5G smarT mObility, media and e-health for toURists and citizenS

Deliverable D2.2
Touristic city, safe city, and mobility-efficient city use cases – final version

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List of Abbreviations

Term	**Description**
3D	3 Dimensional
4G	4th Generation mobile wireless communication system
5G	5th Generation mobile wireless communication system
5GPPP	5G Infrastructure Public Private Partnership
ADO	Airport Duty Officer
AIA	Athens International Airport
AMIS	Airside Monitoring Inspection Specialist
AOC	Airport Operations Centre
API	Application Programming Interface
AR	Augmented Reality
ARAS	Augmented Reality Assisted Surgery
ASOC	Airport Services Operations Centre
ATE	Augmented Tourism Experience
A/V	Audio-visual
BS	Base Station
B2B	Business to business
BBU	BaseBand Units
BSS	Business Support Systems
CCS	Cultural and Creative Sector
CDN	Content Delivery Network
CH	Cultural Heritage
CHT	Cultural Heritage Tourism
CI	Creative Industry
CO	Carbon Monoxide
DASH	Dynamic Adaptive Streaming over HTTP
DICOM	Digital Imaging Communications in Medicine
DL	Down Link
DVI	Digital Video Interface
E2E	End to End
EA	Ellinogermaniki Agogi
ECG	Electro CardioGram
ED	Emergency Department
eMBB	enhanced Mobile Broadband
eMBMS	Evolved Multimedia Broadcast Multicast Services
EMS	Emergency Medical Service
EU	European Union
GAM	Modern Art Gallery
GB	Gigabyte
Gbps	Gigabits per second
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHz	Gigahertz
gNB-RAN	5G NodeB-Radio Access Network
GPS	Global Positioning System
HD	High Definition
HDR	High Dynamic Range
HE	Horizon Europe
HEVC	High-Efficiency Video Coding
HLS	HTTP Live Streaming
HPHT	High-Power High-Tower
HTTP	Hyper Text Transfer Protocol
IIT	Istituto Italiano di Tecnologia
IoT	Internet of Things
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPR	Intellectual Property Rights
IT	Information Technology
KPI	Key Performance Indicator
KVaP	KPI Validation Platform
LED	Light Emitting Diode
LTE	Long Term Evolution
MANO	Management and Network Orchestration
M&E	Media and Entertainment
Mbps	Megabits per second
MEC	Multi-access Edge Computing
mMTC	Massive Machine Type Communication
MNO	Mobile Network Operator
MPEG	Moving Picture Experts Group
MR	Mixed Reality

MTC	Machine Type Communication
NB-IoT	Narrow Band IoT
NO_2	Nitrogen Dioxide
NR	New Radio
OR	Operating Room
OSS	Operations Support Systems
OSM	ETSI Open Source MANO
P1	Parking Facility 1
PM	Particulate Matter
PTM	Point-to-Multipoint
PTP	Precision Time Protocol
RTV	Real Time Video
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RGB	Red Green Blue
RGBD	RGB Depth
RTV	Real Time Video
RoI	Return on Investment
SBA	Service Based Architecture
SDI	Serial Digital Interface
SDS	Security Duty Supervisor
SOP	Standard Operating Procedures
STARLIT	**S**mar**t** living pl**a**tform powered by A**r**tIficia**l** **i**ntelligence & robus**t** iot connectivity
TCP	Transmission Control Protocol
TV	Television
UC	Use Case
UDP	User Datagram Protocol
UHD	Ultra High Definition
UI	User Interface
UL	Up Link
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communication
UWB	UltraWideBand
vEPC	virtual Evolved Packet Core
VNF	Virtual Network Function
VR	Virtual Reality
WCAG	Web Content Accessibility Guidelines
WOR	Wireless Operating Room
WP	Work Package
XR	eXtended Reality

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Executive Summary

5G-TOURS focusses on central principles established in the 5G-PPP Phase3 ICT-19 call; to validate both technical and business aspects of the opportunities created by 5G and getting to the European Vision of "5G empowering vertical industries" (European Commission, 2018). Both technical and business validation perspectives are pertinent to this deliverable as 5G-TOURS establishes a firmer view on the use case (UC) requirements, key opportunities for implementation and directions for validation in later stages of the project. The UC analysis process, places users of the system at the heart of the analysis and sets those users in the context of the vertical and associated service, the value propositions for the industry sector or vertical and its main identified stakeholders are directly derived. The search for the best way in which to "empower vertical industries" occupies 5G-TOURS across all Work Packages (WP)s with some useful insights coming from this document. We are in the innovation phase of 5G adoption in verticals where the vertical demand needs to start taking control of the UC adoption agenda to assure "empowering vertical industries" turns from aspiration to reality and we move away from technology supplier push.

This document presents requirements at a level of abstraction that is typical of a System Design Requirements Specification. The requirements are derived in the WP that manages the UC requirements, (WP2). The objective is to establish User and Network requirements and frame important areas of innovation for the 5G-TOURS in the areas of slicing, AI, and the Service Layer. Substantive functional components have been identified in partnership with WP3 along with an assessment of critical functional and performance requirements in terms of delivering value to users of the 5G-TOURS platforms. User, End User and Network requirements that are provided in this document supersede requirements stated in prior deliverables.

The definitions of the 5G-TOURS platforms are now being refined as techno-economic constructs creating a greater understanding of the services and economic aspects and opportunities through the analysis of value creation and value capture potential. This document identifies the potential scope of the platforms taking into account business platform strategy theory and how opportunity can be defined through this perspective and the ability to simulate scope and scale variance based on various factors such as geographic reach, multiplicity of services and other factors.

The process of requirement derivation has necessitated significant collaboration amongst multi-skilled teams that comprise of vertical market specialists supporting user expectations and experts in network architecture who have framed the innovations and functional boundaries of the technology and solutions. This has led to broader insights in terms of the knowledge and skills required to design, deploy, maintain and operate the city platforms. We have identified a need and are developing accessible templates to gather requirements that are accessible and understandable for all partners regardless of their value chain position and depth of networking and specifically 5G knowledge. We aim for a level of complexity that is realistic for a vertical sector to lead in the gathering of information.

Slicing is a critical capability and 5G-TOURS is underpinned by the 5G-EVE capability in this regard. A 5G-TOURS to 5G-EVE interface analysis has been carried out during the development of the project approach to requirements capture and finalisation of the use cases. This review revealed that whilst the 5G-EVE blueprints are ideal for (ICT-19) Testbed Platform as a Service needs and thus for the purposes of detailed description and deploying of a network slice by R&D teams, the level of expertise required surpasses that which a typical vertical in a commercial deployment would be expected to employ. We also investigated the feasibility of usage of templates developed outside of 5G-PPP such as Generic slicing templates promoted by the GSMA and TM-Forum which provide a useful guideline for templates that help with market adoption.

Since publishing 5G-TOURS D2.1 (5G-TOURS, 2019a), we have refined the project approach to the analysis and definition of user and network requirements. We refine systems key performance indicators (KPIs) and their linkage to those identified in the 5G Infrastructure Public Private Partnership (5G-PPP) working in concert with WP7 and their assessment of validation approaches in D7.1 (5G-TOURS, 2020).

This document is an outcome of the analysis of the specifics for each UC that shall be supported by the platforms. Driven by the analysis of each of the UCs, we provide:

- A description of the key functionalities identifying aspects such as the service layer, depicted in sequence diagrams;

- User requirements based on technical performance indicators;
- Network performance requirements. A joint assessment of network and user requirements enables an emergent narrative relating to transition from 4G to 5G and how the UCs will benefit from 5G capabilities as 3GPP Release 16 and beyond become available in the market;
- A view on the nature of each of the three platform concepts under development in the project;
- A preliminary assessment of the economic value; to set the direction for further Economic assessment in WP2; providing a critical component of the wider business validation which will be carried out in collaboration with WP8 in the latter stages of 5G-TOURS.

5G-TOURS, being focused on the tourism, travel and health industries, has undertaken to start evaluating the COVID-19 impact on its 5G-related aspects. Whether the impact is negative or positive will tip on the potential of emerging networks to support economic recovery of Tourism, Travel and Health in Europe. Along with that, new touristic experiences and models will be created out of these changing and challenging times with necessities such as going online or implementing social distancing. 5G-TOURS has from inception envisioned various experiences and UCs that now look even more necessary and promising. 5G-TOURs overarching concepts of "remote tourism" and "enhanced virtual on-site experiences" present an immense opportunity for 5G-TOURS to provide lighthouse proof of concept and trials evidence. The project continues in all WPs to develop approaches to evidence potential to help with Economic recovery from the impact of COVID-19.

1 Introduction

1.1 Purpose

The primary purpose of this document is to establish a final view on key functional and performance requirements for the 13 UCs of 5G-TOURS. This document provides the authoritative project wide source for the 5G-TOURS User, End User and Network requirements, and thus provides requirement statements that supersede those of any pre-dated documents. The 5G-TOURS consortium identified 13 candidate UCs of interest to the Tourism, Transport and Health sectors in advance of the start of the project. Over the first year of the project the objective has been to confirm the feasibility of delivering demonstrations of the UCs at their target deployment sites, as well as creating a refined view on the value propositions of the UCs and how those propositions can be validated. A range of analysis processes were carried out in Work Package 2 (WP2) and other WPs to establish this objective.

The analysis contained herein has taken as a primary source the UCs as described in D2.1. D2.1 was published at an early stage of the project to capture the initial view of the UC by the application of a rapid development of requirements approach. This approach paid attention to the user requirements and also the wider context of the UC implementation for the purposes of initiating more detailed planning in WP4, WP5 and WP6. Subsequent analysis carried out for this document of both technical and economic aspects of these UCs leads to their refinement and a deeper understanding.

We capture the deeper understanding of the design requirements thinking at a level of abstraction deemed to be sufficient to enable WP3 to innovate in core areas of the network functionality and WP4, WP5, WP6 to refine how the UCs will be realised or implemented in practice for 5G-TOURS. Meanwhile WP2 maintains a view for 5G-TOURS regarding wider system insights principally for the purposes of anticipating commercialisation of platforms and their associated products and services.

