6GNTN

D2.2 USER REQUIREMENTS

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Abstract	This deliverable outlines the user requirements for 6G NTN. Basis are selected use cases and representatives from an external advisory board (EAB)
Keywords	Use cases, Scenarios, Verticals, User requirement, Terminals

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DISCLAIMER

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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

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DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

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

EXECUTIVE SUMMARY

This document reports the outcomes of the activity related to the user requirements definition (Task 2.2 of the project) and it builds on D2.1 "*Use Cases Report*". The document introduces and explains the methodology used to describe and group the user requirements of the respective Use Cases from D2.1. The user requirements are always seen from a service perspective and, hence, represent a service-level requirement. Due to the service level description, it is a solution-agnostic requirement description of the use cases.

In the use cases, different User Equipments (UEs) are used by the end-user to achieve a certain service level. Hence, a grouping is made in relation to the used end-user device having different characteristics.

The Use Cases are the high-level procedures for executing a specific service in a particular situation with a specific purpose. A Use Case may entail several specific scenarios, which may occur while the use case is conducted (*e.g.*, mobility scenarios), where different requirements may apply.

The results and conclusions of this report serves as an input for the work of other work packages (WPs) in the 6G-NTN project and may as well be used as source for input and feedback to standardization activities, *e.g.*, in 3GPP describing the need for evolving NTN standardization from a service perspective.

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ABBREVIATIONS

3GPP	3rd Generation Partnership Project
AI	Artificial Intelligence
BS	Base station
BVLoS	Beyond Visual Line of Sight
C2	Command and Control
C2CSP	C2 Link communication service provider
CoW	Cell on Wheels
C-SWaP	Cost Size Weight and Power
EASA	European Union Aviation Safety Agency
E2E	End-to-end
FR	First Responder
GEO	Geostationary Earth Orbit
gNB	Next-generation Node-B
GNSS	Global Navigation Satellite Systems
GSO	Geostationary orbit
HAP	High Altitude Platform
HV	Host Vehicle
IoT	Internet of Things
ISL	Inter-satellite link
LEO	Low Earth Orbit
LoS	Line of Sight
MFCN	Mobile/Fixed Communications Networks
MEO	Medium Earth Orbit
MNO	Mobile Network Operator
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
PPDR	Public Protection and Disaster Relief
PTT	Push-To-Talk
QoE	Quality of Experience
QoS	Quality of Service
Rel	Release
RIC	Radio Intelligent Controller
SAR	Search and Rescue
SI	Study Item
SON	Self-organizing networks
TN	Terrestrial Network
TR	Technical Report
TS	Technical Specifications
UAM	Urban Air Mobility
UAV	Uncrewed Aerial Vehicle
UAV-C	UAV controller
UC	Use case
UE	User Equipment
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
WP	Work package

1 INTRODUCTION

The proposed requirements are user expectations in terms of services and will have to be consolidated by the System Requirements definition (reported in D2.3 *“Report on system requirements”*) and updated or adapted if new services are proposed. In this document, the requirements are identified as "ideal" for the first issue.

The variety of current and evolving use cases leads to a broad range of user requirements. The referenced use cases stretch over enhanced mobile communication scenarios to public and critical services as well infrastructure related and industrial usage. The resulting performance and capability needs are significantly outmatching current systems.

Hence the future developed 6G NTN system may have the means and capabilities of satellite communication to enable the described use cases. A future 6G NTN system may even have more advanced capabilities and extended communication characteristics for the user benefit.

- Extending the capabilities of satellite communication to enable more use cases.
- Characteristics: Multi-dimensional and multi-layered network, tight interworking with terrestrial networks.
- Potential benefits for use cases: Ubiquitous coverage, seamless connectivity in mobility, positioning, light indoor coverage, service scalability.

1.1 SCOPE AND OBJECTIVES

This document reports the outcomes of the activity related to the user requirements definition (Task 2.2 of the project) and it builds on D2.1 “*Use Cases Report”.* The document introduces and explains the methodology used to describe and group the user requirements of the respective Use Cases from D2.1. The user requirements are always seen from a service perspective and hence represent a service-level requirement. Due to the service level description, it is a solution-agnostic requirement description of the use cases. Use Cases are the high-level procedures for executing a specific service in a particular situation with a specific purpose. A Use Case may entail a number of specific scenarios which may occur while the use case is conducted (*e.g.,* mobility scenarios), where different requirements may apply.

The results and conclusions of this report serves as an input for the work of other Work Packages (WPs) in the 6G-NTN project and may as well be used as some source for input and feedback to standardization activities, *e.g.,* in Third Generation Partnership Program (3GPP) describing the need for evolving Non-Terrestrial Network (NTN) standardization from a service perspective.

The user requirements for all use cases will be collected to evaluate the 6G NTN system level requirements.

1.2 METHODOLOGY FOR USE CASE DESCRIPTION

This deliverable aims at describing the user requirements in a technology-agnostic, holistic manner. The process to perform this description in represented in Figure 1. Hence a certain set of user requirements are further grouped into certain characteristics. Accordingly, a common set of user requirements are considered for the evaluation of the use cases. In the various use cases, not all considered user requirements may apply; however, other user

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requirements, such as, *e.g.,* sustainability and environmental impact, are even to a large extent use case independent.

Nevertheless, also those user requirements form an important aspect for the further evaluation of the user requirements to serve as input for technological or economical aspects.

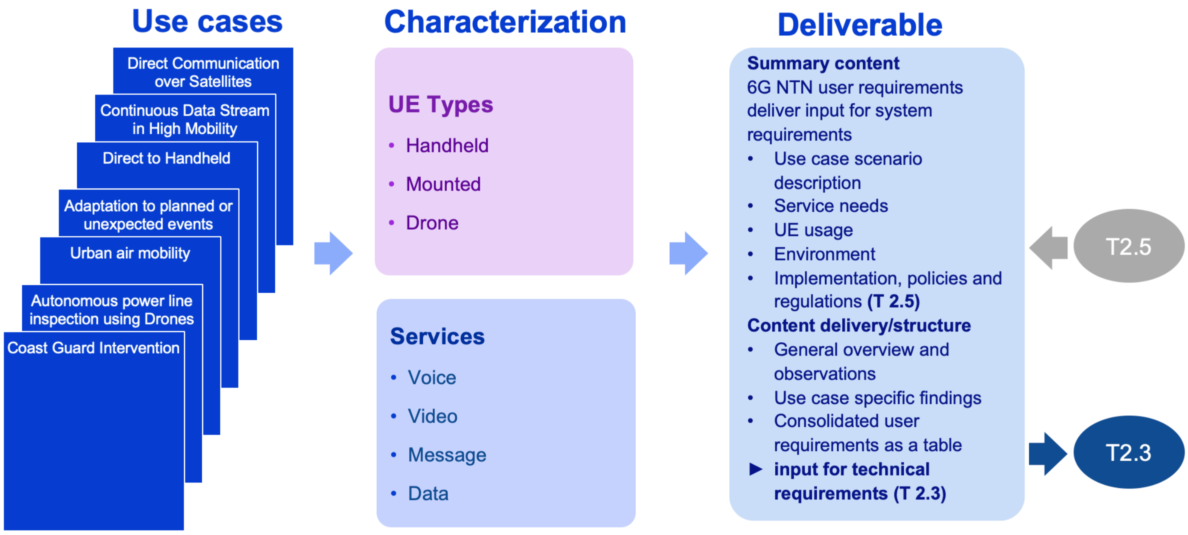

FIGURE 1: PROCESS

1.3 EXTERNAL ADVISORY BOARD (EAB)

As described in deliverable D2.1, section 3.2, the interaction with the External Advisory Board (EAB) allowed consolidating seven identified use cases. D2.1 describes how two general workshops were organized to present the 6G-NTN solution and share opinions on the salient innovation potentials explored by the project that could benefit use cases in general. Then, several working sessions allowed focusing on a specific market segment and led to the consolidation of the identified use cases, together with the inputs provided by the other 6G-NTN tasks and work packages, during the general assemblies and other project-level meetings.

For D2.2, the approach was generally similar. To exchange with the EAB, the 6G-NTN Consortium further used the use cases identified in D2.1, while focusing more on the user needs, with a high emphasis put on user devices and how well they are expected to be served by the 6G-NTN integrated TN/NTN solution. Capitalizing on the skillsets and fields of interest identified in the EAB, the 6G-NTN consortium kept organizing, as part of task T2.2, several working sessions to further investigate the considered market segments, with the user requirements in mind.

It is worth highlighting that, again, the exchanges with the EAB, throughout M3 to M6, corresponded to the active phase of task T2.2, allowing to collect requirements, by different criteria, including use cases, services and device types. This rich information, together with the additional inputs from the rest of the 6G-NTN tasks, led to the clustering of the requirements belonging to a certain common category and characterization, as described in Section 2.4. Finally, it is worth mentioning the extent of the collected information exceeded at times the intended scope of strict user requirements, as presented in this deliverable. In particular, based on the collected requirement analysis, a subset of these requirements related to functional and system requirements, and were therefore converted as input for D2.3.

Acknowledgement: We would like to particularly thank the External Advisory Board 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, has allowed us to significantly deepen our understanding of the use case and user requirements of the 6G-NTN project.

1.4 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 2.

First, D2.1 aims at initiating the analysis to be provided in the other deliverables produced within WP2, listed in the following:

- D2.2 on User requirements,
- D2.3 on System requirements,
- D2.4 on Market and Business models,
- D2.5 on Policies and Regulation.

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 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.

