safety Officer C and, thus, public safety officer D can arrive at Person A's location faster than public safety Officer D.

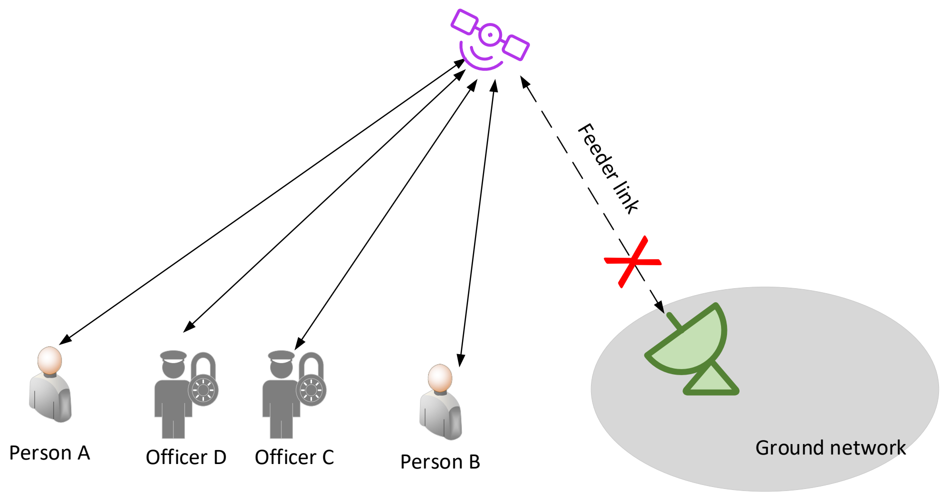

FIGURE 18: SATELLITE COMMUNICATION UNDER THE SAME SATELLITE WITHOUT AN AVAILABLE FEEDER LINK

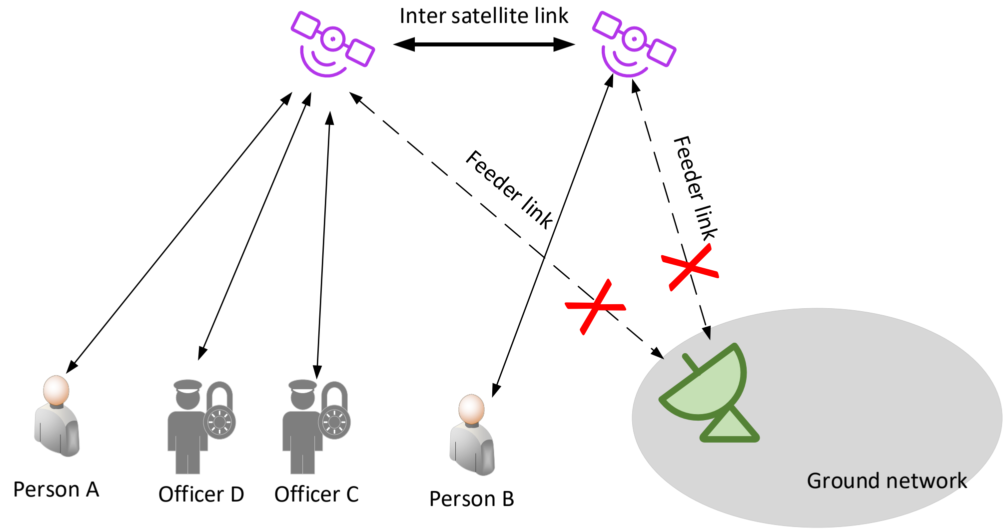

FIGURE 19: SATELLITE COMMUNICATION UNDER DIFFERENT SATELLITE WITHOUT AN AVAILABLE FEEDER LINK

6. Public safety Officer C communicates with the public safety Officer D via the satellite communication without a feeder link, where the communication is set up and taken place between the two public officers via satellite(s), without requiring a feeder link connectivity. The communication can be used by the two officers to coordinate the rescue task.

7. While waiting for the rescue team to approach him/her, Person A would like to call a family member B.

8. Person A detects the family member Person B is reachable via the satellite communication without a feeder link.

9. Person A communicates with the family member Person B via the satellite communication without a feeder link, where the communication is set up and taken place between the two persons via satellite(s), without requiring a feeder link connectivity.

10. Person A, Person B, Officer C, and Officer D can communicate with each other via NTN when a feeder link is unavailable. The communication can be used to rescue and comfort Person A.

Note that Person A, Person B, Officer C, and Officer D may be served by the same satellite, e.g. as shown in Figure 18: or they may be served by different satellites that are connected via ISL, e.g. as shown in Figure 19:. A satellite serving the UE(s) may be a NGSO or a GSO satellite. In case of NGSO constellation, a UE may move to the coverage of a new satellite. In case there is an ongoing communication with a peer UE, the new satellite may either serve the peer UE or have an ISL connection with the satellite serving the peer UE.