1.2 Work Package and Deliverable Context

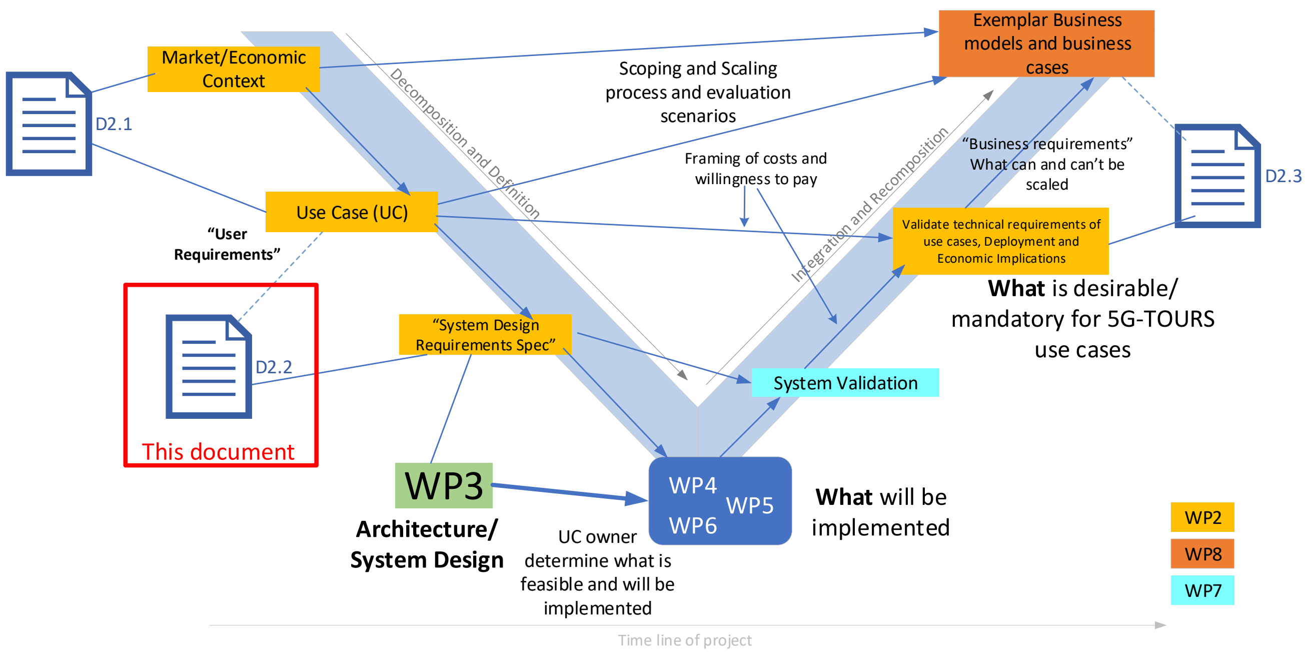

Figure 1: Work Package and Deliverable Interactions

To further aid in the understanding of the context in which this document exists we use the V-model (Figure 1). The V-Model (Stevens & Brook, 1998) is used to visualise the decomposition and definition of requirements and design and the transition into the integration and recomposition phase where activities like testing, verification and validation would occur. By using this V-model framework the interdependence with other WPs, the document already published by WP2 - D2.1 (5G-TOURS, 2019a) - and the planned document D2.3 can be seen in context. A strong motivation in this document is to look ahead to D2.3 which sits in the integration and re-composition part of the V-model and establishes initial views on the key themes that should emerge.

This document provides a central resource for a number of the WPs in terms of the agreed requirements across 5G-TOURS. We will describe the system design requirements for each of the platforms where the UCs will be deployed and provide the basis for other WP tasks to commence with their objectives. Thus, we are required in this document to provide sufficient detail in the requirements to define and refine functional entities and their performance requirements. The development of this document has necessitated close collaboration with six WPs:

- WP3 is the 5G-TOURS competence for network architecture and associated deployment designs. WP2 has collaborated with WP3 in the documenting of requirements for these entities.
- WP4 is the implementation and deployment competence for the Touristic City. WP2 and WP4 experts were brought together to form the analysis team for the UC sequence diagrams, Context Diagram and deployment analysis and User and Network requirements.
- WP5 is the implementation and deployment competence for the Safe City. WP2 and WP5 experts were brought together to form the analysis team for the UC sequence diagrams, Context Diagram and deployment analysis and User and Network requirements.
- WP6 is the implementation and deployment competence for the Mobility-efficient City. WP2 and WP6 experts were brought together to form the analysis team for the UC sequence diagrams, Context Diagram and deployment analysis and User and Network requirements.
- WP7 is the verification and validation competence for 5G-TOURS. KPIs to be monitored are co-created by WP2 and WP7 with WP7 taking on the responsibility for implementation of the test facilities. In a later stage of the project questionnaires will be used to assess willingness to pay and other commercial considerations will be provided from WP2 to WP7 to inform economic assessments.
- WP8 is the Business model analysis competence of 5G-TOURS and Economic analysis of value creation and capture underpins the considerations as 5G-TOURS progresses business validation activities.

1.3 Document Structure

The approach taken by the UC analysis teams is focused on securing a consistent level of outcome for all UCs by addressing each of the following aspects for each UC:

1. Define the major actions, role and skill level of the end users. The general public, with general knowledge of mobile use, or a greater ICT capability.
2. Define the role of the vertical users of the system. By definition, they will be skilled in aspects of the services provided by their sector. They will have roles like security guards, medical specialists and museum management and they will be required to interact with the platform in various ways to support the delivery of their service to the end user.
3. Define any major feature areas of the 5G-TOURS system that should be exercised during the UC. Functional aspects such as the Service Layer, and the nature of the slicing approach are explored.
4. User oriented performance requirements of the 5G-TOURS network.
5. Clarify the depth of requirements necessary to claim that the UC System Design can be declared complete. Both general requirements as well as preliminary technical requirements are to be specified. Since the technical implementation analysis of the UCs are not fully complete, the requirements shall be given in sufficient detail to define the scope of the UCs whilst avoiding over constraining the later design.
6. Establish where deployment plans could have an impact on knowledge to be gained from the implementation and subsequent verification and validation of the UCs.

Whilst addressing the above aspects for each UC a unified approach for describing the various properties of UCs was required and developed by WP2. The unified approach is defined in **Section 2** to secure a System Design Requirements Specification abstraction. We define mandated internal and external entities that are to be considered when describing the UC requirements. **Section 3 to Section 5** take the unified approach to analysis for their respective 5G-TOURS platforms. We capture functional behaviour of the system followed by user and network requirements identification. **Section 6** provides an integrated view of the user and network requirements across all UCs and starts to frame where synergies with respect to different network services and scaling of networks could point to opportunities for multi-service platforms. **Section 7** identifies the approach to extracting value creation potential through Economic analysis, and we conclude and point to next steps in the final section, **Section8**.

2 Our approach to the derivation of the System Design Requirements

Considering the twin objectives of capturing anticipated customer requirements for full commercial systems and the anticipated requirements for a UC trial, 5G-TOURS has established a logical architecture that can encompass both needs. We aim to establish platform and functional requirements that in the first instance focus on our principal objective in this document of clarifying the anticipated commercial and technical propositions beyond the individual UC trials and demonstrators.

Our core approach to the derivation of requirements is through the principal perspective of the end user or customer and actors that are within the vertical. The objective is to "translate" the user requirements to network requirements (general and specific) and eventually into technical specifications. Thus, we follow the following analysis steps:

1. We determine a sequence of events for the use cases including identifying the "significant" actors in the scenarios;
2. We identify user requirements;
3. We translate user requirements into requirements for the network (to be referred to, for shortness, as "network requirements").

In the following sections we identify the requirement types for the users, network and 5GTOURS System / Infrastructure such that in subsequent sections where the UCs are defined, we can identify specific values or ranges of values.

The method of capturing requirements is through the development of at least one (and for some more) sequence diagrams for each UC. A context diagram is created that brings entities together through functional or behavioural interactions. The objective is to apply an incremental formalising of the requirements capture approach that goes beyond a- less structured textual description as is applied in D2.1 (5G-TOURS, 2019a). This enables specificity where needed, whilst allowing developers freedom in their implementation choices but removing ambiguity in an accessible way for project members in the vertical that are not expected to be experts in the internal workings of mobile and specifically 5G networks.

We take an approach to the mapping of user and network requirements that applies radar diagrams to visualise the UC derived requirements in the same dimensions also showing a typical 4G system performance. By the mapping of both the 4G and 5G capability we can determine features in the transition from 4G to 5G and where particular features of 5G may increase value by enhancing the user or vertical experience.

2.1 Securing an SDRS level of abstraction for requirements

Requirements analysis is always about defining the needed level of abstraction. We have implemented a high-level systems analysis approach, focused on the objective of securing a System Design Requirements Specification (SDRS) outcome for fixing the UC requirements. We apply system analysis methods to articulate "needs" of the vertical in a more specific system-level way with the intent of moving away from a "want" or supply side articulation. Typical analysis perspectives addressed during a full SDRS analysis, not all of which are necessary for a UC trials project, typically cover the following:

1. What is required of the system, stated in functional terms?
2. What specific functions must the system accomplish?
3. What are the primary functions to be accomplished?
4. What are the secondary functions to be accomplished?
5. What must be accomplished to completely alleviate the stated deficiency?

6. Why must these functions be accomplished?
7. When must these functions be accomplished, with timing requirements?
8. Where is this to be accomplished?
9. How many times must these functions be accomplished?

SDRS analysis is typical of approaches applied by product and system engineering in companies developing market solutions. We have applied a sub-set of these recognised SDRS aspects as this acts as an approximation of a close to market systems analysis method and 5G-TOURS aspires to close-to-market solutions as we anticipate market opportunities. We focus on **anticipated service user requirements** by analysis of functional aspects in order to avoid a premature commitment to a specific design concept or configuration and, thus, the unnecessary expenditure of valuable resources at this point in time. We also establish performance indicators that are of import to the user. However, we are mindful of the needs of the project to secure adequate detail in the planning of the Proof of Concept (PoC) and Friendly Customer Trials (FCT) activities that are an essential part of the validation process prior to go-to-market decisions.