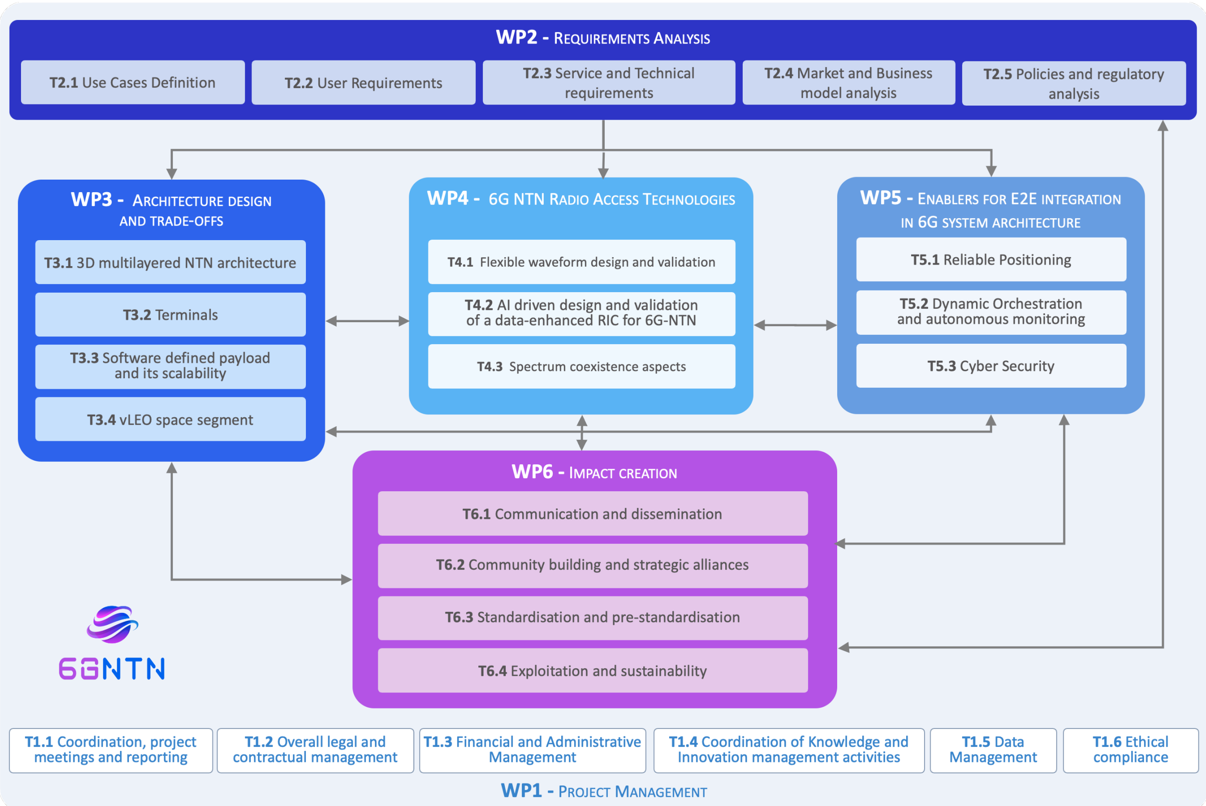

FIGURE 2: 6G-NTN WORK ORGANIZATION

1.5 STRUCTURE OF THE DOCUMENT

This deliverable is structured as follows:

- Section 2 describes the methodology that was implemented in the task to define the user requirements and a categorization of the requirements considered throughout the document;
- Section 3 reports a short description of the use cases described in D2.1, identifying the involved users and the requested service;
- Section 4 describes the user requirements mapped to the identified types of UE terminal, classified as handheld, drone, and mounted;
- Section 5 introduces the service requirements from a user perspective and grouped as communication or localization services;
- Section 6 reports the combination, for each Use Case (Section 3), of the UE type (Section 4) and the service requirements (Section 5);
- Section 7 identifies a list of additional user requirements that might be taken into account throughout the Study, related to cost and sustainability;
- Section 8 concludes this deliverable.

2 USE CASES ANALYSIS

The developed use cases in D2.1. serve as input for the further use case analysis and, in context of this document, all characteristics are seen from the end user perspective.

This subset of the scenarios/use cases was pre-analyzed and discussed with EAB and have been refined based on their feedback.

2.1 USE CASE CHARACTERISTICS

The use cases are the high-level procedural description for executing a certain scenario in a particular situation with a specific purpose. To achieve/fulfill this purpose with user satisfaction, a certain level of user requirements for individual use cases must be met.

The purpose of this document is to collect the user requirements for the evaluated use cases to serve as basis for future technology-specific work that will be reported in D2.3.

A common set of user requirements will be introduced to characterize all use cases and introduce some comparable and similar characteristics for all of them. The captured requirements for the use cases are to be seen from service level and, hence, are to be understood as service level requirements experienced by the user. The translation of the service level requirements into needs and requirements for the lower technology layers is the subject of the work carried out in D2.3, where the technological interpretation of the user requirements is in the main focus.

For the use cases in D2.1, besides detailed descriptions, also the related objectives and innovation potentials were specified. The innovation potentials mostly relate to technological fields. However, as the user requirements are a service level description for the use cases in a technology agnostic manner, the innovation potentials will not be directly reflected within the description of the user requirements. This is also true for most of the objectives except for the compact terminal design which is also a direct user requirement for certain use cases, allowing the usage in accordance with the described use case.

Hence as a main goal, the user requirements will translate and quantify/qualify the needed performance as contained in the textual descriptions in the use cases from service level to fulfill the use case.

From the collected user requirements, it becomes obvious that in many cases the expressed needs exceed by far the possibilities and capabilities that would be feasible with the NTNs currently available and, hence, pave the way for the need of a technological evolution to fulfill those. Furthermore, the use cases addressing mobility scenarios between NTN and TN, and vice versa, or from NTN to NTN, will indicate the maximum allowed transition times for acceptable user experiences. Being beyond what is achievable with current NTN capabilities, these transition times will provide side conditions for architecture and 6G-NTN system considerations to be studied the project.

When evaluating the use cases, a distinction must be made between the system requirements and requirements in the use cases arising from specialized terminals, *i.e.,* normal terminals or terminals which are use case specialized. Both of them provide the 6G NTN system requirements to be fulfilled by NTN network as such, but feasibility of the entire use case depends also on the usage of these specialized terminal for said use case. This means that a certain use case may only be feasible with such specialized terminal functions.

2.2 6G NTN OPPORTUNITIES

While D2.1 described the innovation potentials to be explored within 6G NTN, D2.2 provides the user expectations. The latter help to materialize these opportunities/aforementioned innovation potentials into the 6G NTN developed solution. The end user requirements serve as basis for the related 6G NTN technical requirements to be defined in D2.3 and, hence, ensure the materialization of the innovation potentials within 6G NTN. The identified end-user requirements concerning ubiquitous coverage, seamless connectivity in mobility, positioning, light indoor coverage, service scalability will pave the way for extending the capabilities of satellite communication to enable more use cases.

2.3 REQUIREMENTS CATEGORIES

This section introduces Requirements Categories by grouping user requirements that are considered for all the Use Cases. The grouping is a clustering of the requirements belonging to a certain common category.

One objective is to distinguish general service capabilities driving the system requirements more easily and evaluating whether specialized terminal assumptions are to be made for the different use cases. The user requirements are intended to qualify and quantify the service level performance required for a certain use case without recommending specific technological solutions. However, the use case service level requirement report will serve as input for deriving such NTN technological requirements.

In addition, also use case independent characteristics are considered which are market or environmental related. Market related requirements only will describe the general needs arising from the user experience/needs which accordingly should be realized and made feasible by the specific market evaluations in D2.4 *"Report on Business model metrics and analysis".*

It is worth mentioning that also use case independent user requirements are captured, including sustainability and environmental requirements. Indeed, minimizing the environmental impact and available resources by sustainability has become an important user requirement within the past years and hence special care needs to be taken here on these "general" user requirement.

The user requirements (Use Case Service Level Requirements) are grouped within the following characteristics to improve transparency and readability:

- **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.
- **Terminal features:** *e.g.,* type of NTN device (smartphone, vehicle-mounted, etc.), size and weight constraints, installation, etc.
- **Environment landscape:** including mobility aspects, coverage range, device density, specific radio propagation constraints, etc.
- **Policies and regulatory constraints:** for example, specific spectrum regulation to be considered in coexistence scenarios.
- **Others:** ecosystem, market related, environmental, specific use case needs.

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TABLE 1 - REQUIREMENTS CATEGORIES

Categories	Requirements	Unit
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.	Service capability Message, Data stream, Voice, video	Text
	Required DL throughput	Mbit/s
	Required UL throughput	Mbit/s
	Maximum service interruption tolerance	ms
	Maximum tolerated time of degraded services	ms
	Duty Cycle / amount of data	Text
	Location Services and Accuracy	cm
	Timing Services	
	Criticality (trust, reliability, service availability)	Text
	Latency	ms
	Other wireless technology	Text
	Usage conditions / environmental conditions?	Temp range
	Mobility pattern / Max Speed	Text + km/h
Terminal features: *e.g.*, type of NTN device (smartphone, vehicle-mounted, etc.), size and weight constraints, installation, etc.	Terminal Type	Text
	Terminal Power consumption / battery operation	mW, W
	Max Dimension, antenna etc.	cm
	Max Weight	g
Environment landscape: including mobility aspects, coverage range, device density, specific radio propagation constraints, etc.	Device Density	Device per km^2
	Coverage range / Needs	Text
	Frequency range	
Policies and regulatory constraints: for example, specific spectrum regulation to be considered in coexistence scenarios.	Coexistence and overlap with other scenarios	Text
	Policies and regulatory constraints, including cross border/extra territorial regulations (if any)	Text
Other: Eco system, market related, environmental, specific use case needs	Max lifetime	years
	Min Maintenance periodicity	month
	Deployment time frame	Date
	Charging assumptions	Text
	Other Specific Needs	Text
	Environmental impact, Sustainability	Text

In this document, the requirements categories, Table 1, will be translated into user requirements built on the use cases and mapped to the UE Types; the latter are also derived from the use cases. Figure 3 depicts the applied method.

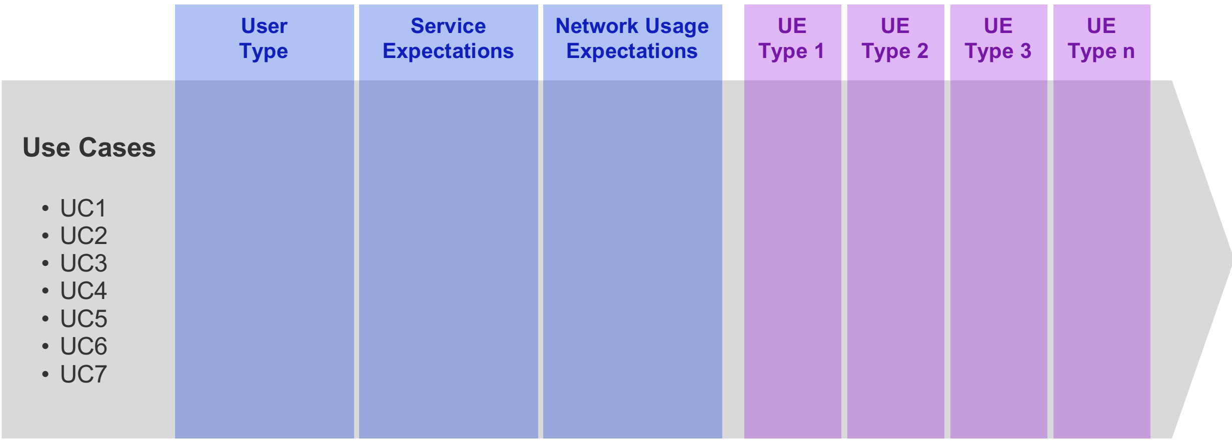

FIGURE 3 - USER REQUIREMENTS FOR UE TYPES

3 ANALYSIS OF THE USE CASE SCENARIOS

In this Section, the use cases described in detail in D2.1 are briefly summarized, highlighting the types of users and providing an indication on the required service to be further used in the analysis of the user requirements.