Scenario 2: Maritime

When two or more ships are sailing in the middle of a sea and relatively closed to each other, they may benefit from communicating with each other, e.g. for fleet management and rescuing in case a ship is sinking. Thanks to the large coverage of satellite system, the communication between two or more ships may take place over 6G NTN. However, it may become difficult and cost-inefficient to achieve and ensure 100% feeder link availability for satellites over a large sea, since a satellite during certain time may be far away from a coast gateway, causing a high propagation loss over feeder link. Thus, the proposed direct communication over satellite(s) could support the desired communication for maritime when the satellite(s) move to a location where a feeder link is not available.

Scenario 3: IoT

A typical advantage of NTN comparing to TN is the wide coverage of NTN. Thus, 6G NTN can be used to connect IoT devices, which may be deployed in remote areas without TN coverage. It is noted, the deployment of NTN (e.g. deploying a satellite in orbit and the corresponding gateway on the ground) for supporting IoT services may have to be executed step by step. In other words, during the initial deployment phase, only a limited set of satellites and gateways may be deployed to support IoT. In this case, 100% feeder link availability may not be guaranteed, especially for the IoT devices located in the remote areas.

As a potential solution to handle this issue, local data centers can be deployed in the remote areas and they can be equipped with the capability to support the proposed direct communication over satellite(s). It is noted, from radio communication perspective, the data center in this case may be considered as a normal user equipment, which may be simpler to deploy, comparing to deploy a conventional gateway for connecting the satellite and offering a feeder link connectivity. Thus, once an IoT device has to transmit a small message, it can send the data to a nearby local data center via the proposed technique. This allows the local data center to collect, process, and react to the message almost in real time. It is worth noting that the considered IoT scenario may only require sporadic small message transmission from each IoT device, comparing to broadband services.

Scenario 4: Defense

During a war, the gateway could become a primary attack target, since destroying the gateway could largely destroy the communication system with different user devices. Thus, a 6G NTN system equipped with the capability for direct communication can operate in case of unavailable feeder links, which could improve the system sustainability. In other cases, if there is an intentional or non-intentional destruction (conflicts, storms, earthquakes ...) the gateway will not be accessible. The system shall be resilient by itself or be recovered by another additional means. In addition, in some cases, the proposed direct communication may also simplify the procedure for deploying a temporary local network in defense, since only an NTN platform needs to be deployed locally. It is further noted, the NTN platform for supporting the direction communication in this scenario may be not only satellites, but also other flying objects such as drones, UAVs, etc.

Scenario 5: Automotive

Since vehicles can operate in the remote areas with no or limited terrestrial network coverage, some technologies are developed to enable vehicle communication in a decentralized manner, e.g. allowing nearby vehicles to communicate with each other over a short distance directly, such as over sidelink. However, sidelink communication may support limited communication range, which could restrict the use of a transmitted message. For example, if a vehicle detects a hazard situation, e.g. a collision, transmitting a corresponding message within a small range over sidelink only allows the other nearby vehicles to avoid a potential collision. However, in some cases, it may be beneficial for the vehicle to transmit the message to other nearby vehicles within a much larger range than the communication range achievable for sidelink. In this way, the vehicles outside the sidelink communication range can also receive the message and take certain proactive actions in a timelier manner, such as to seek for an alternative route plan and to avoid a potential traffic congestion. So, to transmit the message within a relative large coverage area, 6G NTN can be applied, thanks to its large and ubiquitous coverage.

However, since the message is more relevant for the other vehicles located within a certain range of the transmitter vehicle, it is very likely that all the receiver vehicles are under the coverage of the same satellite or two nearby satellites. Thus, it is reasonable to leverage the proposed direct communication over satellite(s), which can route the message from the transmitter vehicle to other receiver vehicles without using a feeder link.

10.2 REASON FOR CHANGE AND BENEFITS OF 6G-NTN

The current NTN solutions up to 3GPP Rel-18 require a feeder link to connect the satellite with the ground network, e.g. to facilitate the end-to-end (E2E) link setup between two communication UEs.

However, a feeder link may not be always available. For example, at the initial deployment phase of 6G NTN, a high density of ground stations (e.g. gateways) cannot be assumed and an NTN operator may need to deploy the ground stations gradually. Thus, during that phase, 6G NTN may need to rely on a limited amount of ground stations, and a satellite may move to a location where a feeder link may not be available. In another example, a ground station may also become unavailable for satellite, e.g. during a disaster, which may cause a power outage or a damage of the ground station.

Since 6G NTN is expected to provide an ubiquitous coverage to complement the TN coverage, it is critical to support direct communication over satellite(s), even when and/or where a feeder link is unavailable. In this way, when the ground network segment supporting NTN communications faces a problem such as a natural disaster, certain communication services can still be provided to UEs for supporting critical activities such as public safety and emergency services. In addition, in a long run for future 6G NTN, the considered direct communication over satellite(s) could enable an NTN communication to take place without relying too much on the construction and status of the ground network segment.