The essential objective is to define what is required without over constraining how it is to be realised at each trials site. Such a needs analysis is realised through the WP2 management of key processes that bring together key roles such as customer perspective, the ultimate consumer/end-user (if different from the customer), the prime contractor or producer, and major suppliers (as appropriate), and facilitating communications between the various parties involved. The 5G-TOURS consortium comprises of each of those roles and thus provides an ideal environment for such analysis to be performed. In particular, we ensure the voice of the vertical's customer is heard with the intent that the system developer is responsive to their needs.

The 5G-TOURS philosophy of democratising or increasing the accessibility of the requirements gathering process necessitates the development and usage of **templates for requirements gathering** and fine tuning of descriptions of use cases using novel methods and standard approaches to diagrams. If particular parameters in a template table are regarded as unimportant by those that gather the requirements, as perhaps the successful delivery of a UC does not require outstanding performance on a particular parameter, then a presentational disadvantage of tabular templates can be that they result in unfilled values in tables. We fully expect and accept completed templates to have unfilled values, this provides information to system implementers in terms of where they can make design decisions based on their sound engineering practices.

The **UC Sequence Diagram** is used to focus the analysis team on finding the most important functional and behavioural aspects of the use cases in terms of actors (humans and machines) and how they interact in a sequence of events. This diagramming technique is derived from the standard UML (Unified Modelling Language) (Jacobson & Booch, 2005) notation method but using a limited set of notations. Similarly, the **Platform Context Diagram** is derived from the Use Case context diagrams of UML.

The techno-economic constructs of the platform will inform the future business validation analysis of 5G-TOURS. We seek to identify common functional capabilities and properties that support the group of use cases that service providers will need to support when deploying the platform. There are functionalities and capabilities that are common across UCs, some that are specific to UCs, but the intention of the platform analysis is to break down any siloed UC thinking. Both diagramming techniques have been used to convey sufficient requirements to define the context and UCs and shall provide enough specificity to declare the UC specification from a WP2 perspective complete such that follow on analysis regarding verification, validation and economic analysis priorities can be further addressed in WP2.

In technology enabled business, the **business platform** emerges as a strategic and managed concept that can be influenced by 4 substantive levers (Cusumano, et al., 2019) that deliver value through creation of an open platform upon which verticals can innovate. Accessibility and modularity are key with the opportunity for tools that focus innovation. The three City platforms are defined by their dominant vertical of influence: Touristic, Safe and Transport. However, the linkages between these themes and the UCs they support are evident as in the later sections of this deliverable we bring together the technical requirements and economic value assessment. Several UCs incorporate aspects from the different themes – e.g., an ambulance involves both safety and mobility, and a bus with on-board entertainment involves tourism, media and mobility.

2.2 Linking End User Requirements and Network Requirements

By taking the view that the end-user (such as a Tourist) needs are a primary driver of the value creation process, we identify requirements that can be explicitly linked to the needs of the end user. When consuming a service over a mobile network, the customer or end-user values the quality of their experience rather than being concerned about technical communications terms like Mbps or milliseconds latency.

End users associate value with the application and experience; they do value the quality of Video and Audio in their Video-Conference sessions, or the fast response in their gaming platforms. Furthermore, they do care about their data being transmitted securely, but not about the number of bits used for the encryption of their data (unless they pay for that).

On the other hand, from the Network Operators and Equipment Manufacturers' point of view, it is ideal for the same (single) 5G network to satisfy all End User Requirements, which means that the same single network should deliver high-bitrate low-latency data as well as low-bitrate high-latency traffic, distinguishably. A solid understanding of the user requirements will help Network Operators optimally design and distribute network resources. This should keep network costs lower and subsequently make end-user service prices more competitive.

As an illustration of the approach we consider a single user requirement of real-time reception of 4K Video, and how this can influence or map into multiple Network Requirements (i.e., Throughput and Latency) and vice versa Figure 2:

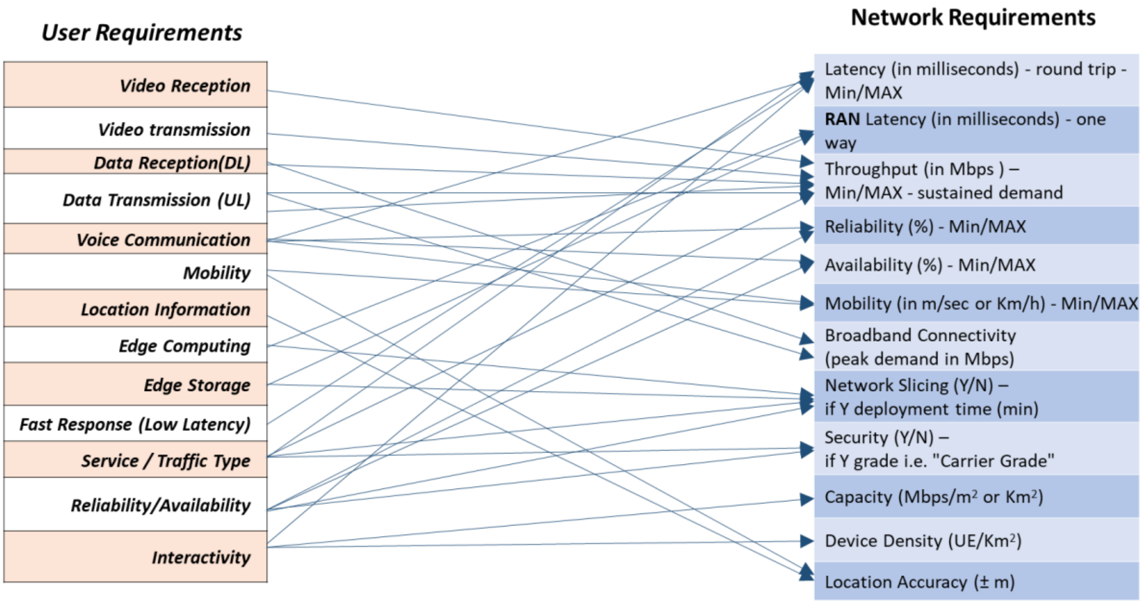

Figure 2: Indicative example of some (not all) dependencies between user-requirements and network requirements

The user requirements are the requirements that are implicitly owned by the end-users (or customers) and need to be defined in order to ensure seamless and satisfactory delivery of the service in a commercial realisation.

It should be noted that user demand for network resources is not uniformly distributed over time and within the coverage area of a network. Although each UC has its unique requirements, a single 5G network infrastructure may well be called upon to successfully implement and deliver all of them in a flexible way. The grouping of similar user requirements as well as the identification of synergies between UCs, even from different Vertical Industries, is important. It will allow network equipment manufacturers and network operators to optimize their design, define network slices and eventually deliver the service the end-users are expecting covert willingness to pay into revenue.

Demand has to be defined both in temporal (variability in time) and spatial (variability in the coverage area) terms. An example of time-varying traffic demand is shown in Figure 3. The data/voice traffic in residential areas is usually, pre-COVID 19 times, high early in the morning and in the evening. In business districts, pre-

COVID-19, the traffic peaks were during office-working hours (8:00 to 17:00). This is an illustration of temporal traffic variations during a 24-hour period. Similar variations can be identified weekly, monthly and yearly.

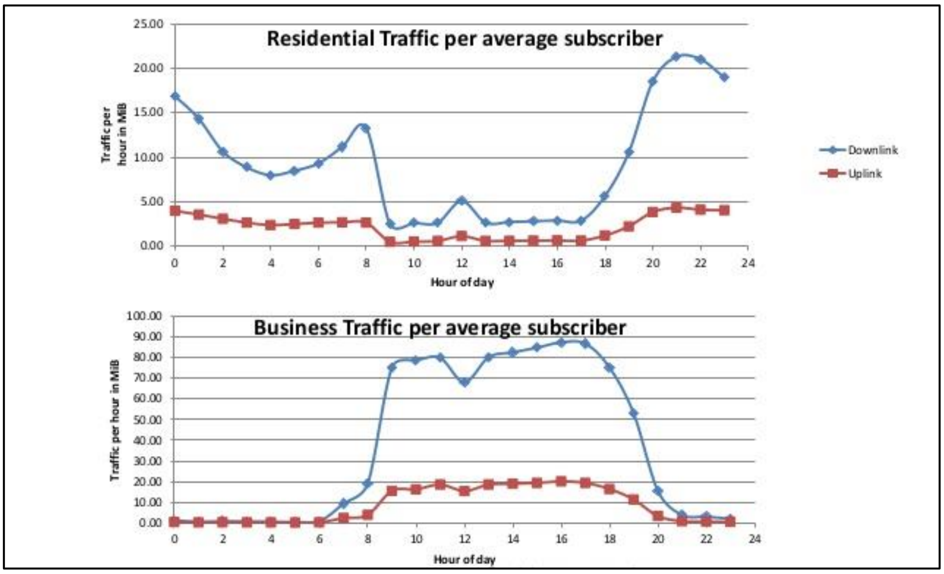

Figure 3: Example of temporal distribution of network traffic demand in residential vs. business areas (Korowajczuk, 2014)

Spatial variation of network traffic is non-uniformly distributed in a coverage area of a mobile network. An example of spatial distribution of the traffic demand in a dense urban environment, is shown in Figure 4. The traffic appears to be concentrated closer to the mobile network Base Stations (BS)s.

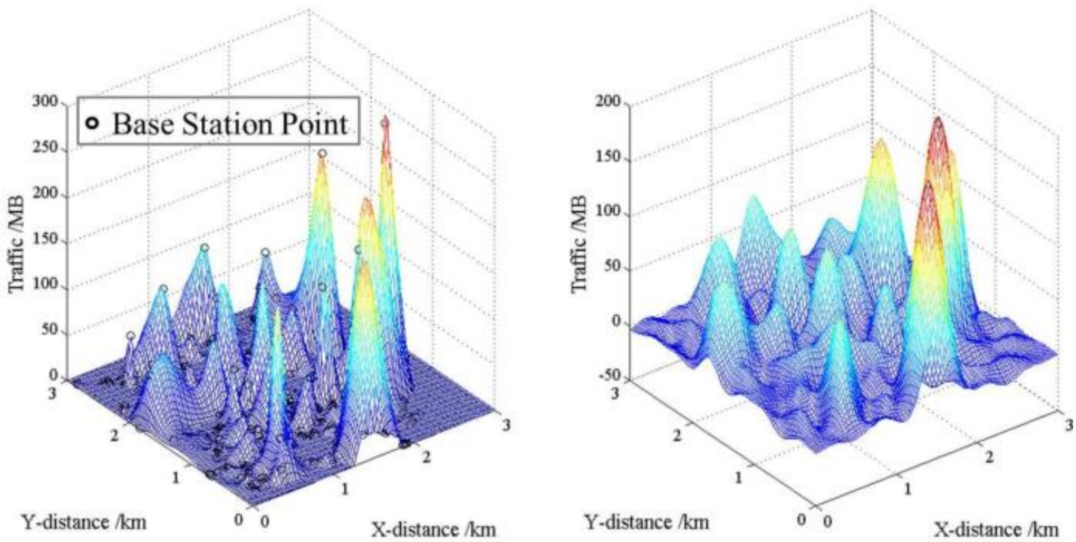

Figure 4: Spatial distribution of network traffic demand (Guan, et al., 2013)

Good knowledge of User Traffic Demand both in terms of time and in terms of space will help Network Equipment Manufacturers, Integrators and Network Operators to improve network planning (i.e. location of e/gNodeB, size of backhauling links, capacity of network elements, etc.) and also optimize the distribution of the network resources.