In addition, in this chapter, we also focus on the user involved in each use case and on the requested service with the aim of rationalizing the number of terminal types to be considered. This rationalization is based on the identification of requirements allowing common technology considerations, cost reductions, and sustainable development of the NTN eco-system.

3.1 UC1 COAST GUARD INTERVENTION

In the context of rescue scenarios, reliable communication including voice and video communication is an important means for Search and Rescue (SAR) teams. The overall coordination especially of all maritime rescue teams including requires voice and video communication via satellite or additional HAPs; hence, NTN is a key for success and improvement of such activities relying also on enhanced positioning method and additional sensor data collection.

The scenario mainly takes place while being NTN connected, due to mobility of satellites, NTN/NTN mobility needs to be considered.

In this use case, two types of users are identified: i) the users connect to the coast guard service by means of a consumer handheld UE, and ii) potentially, a professional terminal to connect to the coast guard.

Both terminal types shall be switchable between NTN/TN.

3.2 UC2: AUTONOMOUS POWER LINE INSPECTION

An autonomous drone can operate in Beyond Visual Line-of-Sight (BVLoS), in a context of power line inspection. In a first variation, the drone performs fully autonomous, routine inspection. In case of anomaly detection, this drone can switch, in a second variation, to a manual mode in which a human pilot remotely takes control to make necessary verifications. In both modes, the drone-mounted UE needs permanent and high-capacity connectivity, and seamless TN/NTN transition wherever necessary, while transmitting data. Furthermore, the drone may be covered by either public terrestrial networks or private ones (*e.g.*, around electrical substations, at take-off and landing).

For this case the main user is someone which is able to control the drone through the NTN via the terminal mounted on the drone. The drone user expects the connectivity to be provided through NTN connection.

3.3 UC3: URBAN AIR MOBILITY

According to Urban Air Mobility (UAM) principles, in order to be able to evolve in urban airspaces, manned and unmanned aircraft systems need to be supported by a set of services that provide safe, efficient, and secure access to airspace for large numbers of drones. Such services need to always rely on a TN/NTN network connectivity that can serve high-altitude airspaces. In addition, such drone operation requires sufficient world-wide network resilience, as well as the support of a unified and interoperable traffic management system able to accommodate a large number of manned and unmanned systems equipped with mounted UEs.

The user is identified as aircraft-mounted device which is able to connect with NTN with a backoff resilience.

3.4 UC4: ADAPTATION TO PLANNED OR UNEXPECTED EVENTS

An unplanned event such as a natural disaster occurs and triggers the rapid intervention of first responders. It is assumed that in the wake of this event, the TN infrastructure is temporarily damaged. Two types of users are considered on the scene: i) victims with consumer handheld UE, and ii) first responders with a plurality of UE encompassing consumer and professional handheld UE, vehicular mounted, drone mounted, and pole mounted. Although the NTN segment can immediately serve these users, some prioritization in resource allocation needs to be defined and enforced for the benefit of the first responders. Since the TN is progressively restored, both TN and NTN need to coexist in these changing conditions. Likewise, all considered UEs need to be able to seamlessly switch from TN to NTN and vice-versa.

The first user, identified within this use case, uses a consumer to always be able to connect even in the event of unexpected events connectivity via NTN/TN. In addition, the second user is an operator to fill a lack of coverage caused by unexpected events. Hence NTN shall be able to integrate momentary additional mounted stations for closing coverage holes.

3.5 UC5: DIRECT TO HANDHELD

A consumer user has subscribed to a Mobile network Operator (MNO), whose network is able to offer an integrated TN / NTN connectivity. This user is in situation of service continuity by travelling into an area without TN coverage. The user is a consumer handheld UE, therefore, needs to seamlessly switch from TN to NTN, and vice-versa when the user re-enters his MNO terrestrial coverage. During its operation within NTN coverage, the application traffic demand either needs to be supported as is, or dynamically adapted, so that the user's Quality of Experience (QoE) is kept consistent. In addition, during his journey out of TN coverage, this user may temporarily enter light indoor conditions, for which NTN connectivity needs to still be supported, albeit with a controlled service degradation.

The user is equipped with a handheld, able to switch between TN and NTN, so that the user gets the best Quality of Service (QoS).

3.6 UC6: CONTINUOUS DATA STREAM IN HIGH MOBILITY

A vehicular mounted UE is used for voice or video conferences. Due to high mobility of the scenario and potential long-duration calls, subsequent NTN/NTN or NTN/TN and vice-versa transitions are a very common mobility scenario. Therefore, network transitions need to be performed reliably without user experiencing substantial degradation of the connectivity. In addition, regulatory or commercial aspects at border transitions may also lead to certain TN/NTN or feeder-link switch scenarios. Furthermore, positioning services with accuracy in meter range are also required.

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The user is a vehicular mounted device being able to switch between TN and NTN, so that the user gets the best QoS.

3.7 UC7: DIRECT COMMUNICATION VIA SATELLITE

In scenarios or cases where no feeder link is available, 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. In this scenario, only NTN service network involvement is considered. One or more UEs of type handheld or maritime may be connected direct under the same satellite for communication exchange. There are also scenarios where more than one satellite may be involved, *i.e.,* connection users in coverage areas of nearby satellites being connected via Inter Satellite Links (ISL). In general, the direct connection of users without feeder link access is a new scenario to be considered in 6G NTN context.

Any UE requests a resilience against interruptions and have a stable communication whatever the incident in the feeder station is.

3.8 MOBILITY OPERATIONAL SCENARIOS

There are common mobility/network transition scenarios, that regardless of the UE type, must meet a certain level of end-user requirements, *i.e.,* not leading to a noticeable interruption or unacceptable service degradation. The following mobility/network transition scenarios are identified:

- **NTN/NTN intra-network:** changing within NTN from one satellite to another satellite, not changing the network connection.
- **NTN/NTN inter-network switch or feeder link switch:** the connection remains with a satellite network, but feeder or respective network connection is also switched.
- **NTN-service area restricted private network:** a local bubble served by one or more satellites and providing service over a restricted area also without feeder link.
- **NTN/TN-transition**: changing connection to terrestrial network, changing network connection. Also corresponding reverse scenario is considered accordingly.

Depending on the scenario, the UE may interact with more than one network at a time, having at least visibility on the involved networks.

4 UE TYPES

This section maps the user requirements to UE types. The UE is the device in direct contact with the user and, therefore, needs to fulfil certain expectations and needs according to the intended usage/use case scenario. Consequently, the UEs are grouped into certain device types for which different user requirements may apply. Also, certain requirements have a dependency on the UE type, e.g., velocity or environmental conditions in which the UE operates, thus further justifying the need of a UE grouping.

Based on the analysis of the use cases reported in D2.1, and according to the industry and general classifications, the following UE types were identified: handheld, drones, and mounted devices. For each UE type, two subcategories have also been identified according to the previous analysis (Figure 4)

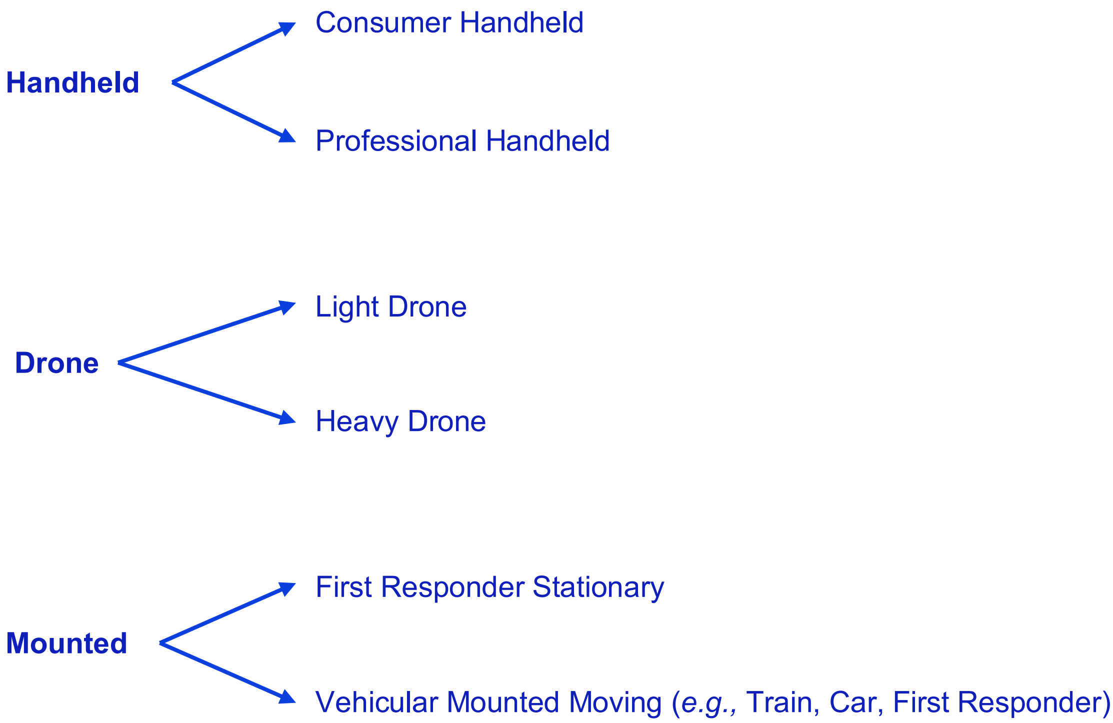

FIGURE 4 – UE TYPES

These UE types and subcategories are described more in detail in the following sections, which will also provide the rationale beyond this grouping.