The benefits envisaged by the 6G-NTN project for this use case cover at least:

- **[Enabler #1]** This use case would highly increase the resiliency of 6G NTN communication, since the NTN communication can take place without a tight dependency on the feeder link availability. Additionally, it will allow to reduce the latency and the load on the feeder link, as the communication is not passing through the ground.
- **[Enabler #2]** New 6G NTN system architecture and protocol designs would be needed to enable this use case, e.g. by equipping the satellite with a regenerative payload, which handles the functions required for routing, configuration, QoS management, mobility, etc.
- **[Enabler #3]** The inter-satellite link or inter-node link can be leveraged to further improve the system performance, e.g. to enlarge the area where the direct NTN communication can happen, and to support the UEs' mobility and service continuity in the NTN environment.

10.3 USAGE REQUIREMENTS AND PRACTICAL CONSTRAINTS

This use case is generic and may be applied within different scenarios. Each of these scenarios have specific usage requirements and practical constraints, which are detailed in Section 4.3 for Maritime, in Section 0 for Public Safety & Defense and in Section 9.3 for Automotive.

11 CONCLUSION

As concluding remarks, Table 4: maps the use cases, proposed in Sections 4 to 10, to the key objectives of the 6G-NTN project and foreseen innovation potentials, described in Section 2.2. For this mapping, each UC is tagged with one to three '+', depending on whether it can partially / significantly / fully illustrate the considered objective. Not that such ranking should be understood less as a technical evaluation, and more as a subjective perception of contributors.

TABLE 4: USE CASE MAPPING WITH RESPECT TO 6G-NTN OBJECTIVES AND INNOVATION POTENTIALS

		UC1	UC2	UC3	UC4	UC5	UC6	UC7
Key objectives of the 6G-NTN Project								
2	3D TN / NTN networks	+++	+++	+++	+++	+++	+++	++
3	Compact terminals	+	+++	++	++	+++	++	+
4	Flexible SD payload	++	++	++	++	++	++	++
5	Flexible waveform	+	+	+	++	++	+	+
6	AI-enhanced RIC	+	+	++	+	+	+	+
7	VNF orchestration	+	++	++	++	++	++	++
8	Reliable and accurate positioning	++	+++	++	++	++	+	+
9	Spectrum usage optimization	++	++	+	+++	++	+	++
10	Standardization and Regulation	++	++	+++	+++	+++	+++	+++
Key Innovation potentials of the 6G-NTN Project								
1	Performance increase	+++	+++	+	+++	+++	+++	+++
2	Ubiquitous connectivity and Resiliency	+++	++	+++	+++	+++	+++	+++
3	Seamless connectivity in Mobility	+++	+++	++	+++	+++	+++	++
4	Light indoors and in-vehicle	+	+	+	+++	+++	+	+
5	Solutions as-a-service	+	++	+	++	+	+	++
6	Space Edge Computing	++	++	+++	+++	+	+	++
7	Adaptation to traffic variation	+	+	++	+++	+++	+	+

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Not surprisingly, the 3D multi-layered network infrastructure, the seamless and transparent connectivity, as well as performance increase, are the most relevant features to be provided by 6G-NTN. Yet, the proposed scenarios will use such enablers in very different ways, which shall be further investigated in future work, especially as part of WP2.

The defined use cases highlight the need for interconnectivity between all the components of the 6G NTN network. This interconnectivity will have to be optimal in terms of cost/feasibility and performance in order to be able to respond to the identified markets. A compromise will be made through feedback (WP2 & WP3) and discussions concerning the priorities according to the estimated accessible markets explored in T2.4

To the exact opposite, radio features, such as flexible waveform and AI-enhanced RIC, remain quite hidden from a usage perspective. The benefits they offer to application-layer services will be clarified over the course of the project.

Other findings can be summarized as follows:

- Direct to handheld communications (UC5) and infrastructure inspection using drone (UC2) are the two types of terminals which will benefit the most from reduced C-SWaP designs, to be investigated in T3.2.

- Innovations enabling a fast adaption to traffic variations are best illustrated by scenarios with a potentially high density of users and high diversity of services, such as in UC3, 4 and 5. This aspect will be explored in T4.2, on AI-enhanced RIC.

- Challenging spectrum management scenarios are expected for disaster communications (UC4), especially during initial deployment phases, when the existing terrestrial network is only partially impaired or when the terrestrial infrastructure is progressively restored. This scenario may serve as a basis for T4.3, on spectrum coexistence aspects.

- Only Urban Air Mobility is less sensitive to the expected performance increase, as it mostly targets low-throughput traffic. However, this UC proposes unique challenges in terms of network-driven services, third-party KPI monitoring and interoperability.

- For all use cases, a good synergy with relevant standardization groups and regulatory bodies is expected to ensure that adequate policies and regulation (including spectrum) will be in place for future 6G-NTN infrastructure. This work will be covered by T2.2 and T2.5, T4.3 and T6.3.

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