Optimally the Network Operator would like to group together similar user requirements (from different clients and/or UCs but similar services) on shared network resources. Competing User Requirements (i.e. Fast mobility and High-Positioning-Accuracy) can be partitioned into different network resources and/or 5G network slices.

In certain cases, stringent User Requirements are only partially satisfied by the network (i.e. transmission of HD-video during a live-concert of a sports' event where the density of the end users is very high also), or network planning should be changed (i.e. extra next generation NodeB (gNB) and or backhauling links).

Network Operators and Service Providers prefer to invest in a single network that will be able to satisfy the majority of the user requirements. Therefore, as part of a successful deployment plan, projections of temporal and spatial traffic patterns help in optimally designing and distributing network assets and resources.

Since knowledge of user requirements, a-priori to relevant network design is essential, 5G-TOURS has developed a standard format to documenting user requirements in a coherent and concise way. We utilised experience in 5G-TOURS gained through carrying out extensive analysis across a wide array of UCs deployed in ICT-19 and ICT-22 projects (5G-EVE, 2019a). A developing consensus across 5G-PPP projects regarding KPIs (5G-PPP, 2019) establishes important requirement categories. User Requirements can vary significantly depending on the Vertical Industry. Many times, there are also differences between the UC and scenarios in the same Vertical Industry. In order to analyse the user requirements from all 13 UCs of the 5G-TOURS project, a qualitative approach is adopted.

2.3 Template for end user requirements

Here we give an explanation of the needed end-user requirements to be provided by the user requirements analyst or analysis team that is qualified to articulate the user needs. Beyond the definition, examples are also provided to aid understanding of what is expected to be provided to capture the end user needs. 16 user requirements have been identified as sufficient to define the requirements in 5G-TOURS, these are divided into 5 logical groups; Content, Functional, Composite, Structural and Service Specific. To gather the user requirements from the 13 UCs a blank Table (Table 35 in Appendix A) was provided to the vertical user who has project responsibility for specification and delivery of the UC from a user benefit perspective. Since the analysts are not required to be network engineers or technology personnel, a qualitative rather than a quantitative approach was taken to indicate the value or importance of each user requirement.

2.3.1 Metrics, Units and indicative values

For the user requirements there is a metric and value that should be defined for the end user requirement. The value indicates the need and/or the level of importance for each requirement. For some of the user requirements, a numeric value range is also given in order to provide an indication of the related network parameter/specification for the more technically inclined end-users.

1. ***Video Reception*:** It is a Boolean value. The expected response is Yes or No. If the answer is yes, then some explanation(s) can be expected in terms of the nature of the video stream (i.e. format) and the number of simultaneous streams/channels that are being received. In case more details can be provided, the indicative bitrates for different video formats are:

** HD Video*	*up to 15 Mbps*
** 4K Video low frame rate*	*15-45 Mbps*
** 4K Video high frame rate*	*45-70 Mbps*

2. ***Video Transmission:*** Similarly, to the previous user requirement, the expected answer is Yes or No. In the case of a positive answer, more can details should be given regarding the format of video stream and/or the number of streams. Indicated values are:

15 Mbps/channel or stream

3. ***Voice Communication*:** This is another Boolean requirement whose expected answer is Yes or No. From the Network point of view, this means the delivery of Voice Switching Capabilities and the demand for 128 Kbps bidirectional traffic on demand with reasonably short Latency of 50-200 msec. In addition, this value can be used to evaluate if the 5G infrastructure providers would need additional components in the Mobile Core, such as IMS VNFs. Indicative values are:

128 Kbps UL/DL full duplex

4. ***Data Reception (DL)*:** the value of this requirement is provided in a qualitative manner by selecting High/Medium/Low representing values of 1 Gbps / 100 Mbps / 10 Mbps (or less) respectively. If these values are not adequate, the vertical can also indicate Ultra High which represents a data stream of 10 Gbps. Indicative values are:

100 <high<=1,000, 10<medium<=100, low<=10 Mbps
(Max for Ultra High is 10 Gbps)

5. ***Data Transmission (UL)*:** the metrics for this requirement are the same as the one above (High/Medium/Low) with the only difference being the direction of the traffic from the User towards the Network. Indicative values are:

100<high<=1,000, 10<medium<=100, low<=10 Mbps

(Max for Ultra High is 10 Gbps)

6. ***Mobility*:** The metric of this requirement is the moving speed of the user and/or end-device. Since this can be varying the range is given as High Speed (300-500 km/h), Medium Speed (50-200 Km/h), Walking/Running Speed (5-10 Km/h) and Stationary (0 Km/h). Indicative values are:

200<high speed<=500, 50<medium speed<=200, 5<walking-running speed<=50, (stopped) 0 Km/h

7. ***Location Information:*** Boolean (Yes/No) response is expected. In the case of Yes, then approximate accuracy should be given rated as High / Medium / Low representing accuracies of +/- 0.5 / 4 & 50 meters respectively. The location information can be both for indoor and outdoor environments. Indicative values are:

High <=1, 1 <medium<= 25, low >25 meters

8. ***Fast Response (Low Latency)*:** The requirement can be defined as Slow/Fast and Very Fast representing network latencies around 100, 25 and 5 ms respectively.

Slow >=100, 25<=fast<100, very fast<25 msec

9. ***Reliability/Availability*:** this requirement can be valued as UHigh/High/Medium or Low representing reliability of 99.99999% / 99.999% / 99.99% (7 nines, 5 nines and 4 nines). Indicative values are:

Ultra-high = 99.99999%, high = 99.9999%, medium = 99.999%, low = 99.99%

10. ***Security / Privacy:*** the metrics for this requirement are None-public / Baseline /Medium /High / Ultra-High grade for no security all the way to military type security/encryption levels. Indicative values are:

Public/Restricted/Confidential/Top-Secret-Military grade

11. ***Service / Traffic Type*:** According to the description of this requirement, the possible metrics are Sustained (continues data traffic) / Bursty (traffic in bursts) and Sporadic (at regular or irregular intervals). Each data flow type can then be defined as High/Medium or Low and indicative values are i.e. for sustained 1 Gbps / 100 Mbps and 10 Mbps (for high/medium and low) respectively. Indicative values are:

    - *Sustained 100<high<=1,000 / 10<medium<=100 / low<=10 Mbps*
    - *Bursty 10<high<=1,000 / 0.01<medium<=10 / low<=0.01 MByte bursts*
    - *Sporadic 10<high<=1,000 / 0.01<medium<=10 / low<=0.01 packets/sec*

12. ***Interactivity & Space Dependency:*** The metric of this requirement is Dense (High Density), Medium Density, Sparse (Low Density) representing >1 UE per m^2 / 1 UE per 25 m^2 / <1 UE per 100 m^2 respectively. For each density, the interaction with the network/service can be characterized as High/Medium and Low representing 1.000 / 100 / 1 transaction per second. Indicative values are:

    - *Dense >1 UE/m^2 and 100<high<=1,000 / 1<medium<=100 / low<=1 transactions/sec*
    - *Medium Dense = 1 UE/25m^2 and 100<high<=1,000 / 1<medium<=100 / low<=1 transactions/sec.*
    - *Sparsity of < 1 UE/25m^2 and 100<high<=1,000 / 1<medium<=100 / low<=1 transactions/sec*

13. ***Edge Computing*:** It is a Boolean value (*Yes or No*) and depends on user perception (derived from Latency and traffic type)

14. ***Edge Storage***: It is a Boolean value (*Yes or No*) and depends on user perception (derived from Latency and traffic type)
15. ***Battery Life:*** This requirement can be valued High/Medium/Low. Indicative values are:

    Duration in years: Low< 1 year, 1 year<Medium<9 Year, High > 10 years

16. ***Other***: This requirement is user specified. If the users have extra requirements not covered already, they can specify them here providing also a brief description.

2.4 Templates for Network Requirements

Having established the user requirements, we progress to network requirement derivation. As technology evolves (4G to 5G), new services are needed and offered with more sophisticated capabilities in the network and devices. The increasing number of Internet users leads to a redesign of network architecture (core, access and radio), forcing designers to take into account new parameters such as the need of global coverage combined with low latency, as well as a high reliability and security level. Requirement analysis encompasses those tasks that go into determining the needs or conditions to meet for a new or altered service or product, taking into account of the possibly conflicting requirements of the various stakeholders.

There are a lot of generic best practice methods to efficiently derive requirements from the initial user requirements (Maguire & Bevan, 2002). After surveying these methods, we have developed a customised approach fit for purpose for this systems domain type which takes into account the diversity of UCs that are implemented in 5G-TOURS. The following process steps are applied:

- General capabilities of 4G and 5G shall be considered and the differences between them are illustrated;
- General 4G/5G requirements for each UC shall be gathered and compiled into tables;
- General gathered requirements for each UC shall be illustrated in graphs in correlation with the general 4G/5G capabilities;
- Final 5G network analysis for each UC requirements can be extracted from the tables and corresponding graphs.

2.4.1 General Vertical network requirements

An analysis of network requirement types identified the most appropriate for 5G-TOURS purposes that could be used to encompass a vertical use case requirement from a network perspective, these are the following.