The evaluation on the various device types in the acceptable scenarios from end-user perspective was aligned with the corresponding vertical members from the EAB during the general use case discussions. At that point, a grouping of the UE types was not considered, but indications were given for the devices used within the use cases and have been included. Consequently, UE types may be within a group, but the respective values for size/weight or power consumption may slightly vary, as each device was within its use case separately discussed. Furthermore, the relevance of certain UE characteristics was weighted differently for different UEs, *e.g.,* especially in case of mounted devices, size, weight, and power consumption heavily depend on the characteristic of the underlying “vehicle”.

4.1 USER REQUIREMENTS FOR HANDHELD UE

Consumer handheld devices are widely used and, for the acceptance and comfort of a user, the typical characteristics concerning size, standby-time, or communication time should not vary much due to the addition of the NTN communication capabilities compared to the so far known handhelds which are equipped with earth-based communication capabilities only. The addition of the NTN communication capability to the handheld should not limit the known comfort but only enhance the communication capabilities to improve the user experience for communication.

For professional handhelds, the fact that they are dedicated to NTN or NTN/TN use allows for some deviation concerning size and weight compared to a consumer handheld when adding NTN communication capabilities, as long as the usage as handheld is not impacted.

4.1.1 Handheld UE Characteristics

- Integrated antenna, very size constraint
- Integrated battery with limited capacity
- Form factor, typical dimensions, e.g.,
    - 15x8x1cm for Consumer Handhelds
    - 20x10x5cm for Professional Handhelds

4.1.2 Usage scenarios

➲ **Personal consumer usage**

- User: a single user connects to both NTN and TN network with a handheld UE depending on coverage circumstances certain different scenarios may occur:
    - Being connected to a terrestrial network and entering into a non-terrestrial network
    - Being connected to a non-terrestrial network and entering into terrestrial network
    - Being solely connected to a non-terrestrial network
- Consumer handheld user enters a region without terrestrial coverage and expects to continue the use of services. For user experience it is important that there is no or only limited interruption noticeable by the end-user.
- Consumer user needs to do emergency communication in an area without terrestrial coverage.

➲ **Professional handheld usage**

- User: a first responder attaches to an NTN network with a professional handheld UE
    - Being connected to a terrestrial network and entering into a non-terrestrial network

    - Being connected to a non-terrestrial network and entering into a terrestrial network

    - Being solely connect to a non-terrestrial network / tactical bubble

- Adaptation to Public Protection and Disaster Relief (PPDR) or Temporary Events

- First responder using a handheld being in a remote location without terrestrial coverage need being connected with their handhelds

- During a terrestrial network outage first responder need being connected with their handhelds

- First responder needs to connect to a specific tactical bubble

4.1.3 Usage Conditions

Usage conditions and related requirements are considered for the environment experienced by the UE and, hence, are linked to the type of UE and its envisaged usage. These UE requirements are also subject to industry definitions and groupings.

➲ **General**

- The user can be a pedestrian (3km/h) or moving in a vehicle (up to 250km/h).

- The handheld device is operated outdoors as well as light indoors, in case of light indoor operation a service degradation to limited service such as SMS is considered realistic.

- Usage can occur in all climate zones.

- Temperature ranges for consumer handheld UE lie between +15°C to +35°C for normal conditions (with relative humidity up to 75 %) and -10°C to +55°C for extreme conditions (see IEC publications 68-2-1 and 68-2-2).

➲ **Professional Handheld**

- Smoke, heat, and water vapor can be present when used in the context of emergency and disaster response.

- Temperature ranges for professional handheld UE lies in a range beyond defined normal or extreme conditions -10°C to +55°C for extreme conditions. However, a usage may also be considered up to a range where first components may get into critical operational mode, which may also lead to non-reversable damage of components which is considered for emergency operation.

- Lifetime expectancy for professional handhelds is up to 10 years.

➲ **Consumer Handheld**

- Lifetime expectancy for consumer handhelds is up to 5 years.

4.1.4 Regulation and other aspects

Regulatory and other aspects applying for the usage of handheld devices, especially in context of NTN operation, are subject of a separate T2.5, where will be analysed in detail. However, also the general regulatory aspects applying for handhelds in general (TN) listed hereafter need to be considered.

- **General**
  - CE, SAR, FCC, IC
- **Professional Handheld**
  - Governmental requirements and regulations
  - Spectrum
  - 3GPP MCPTT / PTT

The section may be updated in case regulatory constraints especially on NTN may impact the end-user experience, for the general results on analysis of regulatory aspects it is referred to D2.5 *"Report on Regulatory requirements"*.

4.2 USER REQUIREMENTS FOR DRONE UE

For drone UEs, the dimension, weight and aerodynamic behavior are of paramount importance as they directly impact the power consumption and, thus, the available flight times. With respect to the 6G-NTN project, we propose to consider two cases: Light and Heavy drones. There exists a wide variety of drones and distinguishing only two categories of drones may seem a little restrictive. Yet, such distinction allows to build harmonized requirements to be used by other WPs of the 6G-NTN project.

As UC2 is about Power Line Inspection, we propose to base the definition of Light drones on the PDRA G-03 AMC6 – Article 11 of Regulation 2019/947, decided by EASA (EU Aviation Safety agency). It specifies a "maximum characteristic dimensions (*e.g.,* wingspan, rotor diameter/area or maximum distance between rotors in case of a multirotor) of up to 3 m" and a "typical kinetic energies of up to 34 kJ" (which encompasses maximum weight and velocity, to minimize the impact of the drone in case of crash). Consequently, any drone bigger than this enters the Heavy drone category.

In the following, we present the main characteristics and requirements that are common to both types of drones and the ones that are specific to each of them.

4.2.1 Drone UE characteristics

4.2.1.1 Specific requirements related to NTN device mounted on Light Drones

Given the weight / size of the aircraft and the embedded payload devices (different types of cameras, sensors, etc.), the following requirements are proposed.

The NTN device mounted on light drone should not exceed 10x10x2cm, including antenna and a few hundred grams (for example, 200 / 300g).

The power consumption of the NTN device mounted on light drone should not exceed 10mW / 1W in idle / connected mode.

- However, note that the constraint on weight and size, should be prioritized over the constraint on power consumption. Indeed, the power consumed by embedded electronics, antennas and chipsets is usually quite low compared to the power consumed by rotors to take-off, fly and land. A gain in weight will necessarily be translated into a more significant reduction in the power consumed by rotors, especially at takeoff and landing.

The NTN device mounted on light drone should be dismountable.

- Light drones, *e.g.,* for inspection, are often offered as "Drone-as-a-Service", *i.e.,* they are reconfigurable. Depending on the mission, the drone operator may want to use different cameras or sensors, and different means of communication. For example, for a short-range Visual Line of Sight (VLoS) mission, the drone operator may prefer to use wireless communications other than NTN and thus, may choose to temporarily remove the NTN device to reduce the overall weight.

4.2.1.2 Specific requirements related to NTN device mounted on Heavy Drones

Such drones will typically enter the "Certified category" defined by EASA, for which flight authorizations are currently delivered on a case-by-case basis. Heavy drones can be considered as large aerial vehicles and cover the following use cases:

- Delivery, where the payload can range from a few kilos to several hundreds of kilos. This UC targets healthcare (*e.g.,* blood samples or medicine delivery), civil engineering (*e.g.,* delivery of raw material or large-scale equipment), but also mass market (*e.g.,* goods / parcel delivery).
- Long-range surveillance, over the earth or the seas. This includes MALE (medium-altitude long-endurance unmanned aerial vehicle).
- Passenger mobility, *i.e.,* taxi drones.

A size of 20x20cm, for a weight <1kg, is believed acceptable for a NTN device mounted on heavy drone. Other configurations / designs are possible.

- For example, there could be a 10cm x 10cm on each of the 2 wings of a MALE. But a trade-off needs to be found between the overall drone size & weight and the size & weight of the NTN device.

The power consumption of the NTN device mounted on heavy drone should not exceed 100mW / 10W in idle / connected mode.

4.2.2 Usage scenarios

Two use cases on drones have been proposed: UC2 to investigate payload data services offered to the end-user (*e.g.,* HD video or sensors), and UC3 to analyze C2 (Command & Control) services offered to the drone controller. A third use case, UC4 on PPDR communications provides another example of drone utilization and constraints. Note that two major assumptions are considered here:

- Satellite communications may not be an obvious solution for VLoS flights, *i.e.,* when the pilot is in the vicinity of its drone and communicates with it via a direct link. Thus, for the 6G-NTN project, only BVLoS (Beyond VLoS) is considered.
- Although two different devices could be considered to support the C2 link and payload data communications, such solution may not be optimal in terms of weight, size and power consumption. Thus, within the context of 6G-NTN, a single device is assumed for both, with integrated terrestrial and non-terrestrial network access.

To build a full drone service, three main components are needed, as summarized in Table 2:

- **A drone, as hardware or aircraft:** here, requirements are given by the drone manufacturer and mostly relate to NTN antenna design and installation constraints.
- **Payload data services:** related to the drone mission and typically fully customized to the end-user requirements.
- **C2 link services**: related to the drone remote control and targeting the drone pilot and airspace authorities.

TABLE 2 - REQUIREMENTS CATEGORIES FOR DRONE UE

<table>
<tr><th>Service component</th><th>Who?</th><th>What?</th><th>Light drones</th><th>Heavy drones</th></tr>
<tr><td rowspan="2">Drone (Hardware)</td><td rowspan="2">Drone manufacturer</td><td rowspan="2">NTN Antenna design and installation constraints</td><td colspan="2">Sections: 4.2.1, 4.2.3 and 4.2.4</td></tr>
<tr><td>Section: 4.2.1.1</td><td>Section: 4.2.1.2</td></tr>
<tr><td colspan="5">AND</td></tr>
<tr><td rowspan="2">Payload data services (for embedded devices)</td><td rowspan="2">Drone mission customer</td><td rowspan="2">Mission-related requirements</td><td colspan="2">Sections: 6.2.1 and 6.2.2.2</td></tr>
<tr><td>Section: 6.2.1.1</td><td>Section: /</td></tr>
<tr><td colspan="5">AND</td></tr>
<tr><td rowspan="2">C2 link services (for piloting the drone)</td><td rowspan="2">Drone controller, Airspace Authorities, U-Space Service Providers</td><td rowspan="2">Identification & Tracking, Telemetry, etc.</td><td colspan="2">Section: 6.2.2</td></tr>
<tr><td colspan="2">Remote Control:
Manual → 1st Req. of section 6.2.2.1
Supervised → 2nd, 3rd Req. of section 6.2.2.1</td></tr>
</table>

4.2.3 Usage Conditions

- **The drone UE will be operated in extreme temperatures and weather conditions.**
  - The UE mounted on a drone shall sustain dust, water (both rain and condensation), and potentially, sea, and salt for maritime use cases.
  - The UE mounted on a drone shall be compliant with standards of electronics in terms of operational temperature range and be able to operate in the temperature range [-20°C, +60°C], without cooling / warming system. When flying, cooling is due to air flows (but in geographic areas with cold winter, this could mean -20°C). Connectivity must be available also on the ground (pre-flight and post-flight service), where it could be very hot (+60°C *e.g.,* over asphalt during a hot summer day). On landing and takeoff, there could be a very high temperature variation in a short period of time, with high risk of condensation.