Latency (also end-to-end or E2E Latency) - round trip:

- Latency (also end-to-end or E2E latency): Measures the duration between the transmission of a small data packet from the application layer at the source node and the successful reception at the application layer at the destination node plus the equivalent time needed to carry the response back.

Radio Access Network Latency - one way:

- Radio Access Network (RAN) Latency is defined as the time it takes for a source (UE / mobile phone) to send a packet of data to a receiver at the Radio Network Base Station (i.e. e/gNB). RAN Latency is measured in milliseconds. Taking account of the uplink direction is enough for the purposes of requirements analysis at this level of abstraction from the network and is most commonly used.

Throughput:

- Throughput (data rate): It is set as the minimum user experienced data rate required for the user to get a quality experience of the targeted application/UC (it is also the required sustainable date rate).

Reliability:

- The amount of sent packets successfully delivered to the destination within the time constraint required by the targeted service, divided by the total number of sent packets. NOTE: the reliability rate is evaluated only when the network is available.

Availability:

- The network availability is characterized by its availability rate X (ETSI, 2018), defined as follows: the network is available for the targeted communication in X% of the locations where the network is deployed and X% of the time (see Table 1 below for different levels of availability).

Availability %	Downtime per year	Downtime per month*	Downtime per week
90%	36.5 days	72 hours	16.8 hours
95%	18.25 days	36 hours	8.4 hours
98%	7.30 days	14.4 hours	3.36 hours
99%	3.65 days	7.20 hours	1.68 hours
99.5%	1.83 days	3.60 hours	50.4 minutes
99.8%	17.52 hours	86.23 minutes	20.16 minutes
99.9% ("three nines")	8.76 hours	43.2 minutes	10.1 minutes
99.95%	4.38 hours	21.56 minutes	5.04 minutes
99.99% ("four nines")	52.6 minutes	4.32 minutes	1.01 minutes
99.999% ("five nines")	5.26 minutes	25.9 seconds	6.05 seconds
99.9999% ("six nines")	31.5 seconds	2.59 seconds	0.605 seconds

Table 1: Different levels (%) of Availability

*month = 30 days

Mobility:

- Mobility refers to the system's ability to provide seamless service experience to users that are moving. In addition to mobile users, the identified 5G UCs show that 5G networks will have to support an increasingly large segment of static and nomadic users/devices.

Broadband connectivity:

- High data rate provision during high traffic demand periods (It is also a measure of the peak data rate required).

8a. Network Slicing:

- A network slice, namely "5G slice", supports the communication service of a particular connection type with a specific way of handling the Control- and User- plane for this service. To this end, a 5G slice is composed of a collection of 5G network functions and specific Radio Access Technology (RAT i.e., WiFi, LTE, etc.) settings that are combined for the specific UC or business model.

8b. Slice/Service Deployment Time:

- In the context of 5G Networks, Slice Deployment time is the amount of time it takes for a Slice to be established end-to-end after the initial triggering has occurred to create (if new) or activate (if predefined). The Slice Deployment time is measured in minutes (min) i.e. ≤ 90 minutes (≤3 minutes for planned/predefined slice).

Security:

- Network resilience against signalling-based threads which could cause malicious or unexpected overload. Provision of basic security functions in emergency situations, when part of the infrastructure may be destroyed or inaccessibly. Protection against malicious attacks that may intend to disrupt the network operation.

Capacity:

- Capacity is measured in Mbit/s/m^2 is defined as the total amount of traffic exchanged by all devices over the considered area. The KPI requirement on the minimum Traffic Volume Density / Areal Capacity for a given UC is given by the product: [required user experienced data rate] x [required connection density].

Device Density:

- Up to several hundred thousand simultaneous active connections per square kilometre shall be supported for massive sensor deployments. Here, active means the devices are exchanging data with the network. Device density is measured in Dev/Km^2.

Location Accuracy:

- Location Accuracy refers to the "degree closeness" of a measured end-user device location (by means of the communication network infrastructure/technologies) to the real location of the device at the time of the measurement. Location Accuracy is measured in meters (m). Location accuracy can be measured in the horizontal as well as in the vertical direction. For the need of the 5G-TOURS only horizontal accuracy is considered.

A survey of each use cases was carried out to establish key network requirements, using a template (Appendix A - Table 41) with the analyst guided by the above definitions.

For the visualisation of the technical requirements, radar charts are used. A **radar chart** is a graphical method of representing multivariate data in the form of a two-dimensional **chart** of three or more quantitative variables (zones) represented on axes starting from the same point. They can be known by other names such as *Spider Charts*, *Web Charts*, *Polar Charts*, *Star Plots*. It is a flexible graph format because one can combine a number of attributes, metrics, and other report objects. Its minimum requirements are that one attribute and one metric be present on the report grid. The relative position and angle of the axes is typically uninformative. A typical example of a radar chart is illustrated in Figure 5 (5G-EVE, 2019).

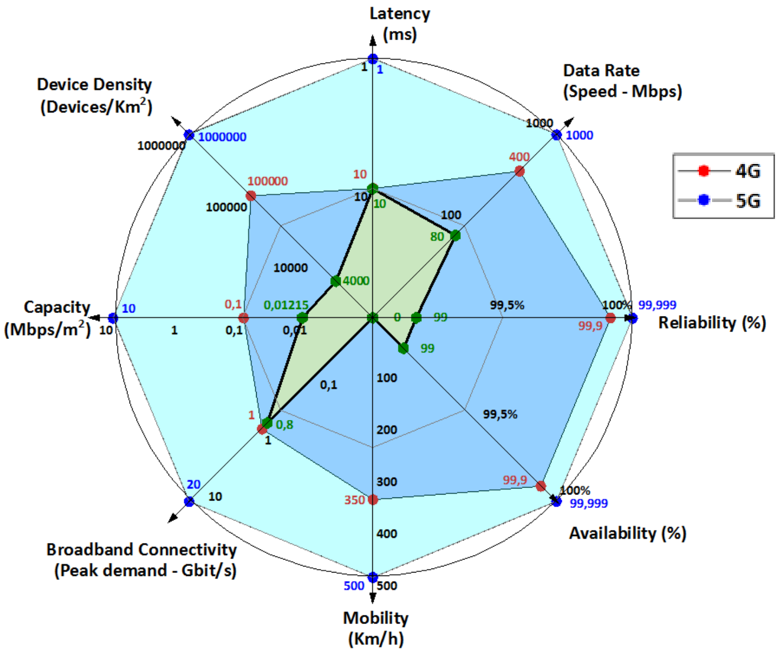

Figure 5: An illustrative radar chart for visualisation of network requirements

We have chosen to enhance this representation to a 10 axis radar chart. Although we have identified 12 types of requirements above, a single quantitative measure for security is not appropriate and the property of availability is conceptually close enough to reliability to make creating an additional axis unnecessary.

As an additional feature of the radar chart template generic 4G and 5G capabilities are mapped to the radar chart template. The radar chart is based on Table 2 and presents the values for each metric with respect to the 4G and 5G network capabilities. Each one of the metrics/capability (i.e., Latency, Reliability, Mobility, etc.) corresponds to a different axis with its own scale.

Table 2: 4G/5G capabilities for mapping the UCs Requirements (5G-IA, 2015)

	General 4G/5G Capabilities	Units	4G	5G
1	Latency (in milliseconds) - round trip - Min/Max	msec	25	15
2	**RAN** Latency (in milliseconds) - one way	msec	10	1
3	Throughput (in Mbps) - Min/Max - sustained demand	Mbps	400	1000
4	Reliability (%) - Min/Max	%	99,9%	99,999%
5	Availability (%) - Min/Max	%	99,9%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	350	500
7	Broadband Connectivity (peak demand)	Y/N or Gbps	1	20
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	N	Y (1 min)
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	0,1	10
11	Device Density	Dev/Km^2	100K	1000K
12	Location Accuracy	m	<5	<1

In the radar chart template (Figure 6) the area shaded light green and delimited by the red-dots is the performance envelope of existing 4G networks. If the requirements of a particular UC fall inside this envelope, then there may be no need for a 5G network in order to realise this UC, although this consideration also depends on a deployed system capacity question that is not addressed in this analysis.

The area that is bounded by the blue-dots is the envelope of an emergent 5G network (shaded light yellow). If the requirement of a particular UC falls inside this area, but outside the area of the 4G network capabilities, then this UC benefits from 5G network features to deliver correct functional or performance aspects. If the requirement of a particular UC falls outside even this area (defined by the blue dots), then this application or UC has to wait for 5G networks to evolve further or the particular requirement needs to be reduced with consequent impact on user experience.

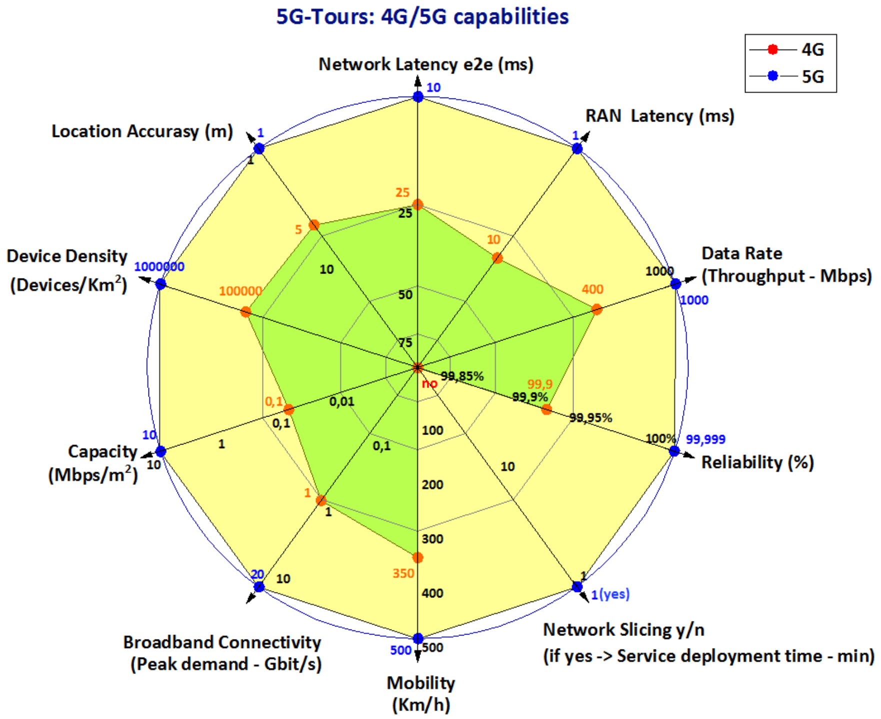

Figure 6: Template Radar Chart for 4G/5G capabilities

2.4.2 Specific Network and End-Device Related Requirements

In addition to the above network requirements additional use case specific requirements regarding the network and devices are required and detailed in the following.

Network oriented requirements:

- **Number of End Points**.The total number of Network Endpoints. This is the last or closest Network Element or Point of Presence to the end-device or end-user, this will be a mobile Base Station (BS).
- **Number (Range) of End Devices per End Point.** The total number of End-Devices (i.e. IoT sensors, Smartphones that can potentially be connected to the End-Point as this is defined above (i.e., the total number of Smart Phones that can use simultaneously or register themselves to a particular BS).
- **Density of End Devices (per sq. meter).** The number of the End-Devices (as defined above) that can be collocated (or share) in a particular space (3D volume or 2D surface area). I.e., the maximum number of IoT Devices that can be found in an area of 1 m^2. Alternatively, if the network is sparse, the Density can be defined for an area of 1 Km^2.
- **Bitrate needs per End Point (Kbps, Mbps, Gbps).** The peak traffic capacity which each end point can service its associated end-devices. For example, if a BS can provide a total of 400 Mbps, this can be throttled down to a single end-user device or it can be shared among all the end-devices associated (connected) to this endpoint.
- **End-to-end Latency (msec).** The total time or delay it takes for a data-packet to travel from an end-device to the destination end-device (server, another end-user, etc.). This is a stochastic quantity and can vary depending on network conditions (i.e., congestion state). The desirable value beyond which the service is not acceptable should be provided.
- **Highest Acceptable Jitter (msec)**. The highest deviation in the latency metric above that can be acceptable without disrupting the offered service and making it unacceptable. For example, a jitter value of 5 msec is acceptable if an information packet can arrive -/+ 5 msec (earlier of later) than its expected arrival time. This requirement is more important in real-time control or synchronous transmission systems. The value for jitter should be much smaller than the value for E2E latency.
- **Number of Class of Service (1-8, more)** Class of Service is a way of managing traffic in a network by grouping similar types of traffic (for example, e-mail, streaming video, voice, control signals, etc.) together and treating each type as a class with its own level of service priority. The number of different Classes / Priorities required will dictate the Data Queues and other Network Element Capabilities (i.e., memory/buffering etc.).

End device-oriented requirements:

- **Type of Device (i.e., Smartphone, TV, VR)** The type of end-devices that need to be connected to the network. Video-Source/Camera, Smartphone, Proximity Sensor, Virtual Reality Headset, etc.
- **Bitrate required (Kbps / Mbps / Gbps)** The amount of data traffic that the device will produce or accept.
- **Max. Latency Allowable (in msec)** The delay in delivery the data packets to and from the end device to the traffic destination. It is more important for real time services (like navigation, voice/video conference, real-time-control) and less important for non-real-time services like SMS, e-mail, or Temp / Power consumption monitoring (without the need for actions based on these values), etc.
- **Max. Moving Speed (km/h, 0 if stationary)** The moving speed of the end-device. I.e., a walking customer with a smart phone (5-8 Km/h), a moving car (up to 180 Km/h), a moving train (up to 400 Km/h) etc.
- **IPv4 & IPv6 support (or both)** Currently most devices (apart from special purpose ones) utilize and connect via IP. The support of IPv4 and/or IPv6 (or both) will allow for proper network configuration.
- **Connection of Device to End Point (Wired/Wireless)** Type of interface and connection of the Devices to the Network Endpoint (i.e., wireless or cable).

- **Type of Connection (i.e., Ethernet, WLAN, Zigbee)** The type of connection the end-device is using to connect to the Network Endpoint (i.e., WLAN 802.11n at 5 GHz, 4G mobile, NB-IoT, etc.).
- **Authentication method (i.e., SIM, eSIM, Key)** Method by which the end device is authenticated (if any required) in order to be allowed to access and use the Network resources (i.e., SIM / eSIM, WPS key, Username/Password, etc.).
- **Other Vertical Specific (non-Network related Requirements)**
  - Battery life requirement (usually in years)
  - Outdoor environment resiliency (i.e., IP67 or IP68), etc.

2.5 Mandated Functional Entities – Requirements and Interfacing

In the remainder of Section 2 we focus on both internal and external functional entities that are mandatory to be embedded into the 5G-TOURS platforms and thus UC analysis in subsequent sections. The major external entity that System Design Requirements analysis must be aware of is 5G-EVE as it provides significant operating environment and interfacing needs. Other entities are internal to 5G-TOURS and are of significant import and thus defined, they are focusses of innovation in 5G-TOURS and shall be explicitly identified where relevant in the UC sequence diagrams in later sections.

2.5.1 External: 5G-EVE

The 5G-EVE project has built an experimental platform that is generic in nature and fit for purpose to realise a multitude of UCs well beyond the scope of 5G-TOURS. 5G-TOURS inherits the logical and functional architecture of the 5G-EVE assets and resources and as much as possible the physical deployment architecture. For some UCs it is the intention of 5G-TOURS to enhance the functionality, coverage and capacity of 5G-EVE. During the requirements analysis in WP2 the required enhancements have been identified. These enhancement requirements are managed in WP4, WP5, WP6 as they manage the deployment. However, WP2 provides requirements to guide the direction of enhancements of the 5G-EVE Experimental Platform as a Service (EPaaS) capability to deploy the 5G-TOURS UCs.

To enable the 5G-EVE objective of supporting multiple projects, they have defined **5G-EVE Blueprints** as a way of conveying precise and structured technical language requirements from 5G-TOURS (or any other project) to 5G-EVE. Therefore, compatibility with 5G-EVE provides an important perspective for the UC analysis process and they make reference to 5G-EVE where necessary, in particular in the high-level view of the platforms and phases of deployment. We have taken as a guide the 5G-EVE Blueprint and developed a further level of abstraction to simulate the level of abstraction at which we anticipate a commercial entity in a vertical to engage with the 5G-TOURS platforms if they were commercially offered. During the latter stages of the project 5G-TOURS will validate these abstractions and any gaps between the trials realisation of the use cases and commercial propositions (Figure 7).

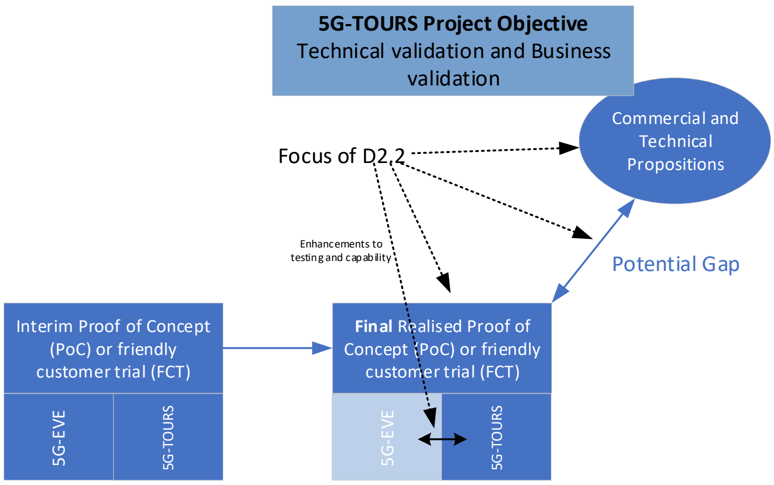

Figure 7: D2.2 Focus on Commercial propositions

2.5.2 Internal: 5G-TOURS Functional Innovation Entities

There is a tight coupling between WP2 and WP3 during the develop ment of System Design Requirements. The objective in WP2 is to provide sufficient requirements that enable innovation in WP3. Specifically, these requirements enable and frame the 5G-TOURS technical innovations in the areas of:

- Enhanced MANO
- AI orchestration
- Broadcast support
- The Service Layer

2.5.2.1 Enhanced MANO and Service Layer

The management and orchestration functionality shall be provisioned by 5G-TOURS and shall be largely built upon capability provided by 5G-EVE. The 5G-EVE management and orchestration platform comprises of three main modules:

- The local Management and Network Orchestration (MANO) deployed at each test site, handles the internal specificities of the hardware deployed there. For instance, the Open Network Automation Platform (ONAP[1]) orchestration will be used in the French site, ETSI Open Source MANO (OSM[2]) and the 5G-EVE orchestration platform in the Italian one and the OSM orchestrator for the Greek site.
- These orchestrators have an interface with the interworking layer, which glues them together and provides a common abstraction for the onboarding of different network services through the 5G-EVE portal. At the interworking layer, all the metrics related to the service QoS are gathered, in order to perform continuous heath check of the service.
- The 5G-EVE Portal offers the capabilities related to the experiment creation, that is the scheduling of a network service creation, its parametrization and the gathering of off line statistics as well as additional functionality (5G-EVE, 2018).

However, the functionality provided by 5G-EVE Orchestration shall be enhanced for the specifics of the verticals addressed by 5G-TOURS. The functional areas that shall be enhanced are:

- **Continuous KPI monitoring**: the most important functionality that is currently missing from the 5G-EVE platform is the capability to perform real-time monitoring of the service KPIs, as indicated in this document. Thus, 5G-TOURS shall provide this feature for the relevant metrics of each UC.
- **Dynamic SLA**: While in this document we provide hard requirements for some of the service metrics, verticals may want to be able to relax them according to the changing environments and the need of the application (i.e., additional number of user, change of the coverage). This capability is not supported by 5G-EVE platforms and shall therefore be provisioned by 5G-TOURS.
- **Business oriented orchestration support**: sometimes the re-orchestration of the network shall happen according to parameters that are not only network related, but also related to the operation of the service. For instance, a vertical service provider may request a scaling down of the network for cost related issues, decide to partially switch off the service provisioning infrastructure or re-locate one function at the edge. This capability is not supported by 5G-EVE platforms.