➲ **The drone UE will need to be operational whatever the aircraft material and drone motion.**

- Aerodynamics constraints must be considered. Moreover, NTN antenna characteristics can be affected by the material used to build the aircraft (*e.g.,* reinforced carbon fibers), the position of the antenna itself on the aircraft, and the proximity of rotors and battery. Typically, the antenna will be positioned on the top of the drone (and not below) as it can fly at low altitude.

- The integration of an NTN-terminal should also 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). Orientable antenna may be of interest in this case.

4.2.4 Regulation and other aspects

➲ **The drone UE to be compliant with national and international regulations (aviation and spectrum).**

- Besides general regulations, for communication equipment, there are special regulations for drones, which may vary by country, region, and state. Additional laws may exist, prohibiting or restricting drone activities within certain areas. The reachability and control that is required when operating a drone, may set additional requirements on the reliability of the communication connection and on positioning.

- Further regulations may exist about the correct utilization of spectrum by drones, especially with respect to co-existence scenarios. In November 2022, the ECC (Electronic Communication Committee) adopted, 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).

4.3 USER REQUIREMENTS FOR MOUNTED UE

4.3.1 UE Characteristics mounted devices

- The fixed first responder device type is also considered in context of mounted devices, even if it is used in a stationer manner after getting out of a vehicle, as concerning its characteristics, it is rather in the same dimensions as mounted devices compared to handhelds.

4.3.1.1 Fixed first responder UE

Compact and easy-to-operate and deploy nomadic devices that are deployed on a temporary basis, can be mounted on a mast/pylon, on a base on the ground. Antenna is similar to the other compact mounted devices, *e.g.,* < 20 cm x 20 cm.

- Weight: < 5 kg's for easy carry by one person (including battery)

- Antenna size less than 20x20 cm as operated in a fixed manner /stationary

- Power consumption < 10 W for battery activated operation

4.3.1.2 Characteristics vehicular/vessel mounted UE

The UE may be mounted to a vehicle or to a vessel (maritime also considered here), as considered in the scenarios. Such scenarios have in common that there are only limited constraints related to size and weight of the UE mounted device. The size constraints for vehicular (automotive) mounted device may be more restrictive than for vessel (*e.g.,* ship mounted) devices in terms of geometry and optic. As a special subgroup of the mounted devices, fixed installation equipment of first responders can be considered. It has same size and weight restriction as vehicle mounted devices, with the exception that mobility for this type of device is considered to be 0 km/h when in use.

- Typical dimension for a vehicular mounted device is 10x10x2cm where the antenna size is incorporated in these numbers.
- For vehicular mounted devices the power consumption is limited, it is less a restriction during momentary operation but also a restriction during idle/standby times. Currently values of [300mA] during operation and in [10uA] during idle/standby are believed to be acceptable depending on reachability requirements.
- Typical dimension for a vessel mounted device is 40x40x0,5cm, where even larger antenna sizes are acceptable, *e.g.,* for large ships also an acceptable size of up to 60x60 cm was found.
- For vehicular/automotive mounted devices the power consumption is limited, it is less stringent during momentary operation but also a restriction during idle/standby times. Currently values of [300mA] during operation and in [10uA] during idle/standby are believed to be acceptable depending on reachability requirements.
- Concerning geometry for vessel (ship) mounted devices.
- For vessel mounted devices, there is only limited restrictions on power consumption or weight, hence up to 1A power consumption and several kilos of weight are acceptable, as compared to overall weight and energy of the transporting vessel this is negligibly.

4.3.2 Usage scenarios

4.3.2.1 Fixed first responder UE

- Used at a fixed location in case of catastrophic event.
- UE is mainly connected to NTN, therefore only NTN to NTN mobility needed, due to satellite movement, device itself is fixed.

4.3.2.2 Usage for vehicular/vessel mounted UE

- For vehicular mounted devices, a continuous connectivity provision is important for the end-user experience. The UE may move continuously while voice or video calls are ongoing, including HD-multiparty calls. Thus, also during mobility these end-user activities need to be maintained including also subsequent NTN/NTN changes or NTN/TN network changes and vice versa. Consequently, handover between NTN/TN or NTN/NTN, *e.g.,* in case of feeder-link switching, need to be performed transparently for the end-user, with no or minimal momentary degradation only.

- The UE may move up to 250km/h and, therefore, special care needs to be taken for these high-speed scenarios.

4.3.3 Usage Conditions

4.3.3.1 Fixed first responder UE

- Smoke, heat, dust, and water vapor can be present when used in the context of emergency and disaster response.
- The fixed first responder UE mounted on ground or mast shall be compliant with standards of electronics in terms of operational temperature range and be able to operate in the following temperature range [-20°C, +60°C], without cooling / warming system.
- Lifetime expectancy for fixed first responder UE is up to 10 years.

4.3.3.2 Usage conditions vehicular/vessel mounted UE

- Vehicular mounted UEs may experience high speed mobility scenarios up to 250km/h.
- Depending on the placement of the UE in the vehicular/car environment, *i.e.,* in proximity to the engine, the device may experience extreme environmental conditions up to a range of -40°C to +90°C. The environmental range is beyond the range that is considered as extreme conditions and hence in said range beyond extreme conditions service degradations may occur.
- A vehicle is a long-lasting device with lifetimes of up to 20 years. For such long lifetimes maintenance with a minimum periodicity of 1 year need to be considered.

4.3.4 Regulation and other aspects

- During the usage of vessel or vehicular mounted devices, border changes need to be considered. Based on regulatory or commercial aspects the mobility scenarios NTN/NTN or NTN/TN may be conducted in different ways.
  - However, these regulatory aspects, when entering a certain region or country with new regulations, especially for NTN, need to be considered within the framework of T2.5.

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5 SERVICE REQUIREMENTS

As previously mentioned, the service requirements are seen from the user perspective.

A user wants to perform a certain service in a certain scenario, hence fulfilling the need of the service is very important for the end-user experience. The services are described in an abstracted manner from the end-user perspective. The translation of these service needs into technical requirements, to be achieved by the 6G-NTN system, is subject of D2.3, which will formulate the technical requirements.

The end-user service requirements were discussed on the basis of the scenarios with the members of the EAB, especially those from the respective verticals directly involved. In addition to end-user service needs on high level, detailed requirements regarding technical perspective (*i.e.,* required throughput, positioning accuracy etc.) were also received. Those values will be considered within D2.3, which deals with the technical requirements and the respective profiles.

The services are structured hereafter into different service categories. A distinction is made between Communication Services and Localization/Positioning Services. Some services may be associated to a certain scenario where a specific UE type is used in that context.

A summary of the services experienced in the various use cases can be found in Table 3 and Table 4 and are further described in the following sections.

TABLE 3: REQUIREMENTS CATEGORIES FOR COMMUNICATION SERVICES

Communication Services	Types References	Throughput	Latency	Reliability / Criticality	Degraded service tolerance
Voice	Consumer IP voice Critical / MCPTT	Low / kbps	Low	Consumer / 5G / 6G level Critical as 3GPP defined	Mid for consumer Low for critical
Message	IP data package Broadcast	Low / kbps	Mid	Mid for IP data package Broadcast	Mid for IP data package Low for broadcast
Data	Telemetry Real time control Consumer / app usage Software update	kbps to Mbps for telemetry kbps real time control Mbps for consumer Mbps for updates	Mid for telemetry Low for real time control Mid for consumer High for updates	Mid for telemetry High for real time control Mid for consumer Low for updates	Mid for telemetry Low for real time control Mid for consumer High for updates
Video	2-way multiparty video call Camera transmission	4-8k video call (~10-20Mbps) 4-8k camera (~10-20Mbps)	Low for video call Mid for camera	Mid for video call Mid for camera	Low for video call Low for camera

	➲ Critical video	➲ 4-8k critical video (~10-20Mbps)	➲ Low for critical video	➲ High for critical video	➲ Low for critical video, Low-res fallback video

TABLE 4: REQUIREMENTS CATEGORIES FOR LOCATION SERVICES

Location Services	Types References	Accuracy	Update rate	Degraded service tolerance
Standard	➲ Standard ➲ Enhanced	➲ Mid (~10m) ➲ High (<1m)	➲ Low ➲ High	➲ Mid ➲ Low for critical services
3D-Location	➲ Only for aerial use cases	➲ For navigation and collision avoidance	➲ High – drone speed is the main contributing factor	➲ Very low, since air safety related, etc.

5.1 COMMUNICATION SERVICE EXPECTATION

Service capabilities may include, for example, types of service (Voice, Data, Video, etc.), high-level traffic characteristics (downlink / uplink, continuous / intermittent, etc.), and heterogeneity of communication.

For the different use cases, the user needs service capabilities messaging, continuous data stream for telemetry, audio and video. These services need to be supported bi-directionally.

Communication services need to be maintained during network transition, also between TN and NTN and vice versa. A noticeable interruption or major service degradation experienced by the end-user should be avoided.

The user expects the support for duty cycles from continuous operation to random access and sporadic usage.

Energy efficiency during random access and sporadic usage are important requirement.

5.1.1 Voice / Audio

- **General / Summary**
  - Outline general voice needs.
  - Around 100ms for bi-directional audio communication is needed, while one directional audio streaming can accept latencies in the range of 1s.
  - Duty cycle.
- **Use case specifics**

- Real-time reliable voice (including 3GPP MCPTT / PTT) connection between UE terminals and the command center is important for critical use cases such as coast guard.
- Extremely reliable, even under challenging weather conditions (>99.9% p.a.) for *e.g.,* coast guard and other terrestrial critical use cases.

5.1.2 Messages and Notifications

➲ **General / Summary**

- Message and notification are characterized by a low IP data stream for realizingText message and Multimedia message. General messages also include broadcast.

➲ **Use case specifics**

- Real-time reliable voice (including 3GPP MCPTT / PTT) connection between UE terminals and the command.
- Critical Downlink (DL) data for emergency notifications and critical messaging.
- Critical Uplink (UL) messaging for report or position provisioning.

5.1.3 Data

➲ **General / Summary**

- Standard data transfer
- A typical use case would be application data or web browsing sensor data transmission and device update or DL data for configuration and software updates.
- The data provisioning is characterized by a need for medium latency and reliability as corrective mechanisms exist for data provisioning.
    - Criticality: Sensor data transmission: Medium/Low data rate, real-time sensor data collection and processing.

➲ **Use case specifics for critical messages and notification**

- Critical UL data for telemetry and measurements (including 3GPP MC data).
- Real time remote control
    - Remote control of assets such as drones require immediate transmission of data and control sequences.
- In case of critical message and communication in critical situations, a service degradation may be acceptable for a momentary time as long as the service basics as such are still provided (Minimum service).

5.1.4 Video

➲ **General / Summary**

- UL data for entertainment and personal use

    - 4K to 8K video resulting in throughputs between
        - UL/DL: average 1Mbps, Peak 10Mbps
        - UL/DL: average 10Mbps, Peak 100/200Mbps (maximum)
    - The user requires uninterrupted communication like video calls and conferences as well as audio communication. Also, critical data stream such as telemetry or remote control of static and mobile assets (such as drones) have to be maintained.
    - Around 100ms for bi-directional video communication is needed, while one directional video can accept latencies in the range of 1s.
    - Tolerance for service interruptions lies in the tenths of ms.
    - Tolerance for degraded service lies in the tenths of ms.
- Duty cycle

➲ **Use case specifics**

- Real-time reliable video (including 3GPP MC video), data collection, and partial processing of data with edge computing capabilities aiming at detecting and identifying 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.
- Direct to Handheld: Video such 4K video flow may be dynamically downgraded at applicative level and the 6G NTN link shall offer sufficient capacity to continue streaming video flow with a lower resolution such as Standard Definition (SD) or High Definition (HD) quality.
- Video: Highly reliable transmission of data (>99.9%).
- In case of video communication in critical situations a service degradation may be acceptable for a momentary time as long as the service basics as such are still provided. (Degradation in resolution).

5.2 OTHER REQUIREMENTS

5.2.1 Location and Timing Services

➲ **General user Requirements**

- For most use cases, the location accuracy is expected to be in the range as experienced in 5G NTN (i.e., ~1 meter) but with a drastic reduction of the acquisition time (i.e., up to 100 seconds in 5G NTN). A higher accuracy beyond Global Navigation Satellite System (GNSS) should be possible especially for a broad range of mobile applications such as drones, first responders or precision farming.
- For mobility use cases, a reasonable positioning update rate has to be considered scaling with the experienced movement by the end-user.

➲ **Specific user requirements**

For emergency services such as Coast Guard Intervention and adaptation to planned or unexpected events: reliable positioning in the range of ~1m:

- The accurate positioning of the actors within the SAR team (Ships, Helicopters, 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.

Drone based use cases such as “Autonomous power line inspection using Drones” and “Urban air mobility”

- A very tight control of the drone 3D location is needed for air space safety and efficient usage or flight corridors having a limited width, following defined routes and the manual flight modes. Accuracy greater than 1 meter (e.g. 10 cm target accuracy) at high reliability should be provided by the network to prevent excessive safety gaps between drones, UAM or allow narrow flight corridors.

5.2.2 Reliability

A reliability of 99.999% or greater would allow to support UAM/drone control.

5.3 COEXISTENCE

In the use case scenario, there might be other wireless technologies involved. For example, short range communication, side channels or others.

The user expects co-existence and avoidance of cross-talk, interference and jamming is ensured.

5.4 POLICIES AND REGULATORY CONSTRAINTS

Policies and regulatory aspects for service scenarios only exist to the extent that there are regulatory or policy constraints for the use case in which the service was used. General NTN regulatory aspects are subject of another work package within this project.

5.4.1 First Responder and Professional Communication

In case of first responder or Coast Guard Intervention, special policies and regulations apply. 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.

5.4.2 Aerial Vehicles

Drone based use cases are subject to airspace regulation by regulatory bodies, considering accuracy in flight position and respecting regulations and no fly zones. More detailed descriptions can be found in the UE drone description in section 4 and with respect to NTN regulatory constraints, reference is generally made to the regulations of D2.5.

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6 COMBINED USER REQUIREMENTS

As described in the previous chapters, a certain UE (Section 4) is used in a certain scenario (Section 3) and the user expects that the service requirements, described in Section 5, are achieved.

Each of the use cases of D2.1 is characterized per UE (Section 4) and service expectation (Section 5). Both UE and the Service expectation are complemented in this section with a usage resulting in user requirement. The structure is adapted to the device type and combined as far possible, outlining for each device type its specific characteristic leading to combined and consolidated set of user requirements to be fulfilled by that type of device and the NTN system as such.

Table 5 provides an overview of the collected use cases developed in D2.1 and their assignment towards the various UE device types identified during the user requirements evaluation.

TABLE 5: COMBINED USER REQUIREMENTS

	User	Service Expectations	Network configuration & mobility scenarios	UE Types	Handheld Consumer	Handheld Professional	Mounted Maritime	Mounted Vehicular	Drone	Large drones
Use Cases (defined in D2.1)		**General / all use cases** • Audio • Data • Video	**General / all use cases** • NTN only continuous coverage • TN-NTN seamless handover	**Geometry**	Size / weight constraint Limited battery	Size / weight constraint Limited battery	larger antenna geometry	Limited antenna geometry	Size / weight constraint Limited battery	>100kg
				Lifecycle	Standard	Extended	Extended	Extended	Extended	Extended
				Operational Conditions	Standard (outdoor)	Extreme, water vapor, smoke	Extreme, water vapor,	Extended Conditions	Extended Conditions	Extended Conditions
				Environment	Semi Outdoor[1]	Land, sea, air	Sea, air	Canyon, tunnel.	Air	Air
				Mobility	Pedestrian, on vehicle use	Pedestrian, on vehicle use	Mid-speed, water bound	High Speed, road bound	3D-Mobility	3D-Mobility
UC1: Maritime Coverage for search and rescue coast guard intervention	• Vessel Op. • UAV-Contr. • Pilot	• Critical Comm. • Realtime control • Telemetry Data	• Tactical Bubble • Direct UE to UE via sat	→		X	X			X
UC2: Autonomous power line	• Aut. Drone • UAV-Contr.	• Realtime control • Telemetry Data	• Private TN – NTN • NTN via HAPS	→					X	X

[1] Semi-outdoor refers to the condition in which the UE is an GNSS-hostile outdoor environment such as an urban canyon or a wooded area, where there are not enough satellites in visibility to accomplish a GNSS positioning. Please refer to D2.1 and reference therein for further details.

inspection using drones										
UC3: Urban air mobility	• UAV-Contr.	• Realtime control • Edge network services • Broadcast • 3D-Location	• TN - NTN info. exchange • Direct UE to UE via sat • NTN via HAPS	→					X	
UC4: Adaptation to PPDR or Temporary Events,	• First resp. • Ambulance	• Critical Comm. • Broadcast • Location, 3D-Location	• Tactical Bubble • Direct UE to UE via sat • NTN via HAPS / a. node	→		X		X	X	X
UC5: Consumer Handheld Connectivity and Positioning in Remote Areas	• Priv. user	• Emergency Call • Broadcast • Location	• Cross-border mobility	→	X					
UC6: Continuous Bi-directional Data Streams in High Mobility	• Passenger • Driver	• Conference (video) Call • Emergency Call • Broadcast	• Cross-border mobility	→	X			X		
UC7: Direct Communication over Satellites.	• Priv. user • First resp.	• Emergency Call • Broadcast • Location	• Direct UE to UE via sat	→	X	X				

6.1 HANDHELD BASED USER REQUIREMENTS

This section summarizes professional and consumer based handheld devices. Even though they are separated in different sub-sections, the major findings concerning service/traffic profile justify this combined treatment. However, the well observed differences concerning acceptance of size and weight or also the higher tolerance of professional devices with respect to ambient and environmental conditions will also be described, even though they are not leading to major differences concerning the related requirements.

6.1.1 Consumer Handheld User Requirements

For consumer handheld devices, the most important service scenarios towards the various use cases are voice service and positioning in remote areas where no other communication means are available. The availability of positioning and voice service includes respective emergency service. As an additional identified need, the reception of broadcast information for warning or entertainment purposes was identified. The related requirements for these services are summarized in the communication service requirements (Section 5.1). For the positioning and location accuracy, a tolerance of ~10m is acceptable for such consumer use cases.

<u>NOTE: Operational conditions and mobility is described under UE, since linked to UE.</u>

6.1.1.1 Consumer Handheld – Entertainment & Communication

A Consumer (User) connected to a 6G NTN wants to have a video call, sending data or using smartphone applications either in roaming or in his home network.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor and semi outdoor, all-weather zones.

6.1.1.2 Consumer Handheld – Emergency Call

A Consumer (User) wants to send an emergency call via NTN either in roaming or within his home network.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor and semi outdoor, all-weather zones.

6.1.1.3 Consumer Handheld – Message Broadcast

A Consumer (User) wants to be able to receive broadcast messages such as hazard warnings via NTN either in roaming or within his home network.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor and semi outdoor, all-weather zones.

6.1.2 Handheld professional use

Location services beyond GNSS are a requirement for a broad range of mobile applications such as drones, first responders or precision farming.

6.1.2.1 Professional Handheld – First Responder direct video and data

A Professional Handheld User / first responder wants to be able to send video and data directly to other professional handheld users via a dedicated NTN network / tactical bubble.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor and semi outdoor, all-weather zones, smoke and water vapor from fire-fighting.

6.1.2.2 Professional Handheld – First Responder operations center link

A Professional Handheld User / first responder wants to connect to the operations center via a dedicated NTN network / tactical bubble to send and receive video and data.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor and semi outdoor, all-weather zones, smoke and water vapor from fire-fighting.

6.1.2.3 Professional Handheld – First Responder location accuracy (*e.g.,* for situational awareness service)

A Professional Handheld User / first responder wants to be trackable in outdoor / semi-outdoor / light-indoor / in-vehicle conditions, with a positioning accuracy at least as precise as offered in current GNSS-based satellite and cellular solutions.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor, semi-outdoor, light-indoor and in-vehicle, all-weather zones, smoke, and water vapor from firefighting.