To enable these requirements, the 5G-TOURS Management and Orchestration system and the service layer, shall extend the one already provided by 5G-EVE with this functionality. The design strategy employed by the project is discussed in D3.2 (5G-TOURS, 2020a).

[1] https://www.onap.org/

[2] https://osm.etsi.org/

2.5.2.2 Artificial Intelligence and Big Data driven Orchestrators

The 5G-TOURS AI and Big Data driven orchestration approach shall provide network operators and the verticals with tools to perform common operations in the network. In particular, two specific requirements for the overall 5G-TOURS AI and Big Data framework shall be taken into account and will complement and have implications for the 5G-EVE MANO and Service Layer discussed above.

The first requirement relates to the capability of automatically scaling the network, with as close to zero touch from the network operator as feasible. This functionality shall rely on previous data about the load of the network. This has different meanings depending on the network domain, as it could be related to radio resource utilization (for the RAN), aggregated user throughput (for the Core), and infrastructure utilization (for the Orchestration). The key objective is to avoid, under limited resources conditions, unnecessary utilisation of a too overprovisioned setup from the resource utilization point of view, which could lead to unnecessary allocations, as depicted in Figure 8.

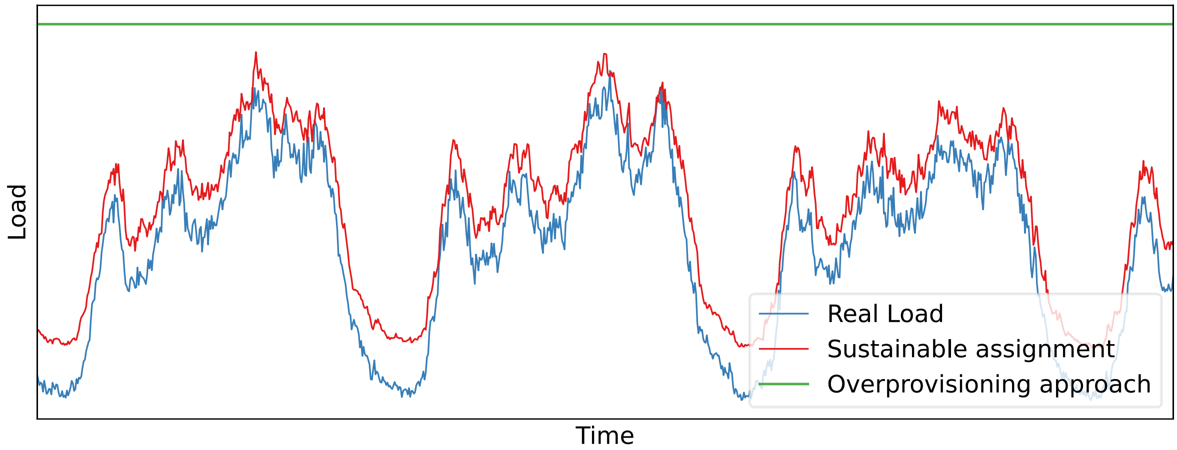

Figure 8: Dynamic Resource allocation efficiency

This operation shall be as seamless as possible for the infrastructure provider, and parametrised in the configuration of its behaviour, for instance by setting up a trade-off between the unnecessary resource allocation and the possibility of a wrong resource assignment. Together with this functionality, the AI system shall also be exposed to the vertical suggestions about possible re-orchestration strategies. That is, the operator has the full knowledge of its infrastructure and shall be able to suggest or recommend through interfaces to the AI (through the usage of AI solutions) possible re-orchestrations. The vertical service provider will have access to other sources of information in its operations as well as access to the continuous KPI monitoring. By application of its own business intelligence, perhaps taking into account metrics such as the users QoE, which are not available to the network operator, it shall be able to differentiate offerings. By enabling this enhanced closed loop between vertical and operators, 5G-TOURS shall increase the usability of the network infrastructure, enabling for instance, new business models.

2.5.2.3 Broadcast Support

The support of broadcast in the 5G-TOURS architecture is an additional capability needed in some specific UCs. The increasing number of targeted users in the network benefits from an efficient way of distributing ultra-high-quality content Broadcast support is orthogonal to our definition of the overall architecture, which is impacting only one specific site; the touristic city of Turin. However, broadcast shall be encompassed by the overall architecture and be interfaced effectively with other modules. For instance, the enhanced MANO shall correctly handle the broadcast specific VNFs and orchestrate them in the network for the UCs where they are required, and also with the Service Layer, to allow verticals leveraging the broadcast capabilities. This also affects the 5G-EVE infrastructure which shall present the required assets and configurations.

The existing commercial solutions for broadcast and multicast services in cellular systems are based on LTE and not on 5G. In 5G-TOURS, the use of broadcast is focused on multimedia distribution, specifically within UC 4 and shall built on the knowledge gained through 5G-XCAST[3], from two particular points of view:

- **LTE-based 5G Terrestrial Broadcast:** Video content shall be transmitted via a broadcasting network. This network shall transmit video (downlink-only mode) to all users simultaneously. The performance shall not change regardless of the number of devices receiving the signal. The UC shall use a High-Power High-Tower (HPHT) topology to transmit the content, starting with 3GPP Release14. The network architecture shall be updated from the current Release14 to Release16 during the project to become more representative of anticipated commercial realisations.
- **5G Multicast:** content transmitted using a mobile network. For this part, first the Evolved Multimedia Broadcast Multicast Services (eMBMS) capabilities shall be demonstrated with particular locations upgraded with multicast/broadcast capabilities. In parallel, the project shall develop 5G multicast realising two new network functionalities residing inside the 5G Core. One functionality at the Control Plane and the other at the User Plane, which shall be included as part of a commercial 5G Core Network, namely Open5GCore. 5G-TOURS shall integrate the capability into the 5G-EVE facilities to create the final 5G-TOURS site capability that would be representative of a commercial realisation of the UC.

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[3] https://5g-ppp.eu/5g-xcast/

3 The Touristic City Platform

Within the unified analysis methodology and functional entity constraints as set out in Section 2 we have developed an initial view of the Touristic City Platform. As a reminder, we seek to define key functional and performance requirements that uniquely define the platform, the machine and human interactions and thus by extension the potential business opportunities, to be investigated further and refined during future WP2 activities.

3.1 The Platform

The platform shall support 5 UCs; Augmented tourism experience, Telepresence, robot-assisted museum guide, high quality video service distribution and remote and distributed video production. By reviewing the functional connectivity of users and mandated functional entities across the supported UCs a priority list or dominant functionality and feature view emerges and is captured in a context diagram (Figure 9).

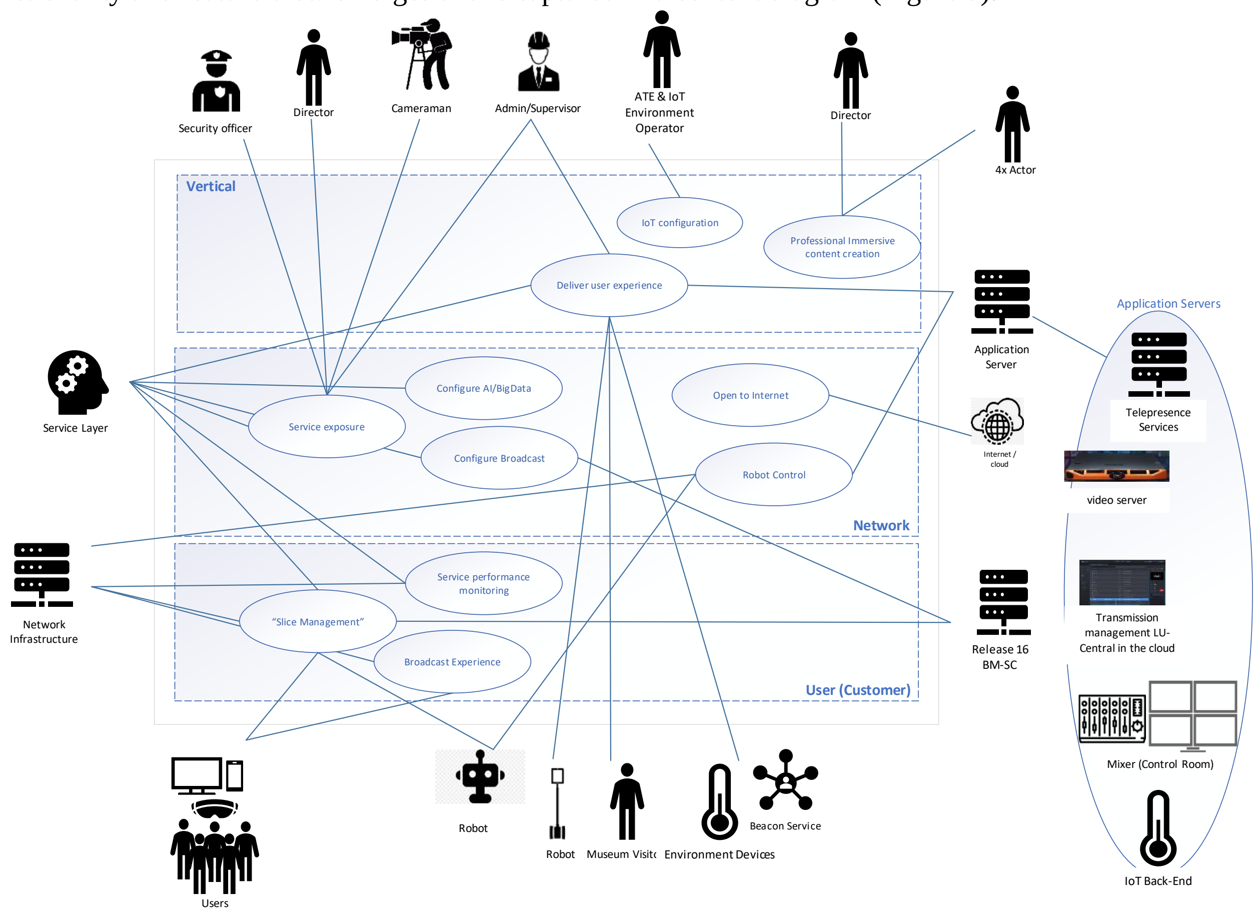


Figure 9: The Touristic City Platform Context Diagram

The following are worthy of not as emergent properties of the platform.