6.1.2.4 Professional Handheld– Near-ubiquitous geographical service coverage for First Responder

A Professional Handheld User / first responder wants 6G NTN to provide a near-ubiquitous geographical coverage.

Operational condition:

- Mobility: afoot or on board a vehicle. On the ground or in the civilian airspace or in coastal areas or offshore.
- Environmental conditions: outdoor, semi-outdoor, light-indoor and in-vehicle, all-weather zones, smoke and water vapor from firefighting.

6.1.2.5 Professional Handheld– Prioritized network resource for First Responder

A Professional Handheld User / first responder wants 6G NTN to provide a constant network connectivity able to serve all professional applicative needs, irrespective of the number of other non-Professional Handheld Users in the same coverage.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor, semi-outdoor, light-indoor and in-vehicle, all-weather zones, smoke, and water vapor from firefighting.

6.1.2.6 Professional Handheld– Use of flexible nodes for first responders

A Professional Handheld User / first responder wants 6G NTN to allow bringing on a specific area additional network capacity for the exclusive or prioritized Professional use.

NOTE: This user requirement 6.1.2.6 assumes the dynamic allocation of additional network capacity (*e.g.,* through additional satellite steerable beams over the considered cells, or through the deployment of flexible 6G-NTN nodes). In contrast, user requirement 6.1.2.5 assumes a fixed network capacity, which must be prioritized for Professional Handheld usage.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor, semi-outdoor, light-indoor and in-vehicle, all-weather zones, smoke, and, water vapor from firefighting.

6.1.2.7 Professional Handheld– Deeper indoor communications for first responders

A Professional Handheld User / first responder wants 6G NTN to allow bringing on a specific area flexible network nodes able to support deeper indoor communications.

NOTE: This user requirement considers that the operational altitude of flexible nodes will be lower (drones, MALE, HAP, all below or within the low stratosphere). Therefore, thanks to a smaller attenuation due to lower distances, such user links could serve users in deeper indoor conditions (i.e., further from the “first wall” or “outer hull” than typical light-indoor conditions may allow).

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: deeper indoor, all-weather zones, smoke and water vapor from firefighting.

6.1.2.8 Professional Handheld– lower latency communications for first responders

A Professional Handheld User / first responder wants 6G NTN to allow bringing on a specific area flexible network nodes able to support lower latency communications.

NOTE: This user requirement considers that the operational altitude of flexible nodes will be lower (drones, MALE, HAP, all below or within the low stratosphere) or able to locally serve users thanks to a direct user-to-satellite-to-user architecture. Therefore, Professional users expect the deployment of lower-latency local services, such as the ability to implement command & control (C2) for any type of remotely piloted vehicle, including remotely piloted aircraft systems (RPAS) and terrestrial robots being deployed in hazardous areas.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor, semi-outdoor, light-indoor, deeper indoor and in-vehicle, all-weather zones, smoke, and water vapor from firefighting.

6.1.2.9 Professional Handheld Highly resilient communications for Professional (*e.g.,* governmental, military and first responder) users

A Professional Handheld User / first responder wants 6G NTN to be highly resilient to any case of ground equipment compromission.

NOTE: This user requirement considers that ground equipment, such as ground stations supporting feeder links with the 6G-NTN nodes, may not prevent the 6G-NTN nodes to continue serving Professional Handheld Users, thanks to direct communications over satellites, as described in D2.1/UC7.

Operational condition:

- Mobility: afoot or on board a vehicle.
- Environmental conditions: outdoor, semi-outdoor, light-indoor, deeper indoor and in-vehicle, all-weather zones, any atmospheric composition that may be met by such users.

6.2 DRONE BASED USER REQUIREMENTS

There are two types of connectivity services for drone-based users:

- **Payload data services:** related to the drone mission and typically fully customized to the end-user requirements.
- **C2 link services:** related to the drone remote control and targeting the drone pilot and airspace authorities.

6.2.1 User requirements related to payload data services

This set of requirements is related to the drone mission and thus, is typically fully customized to the end-user expectations and to the devices embedded on the drone (sensors, cameras, etc.). The following requirements are derived from UC2.

Note that other general requirements can be proposed about seamless and ubiquitous connectivity, as well as accurate positioning. They are described in the following section, dedicated to the C2 link, where the need to meet such requirements is much more stringent, as they are related to airspace safety.

6.2.1.1 Drone - Infrastructure inspection & surveillance

A Drone-based user for inspection wants 6G NTN to support the aggregated air-to-ground traffic data generated by the different payload devices,

- *e.g.,* one LIDAR and / or one camera for 4K video streaming and / or one sensitive camera for night image processing). Such traffic is intended to remote cloud (for data processing), is typically uplink and is generally around some tens of Mbps. It may reach up to 200 Mbps but can be much less. For example, a few kbps are sufficient to transmit the temperature of a controlled medical delivery (Internet of Things (IoT)- type communication).

A Drone-based user for inspection wants 6G NTN to support low-latency / low-jitter air-to-ground communications, between the drone and the remote cloud, for real-time AI-enabled data processing.

- Such processing is usually quite sensitive to delay and throughput variations. To compensate for the reduced throughput and increased latency induced by NTN communications, a drone may embed part of Artificial Intelligence (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 and cloud offloading capabilities would be of high interest.

6.2.2 User requirements related to C2 services

We first distinguish three flight modes:

- The manual remote control (as in UC2 – scenario 2) where a human is piloting the UAV.
- The supervised remote control (as in UC2 – scenario 1) where the drone is autonomous but supervised by a control center.

- The fully autonomous flight mode, which allows the drone to keep flying or return home in case it loses all means of communication with its controller or pilot. In the context of 6G-NTN project, this last mode should be considered more as a failsafe or emergency procedure and less as a nominal flight mode.

6.2.2.1 Throughput and Latency requirements related to drone remote control

The following requirements can be proposed for the manual and the supervised flight modes.

Drone - A Drone-based user with manual remote control

A Drone-based user with manual remote control wants 6G-NTN to support a minimum data rate of a few Mbps and a maximum latency (round-trip, from UAV to controller and back to UAV) of 150ms (ideally 100ms), for telemetry, "keep alive" data and a video for drone piloting.

- Manual control requires reactivity as there is a "man-in-the-loop".
- Bad weather conditions require precision of landing and a RTT <100ms for manual landing is needed.

Drone - A Drone-based user with supervised remote control

A Drone-based user with supervised remote control wants 6G-NTN to support a minimum data rate of 20-80kbps and a maximum latency (round-trip, from UAV to controller and back to UAV) of 200ms for telemetry and "keep alive" data.

- Such traffic is relatively periodic, *e.g.,* to report the drone position, and one message every some tens of millisecond is expected.

A Drone-based user with supervised remote control wants 6G-NTN to support the upload of a new flight plan, before take-off (ground connectivity) or during flight (air connectivity), as an on-event type of traffic.

- The volume of such upload is generally around 200Mbytes.

6.2.2.2 Requirements addressing the drone pilot's concerns

Next, in order to avoid a loose a connectivity or to enter a failsafe procedure, the three following requirements are proposed.

A Drone-based user, with either manual or supervised remote control, wants to be served by a ubiquitous TN / NTN connectivity, without network gaps within the considered 3D service airspace.

- Such ubiquitous service should take into account the drone trajectory and mobility pattern. Currently, drones are allowed to fly at a maximum altitude of 120m, but for future use cases (especially for Urban Air Mobility), much higher flight altitude are expected, up to 10km (manned aircraft cruising altitude).
- The fly zone is generally bounded to the airspace volume declared during flight authorization procedures. Such volume can be quite restricted (*e.g.,* an industrial site) or much bigger (*e.g.,* coast surveillance), or can be limited to a long-range aerial corridor (currently ~300m wide, but the size will be reduced with the enhancement of integrity and accuracy of connectivity services).
- Connectivity should be available whatever the environmental and weather conditions.

- In very degraded flight conditions, an interruption of the connectivity service of up to 10 [s] is still acceptable for a supervised flight control mode, but this should not occur too often (> 10min).

A Drone-based user is expected to seamlessly and transparently handoff between terrestrial and non-terrestrial networks, while transmitting data (*i.e.,* in connected mode).

- From the perspective of the drone pilot, a seamless and transparent handoff can be defined as a handoff which enables to keep the same flight control mode, *i.e.,* if manual control is used before handoff, it can still be used after handoff.
- From the perspective of the airspace authorities, a seamless and transparent handoff can be defined as a handoff which does not break the ground-to-air and air-to-ground information flows, for geo-awareness and safe drone traffic management (continuity of U-Space services).
- In addition, a seamless and transparent handoff can be defined from the perspective of the end-user (for payload data – Section **Error! Reference source not found.**) as a h andoff which allows application services (such as AI data processing) to be pursued normally.

A Drone-based user wants accurate timing services and highly reliable positioning, able to complement legacy GNSS positioning techniques and offer higher resilience with respect to drone navigation.

- To safely operate the drone, location-based mechanisms ensure anti-collision and autonomous deconfliction, accurate geo-fencing, precision take-off and landing procedures, etc. Positioning computation should experience low latency, especially if the drone is moving fast (60 – 100km/h).
- A Localization accuracy <1m is acceptable for takeoff and landing, but also for flying at low altitude, where there are many obstacles.
- Hyper-geolocalization can also be used for payload data (Section 4.2.2), to map the images collected by the drone to their actual localization. This includes, for example AI-based routine maintenance as described in UC2 (autonomous power line inspection using drones) and precision agriculture.
- In general, the positioning via NTN shall not depend on GNSS availability but be an autonomous complement.

A Drone-based user, with either manual or supervised remote control, wants to receive in advance (pre-flight) and in real-time TN / NTN Coverage Availability Information (3D coverage map).

- A drone controller or pilot needs to monitor network Key Performance Indicators (KPIs) related to coverage to anticipate any potential loss of connectivity / interruption of service. Indeed, he or she cannot afford waiting for a connectivity failure to trigger a change of flight control mode.
- Developing monitoring functions on the drone (*i.e.,* at application layer) for predictability of QoS (before and during flight) remains quite tricky and would consume unnecessary bandwidth. Such monitoring function are thus expected at the network side.
- For example, this would allow the drone pilot to move from manual remote control to supervised remote control before experiencing service degradation.
- In the example of UC3 - Scenario 1, flight authorization can be easily obtained thanks to such coverage information. This proves that a good level of safety is guaranteed.

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- High interoperability of network service exposure and coverage information exchange between the different layers of the 3D architecture (from terrestrial to very Low Earth Orbit (vLEO) / LEO / medium Earth Orbit (MEO) / Geostationary Earth Orbit (GEO)) is critical.
- Remark: such user requirement, proposed here for a drone scenario, may be generalized to other vertical and use cases. For the energy sector, the need to monitor network KPIs (latency, throughput, link availability) and to be aware of network maintenance activities or topology changes is essential to plan and conduct critical operations on the power grid, such as rolling blackouts. Indeed, such operations are remotely controlled and rely on IoT. An interruption of connectivity services during such critical operations would be highly detrimental to the electrical supply, potentially on over vast areas.

A Drone-based user, with either manual or supervised remote control, wants to be able to choose in advance the type of connectivity service (TN or NTN) for the C2 link, when several options are feasible.

- Ping pong between TN and NTN should be minimized, especially if they imply some service interruption and / or a change in flight control modes.
- Staying with NTN or with TN connectivity during the whole flight is preferred, if throughput and latency requirements are met for the C2 link, and even if this would imply less overall throughput for payload services.

6.2.2.3 Requirements addressing the Airspace Authorities' concerns:

A Drone-based user wants 6G-NTN to support interoperable and unified services for drones, whatever their means of connectivity (TN or NTN) and whether deployed in low, medium, or high drone traffic densities.

- In particular, managing drones within shared airspace volumes or aerial corridors requires the sharing of drone identity and positioning for geo-awareness, as in UC3 – Scenario 2. The authorized drone density will depend on the capabilities of the connectivity service provider, as a minimum temporal or distance spacing between drones is required to ensure safety. The more trustable ID & Tracking of drones, the more the density of drone can be increased.
- Similar level of data integrity, security, and QoS is expected for both TN and NTN.
- Such services can include the ones defined in 3GPP for TN Aerial UEs.
- 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 network layers).

6G shall provide broadcast or multi-cast services to drones, whatever the connectivity (TN or NTN).

- To receive safety notifications based on the drone geographical position, as in UC3 – Scenario 3.

6G shall provide edge computing services to drones, whatever the connectivity (TN or NTN).

- Computing components should "geographically" follow the drones and dynamically migrate services as close as possible to them, especially for drones deconfliction and anti-collision.

- This requirement would highly benefit from automated deployment of network services, for guaranteed quality of service, and flexible orchestration of edge computing components.

6.3 MOUNTED DEVICES BASED USER REQUIREMENTS

6.3.1 NTN usage for vehicle mounted (Automotive)

General requirements

The driver and / or multiple passengers of the vehicle want to use the 6G NTN UE embedded in the vehicle for bi-directional video (including video conference), voice and messaging communication while in motion.

General operational conditions:

- Mobility: high mobility.
- Environmental conditions: outdoor, all-weather zones, device mounted inside vehicle with exposure to additional heat and/or limited heat dissipation.

6.3.1.1 High mobility– NTN usage in mobility

The communication use is solely done via 6G NTN.

6.3.1.2 High mobility – NTN to TN usage in mobility

The UE is switching from TN to NTN communication due to TN coverage constraints.

When TN is available the UE is switching back to TN communication.

6.3.1.3 High mobility – NTN cross border

The UE is switching from TN to NTN communication due to TN coverage constraints.

When TN is available the UE is switching back to TN communication.

6.3.2 NTN usage vessels

6.3.2.1 General requirements

Vessel mounted devices for helicopters, drones, and small ships are designed to allow for a reliable communication link to TN and NTN base stations and relay the information to onboard passengers and mounted sensor equipment (cameras, measurement equipment, radars, etc.). This communication link requires a highly reliable connection to the base station. A separate antenna is foreseen for that link of typically 20cmx20cm to 60cmx60cm dimensions.

The UE on the vessel consists of a communication relay station for all onboard persons and equipment of need of communication. The vessel UE foresees a way to priorities local traffic, to implement a side-link communication to neighboring vessels, and to foresee local storage.

6.3.2.2 Vessel usage scenario

The operation of the link to the vessel UE needs to rely on a reliable connection that works across TN and NTN coverage areas and can roam through these coverage areas without loss of connectivity (*i.e.,* "seamlessly").

The vessel user equipment shall be capable of roaming over country border connecting to different networks simultaneously to ensure a transition without data loss.

6.4 MOMENTARY FIXED LOCATION DEVICE "FIXED OPERATED"

6.4.1 NTN Usage for temporary coverage

This category of user requirements relates to devices which are deployed on a temporary basis. This is for instance the case of PPDR or temporary events deployment cases, whereby users often need backhaul connectivity to transport user data from temporary base of operations and other ad hoc premises to the remote user's headquarters and more generally, to the Internet. With the support of an integrated high-capacity TN/NTN architecture, such as 6G-NTN, this requirement could be considered as obsolete. This is due to the fact that most PPDR or temporary event devices, including professional or consumer smartphones, may be served by direct radio links, even in case of post-disaster where terrestrial communications may be impaired. However, even with a great link diversity offered by 6G-NTN, there are still cases for which temporary backhauling links may be specifically needed, such as:

- The need to reliably backhaul high-capacity user traffic, possibly aggregating data from legacy and non-6G-NTN-capable devices,
- The need to connect deep-indoor users, whose devices could not be served by communication links restricted to outdoor or light-indoor conditions.

NOTE: Operational conditions and mobility is described under UE, since linked to UE.

6.4.1.1 Vessel scenario – Fast deployment with low-complexity configuration and maintenance for temporary fixed mounted device user

A PPDR or temporary event user wants his temporary fixed mounted device to be quickly deployable within the 6G-NTN. Moreover, the installation, operation, and maintenance of the device need to be easily achieved, with minimum staff and technical knowledge. In particular, users expect that 6G-NTN will support fixed mounted devices equipped with auto-pointing antenna and other zero-configuration features.

Operational condition:

- Mobility: fixed and mounted on a support (*e.g.,* ground, temporary mast or pylon, motionless vehicle, roof, etc.)
- Environmental conditions: outdoor, all-weather zones.

6.4.1.2 Vessel scenario – High reliability and capacity for temporary fixed mounted device user with small form factors

In the context of PPDR or temporary event, users are likely to use lightweight fixed mounted devices with small form factors, which follows the approach of fast deployment of tactical solutions. Even with these compacity features, users want their temporary fixed mounted device to operate nominally within the 6G-NTN, *i.e.,* support highly reliable, high-capacity backhauling traffic.

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Operational condition:

- Mobility: fixed, and mounted on a support (*e.g.,* ground, temporary mast or pylon, motionless vehicle, roof, etc.).
- Environmental conditions: outdoor, all-weather zones.

7 ADDITIONAL USER REQUIREMENTS

7.1 END USER EXPECTATIONS FOR COST

As end-user, private persons, and medium and large enterprises may have different expectations on cost level. The end user cost/charging or service purchase was also questioned to the EAB, to get some more concrete values with respect to end-user expectations.

However, for these aspects no clear answer/guideline was received. The reason may lie on the long deployment time and, therefore, it is not possible to provide a clear view at present. Nevertheless, there are some general aspects related to the end user expectations on cost/charging handling.

There is a clear expectation that the flexibility of today's cost models for the end-user will also be available when using 6G-NTN services. Today, various charging and cost models for the end-user are available. They allow tariff models, roaming scenarios or pay-per -use model which the end-user would expect also to be possible when accessing the service of a new NTN network. However, such scenarios and considerations and their implications on business aspects are to be further addressed in the business scenarios addressed in D2.4.

In general, any cost/charging model needs to be simple from the end-user perspective, *i.e.,* to have the possibility to be related to one cost/charging provider. As a consequence, one of the options considered could be roaming. Indeed, current scenarios between different TN networks would also apply for NTN networks and, thus, the end-user only interacts with his normal service provider, regardless of the system providing the service.

On a side remark, public safety cost considerations imply that also consumer end-users are part of the market and that the required additions would be integrated into the overall system functionalities and would not entail high additional costs.

7.2 SUSTAINABILITY

In addition to cost considerations, the user also has sustainability considerations and expectations. For sustainability lifetime, factors such as updatability and possibility to repair and recycle are of significant interest to users. Furthermore, users expect state-of-the-art designs that enable optimized power consumption, thereby reducing overall power consumption costs and impact.

Users want to be able to maximize the lifetime of their equipment without having to change it for at least a minimum of 5-10 years (the maximum period depends on type of equipment). Although consumer devices are replaced before their time, it is also necessary to ensure a longer lifetime usage through regular updates that reflect the increasing sustainability and considerations on environmental made by users. Terminal compatibility must be ensured also with an evolved system (legacy support) as the system evolves over a longer period. In general, mobile communication systems remain in the field more than a decade, thus, also earlier releases are supported within this time frame.

The users expect to be able to use their equipment anywhere in the world without having to update or change it. Therefore, they expect high degree of compatibility on electrical interface and connectivity.

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The users expect one type of equipment that supports any type of service he wants to consume (broadband, wide-band) and they want to minimize the number of different pieces of equipment to carry. Therefore, for the end-user is desirable a single equipment for worldwide coverage.

The growing awareness of sustainability on the part of the users directly leads to the need to recycle and repair, but also to use materials that can be recycled.

The user expects that a terminal could be repaired in case of damage without replacing the whole terminal for sustainability reasons.

Especially for Consumer Handheld terminal, the end user expects the power consumption to be comparable, when connected to NTN, to the values achievable with TN in such a way to not increase the overall power consumption to reduce energy. In accordance with this, optimization for power consumption must also be considered in other/all UE types, as energy is also a cost driving factor.

Even though the sustainability considerations do not directly affect the use cases, they are of great importance for the user ad there is a growing environmental awareness making sustainability also essential for the end user perception and acceptance of a future NTN communication system.

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8 SUMMARY

The user requirements were analyzed throughout this deliverable. The end-user expectations concerning connectivity for services to be available everywhere, *i.e.,* having at least entire outdoor coverage also in rural or sea area, were described. The end-user expectations clearly indicate a need for non-terrestrial networks that go far beyond scope and feasibility of service levels of the current 5G networks (data, video, telemetry). In addition, the end-user expectation for seamless mobility between various networks, whether TN or NTN based, is beyond the scope of today's user perception on 5G NTN and its inter-working.

In particular, even mixed TN-NTN scenarios with subsequent transitions that have only a limited tolerance towards delay and service interruptions are beyond achievable values by the current NTN-TN architectures.

The analysis performed on the user requirements clearly indicates a need for advanced systems, the characteristics of which shall be evaluated in D2.3 on the basis of the end-user service requirements to be fulfilled.

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