The Service Layer is highly connected into the functionality provision to the vertical users, evidencing its importance in this platform. This functionality shall be realised with features for the flexible management of services with emphasis on Dynamic SLA management. This capability shall enable dynamic Service Level Agreements (SLA) parameters for a network slice, which shall allow flexible decisions on the requested parameters, dynamically changing during the ongoing service. For instance, requirements on the maximum number of users in the network will vary throughout the day, so the UC may request rapid changes to this KPI, without going through the usual OSS/BSS procedures that are typical of today's networks. Specifically, this feature shall be enabled on the VR/XR UC, with the following parameters:

- **Number of users:** The verticals shall be able to specify a range in the number of active users at any point in time. The enhanced MANO shall enforce this rule as long as the minimum QoS (i.e., the one defined in the blueprint) is reachable. This task is performed by the Enhanced MANO through continuous monitoring of the available resources, which ensures that all users shall experience the minimum QoS even in the worst-case scenario.

- **Amount of resources:** The interaction with the network operator and the vertical service provider will likely be based on monetary interactions (Samdanis, et al., 2016), as It is anticipated that operators will charge the verticals according to the QoS levels which, in turn, may well be based on the amount of resources allocated to the network slice offering the services depending on the pricing model applied. This approach, also known as Network Slice as a Service (NSaaS) (Messaoudi, et al., 2020) enables QoS levels configuration with the Network Operator able to set up specific values (e.g., such as the number of allocated servers) or configure an Artificial Intelligence to carry out the configuration. Similarly, other approaches such as Mobile Network as a Service (V. Sciancalepore et al., 2019) may be employed.

Applications Servers of various types, from various suppliers, feature strongly. During the analysis we deemed it necessary to indicate that the generic "application server" was sub-divided in several of the use cases and thus should be drawn through into this context diagram analysis. In the realisation of the commercial platform propositions the modularity of application servers and the way in which applications seamlessly integrate into the platform to support various UCs may be business critical.

Vertical users are instrumental in the operation of the platform, this is what we expect to see. Vertical users like directors and security guards must control key events in the service delivery, the network and supporting devices is there to support their Operations in a useful and meaningful way and thus accessibility of the functionality by them is important.

Having established these emergent properties of the platform the deployment considerations take into account how the required capabilities will be supported at the trials sites and any technology standards interdependencies to be taken into account by WP2 in its further analysis as this anchors WP2 analysis in the reality of what may or may not be substantiated by any verification and validation in the trials sites.

3.2 Deployment considerations

UCs on this platform will require enhanced network functionality to those that are provided by 5G-EVE, in particular broadcast support for multimedia. This shall require a careful planning of the phases of realisation of the capability transitioning through from 3GPP Release15 to Release16 and additional enhancement to include innovative Management and Orchestration (MANO) functions.

5G Broadcast

The video service distribution UC requires the presence of broadcast and multicast delivery mechanisms to optimize the wireless channel access in the video distribution. Three approaches shall be provided by 5G-TOURS:

1. A mobile-centric approach will rely on multicast/unicast switching modules and shall provide a pioneering initiative in the field of 5G broadcast communications in Europe.
2. As a second alternative, the broadcast-centric UC will make use of a HPHT topology to showcase advanced features. EnTV[4] Rel-14 capabilities in a fixed reception scenario shall be supported in the early phase, with a low disruption upgrade to employ a fully-fledged Rel-16 capability, with specific hardware deployed in vehicles at the demonstration site.
3. The utilisation of multicast capabilities in the 5G Core, a 5GC mode of delivery of the UC.

Enhanced Management and Orchestration

5G-TOURS analysis has determined that the state-of-the-art MANO solutions employ static rules during network operation which fall short of needs regarding usability of the network and how services are offered to

[4] EnTV is a feature that enables wide-scale TV distribution, enhancing the existing capabilities of 4G Broadcast (eMBMS)

verticals; such an approach risks low adoption of the 5G network. 5G-TOURS shall therefore extend the MANO with a new **zero-touch feature** for management of the network. This shall be enabled by presentation of new interfaces towards the UC service providers, enabling a more efficient usage of the network by the vertical service provider. This additional functionality shall be included as part of the service layer design.

Several UCs shall require **continuous monitoring** of the network services Key Performance Indicators (KPIs):

- eXtended Reality/Virtual Reality (XR/VR): latency and user throughput.
- Robots: latency.
- Broadcasting: coverage, DL bandwidth.
- TV production: latency, error/loss rates, coverage and mainly UpLink throughput.

Continuous monitoring of these network services is not possible through current network infrastructure elements. The way in which these features shall be exposed to the UCs shall ensure that they are able to verify fulfilment of the requested network parameters.

AI and Big Data

Zero-touch management of the network by intelligent management and orchestration will be particularly evident on this platform and is enabled by the AI module of 5G-TOURS. The AI module shall use monitoring information supplied by the orchestration infrastructure (time series based infrastructure load and the previous re-orchestration events) to generate re-orchestration decisions that will be suggested to benefit the vertical, and that indirectly steer decisions through high level parameters. Therefore. in the context of this platform the VR/XR related UCs shall benefit from this as part of the enhanced MANO extension. TV production shall also be able to benefit from this functionality. A detailed survey of the AI capabilities across the 5G-TOURS, including those that are derived in detail during platform implementation analysis, is captured in D3.2. (5G-TOURS, 2020a).

The specifics of the site deployment architecture will be analysed in detail in other work packages of the project. However, where there are known stages in the release of the UCs or features to support UCs, or to give a sense of the scale of the deployment, such issues are noted as platform requirements. The site deployment architecture spans different locations in the city of Turin (i.e., the two museums, where the access network and edge facilities will be deployed, plus the TIM Lab network for the Core) and it is fully integrated in the 5G-EVE Italian site.

5G Coverage

UCs will be implemented at the Palazzo Madama museum and GAM. For Palazzo Madama a mixed outdoor / indoor coverage will be deployed, essentially to support the trial of UC5 (Remote and distributed video production). All the other UCs shall be implemented only in an indoor environment and follow the two phased approach below.

Deployment phases

In the touristic city, the 5G-TOURS partners are following a two-phase approach in which the network will be empowered with further releases of the 5G Technology:

Phase 1

The phase 1 of the network implementation foresees that the 5G indoor coverage of the museum will be connected to the TIM commercial network whose CN node is located in Milan (i.e. Field Core TIM). From this perspective, the indoor coverage will be a full-fledged extension of the outdoor coverage for those UCs that will require both of them in an early phase of the project. The network implementation of the phase 1 will address only the objective of validating the 5G KPIs.

Phase 2

The phase 2 of the network implementation foresees that the 5G indoor coverage of Palazzo Madama and Modern Art Gallery (GAM) will be connected to the TIM laboratory network (as part of the 5G-EVE infrastructure, i.e. 5G-EVE lab CN). In this case, the outdoor and the indoor coverage will practically be two independent networks coexisting in the same area and operating on the same frequency range. The network implementation of phase 2 will address both objectives to validate the need of 5G and demonstrate the benefits of the 5G-TOURS innovations, taking advantage of the 5G-EVE laboratory network functionalities that will be made available to 5G-TOURS. Phase 2 will therefore provide an almost full integration with the 5G-EVE infrastructure (i.e. laboratory network). In this phase, the project will validate its beyond 5G concepts.

Backhaul connectivity

The network infrastructure will require the support of a broadband wired connection over optical fiber to the museums. Moreover, an important aspect that has to be considered during the design phase of the backhaul network is related to the network coverage planning, which consists in determining the coverage provided by the different cells. An optimal network planning will guarantee a good service provision in terms of connection stability and performance. In case of a mixed outdoor / indoor coverage such as the one that will be deployed at the museums, the network planning plays a fundamental role to determine the boundaries of the respective cells to properly manage the mutual interference that may occurs between the two coverage types.

This aspect becomes even more relevant in case the two coverage areas come from two different networks (e.g. CN to which these cells are connected); concerning the Turin site, such issues will be more significant in the phase 2 of the network deployment. Besides the planning aspects, the operational functionalities (i.e. network radio features) are another important factor that contributes to the network radio performances. Handover support as well as DL (or UL) carrier aggregation (or dual connectivity) are just a couple of examples of such functionalities; the first will guarantee the service continuity when the device will pass from one cell to another (i.e. from the outdoor to the indoor coverage), while the second will improve the throughput by aggregating different carriers of the same or different technologies such as LTE and NR, as in the case of 5G Non-Standalone (NSA) network architecture.

3.3 UCs

We now present the UCs as an outcome of the analysis team that was asked to finalise a flow of events and the interaction of key users and functions of 5G-TOURS using the unified across 5G-TOURS sequence diagram method.

3.3.1 UC1 - Augmented tourism experience

This UC shall provide the visitors of targeted museums with an improved and more engaging experience based on the use of augmented content such as interactive 3-Dimensional (3D) models, virtual avatars and scenarios, immersive (360 degrees) videos and interactive walls. There have been no substantive changes to the UC definition since publishing D2.1 (5G-TOURS, 2019a) but analysis is ongoing regarding the potential for refinement as a response to COVID-19.

The UC is divided in two subcases:

- The first sub-use case (UC1a) shall create an integrated, immersive visit in a museum and surrounding areas using an application based on a location beacon technology. Through this app, the visitor shall have access to additional information such as the possible tour to run, level of crowding in a museum room, map of the museum and related points of interest as well as to more content related to specific rooms and artworks. It shall be possible to interact with 3D objects or participate in a virtual scenario with the aim of improving the visitor knowledge by taking actions. Furthermore, once outside the museum, the app shall assist visitors by suggesting further places of interest or interacting with "smart city services". Finally, once at home, the city tourists can retrieve artworks previously stored or explore new realities not seen during the tour. Note: location-based applications, such as the example of the room crowding, becomes critically important in the COVID-19 era. This is just one such example of how the 5G-TOURS concept of "enhanced virtual on-site experience" that's behind this UC is of use and increased relevancy.
- The objective of the second sub-UC (UC1b) is to allow users to enter the life of artists and to directly test their art creation process as well as learn about it through gamification. It's an educational case study addressed to students or families with children. The experience mixes XR (Extended Reality) with gamification to create an immersive experience and shall allow children to work on an interactive wall reproducing the artist canvas by choosing shape and coloured contents.

3.3.1.1 UC Sequence diagrams

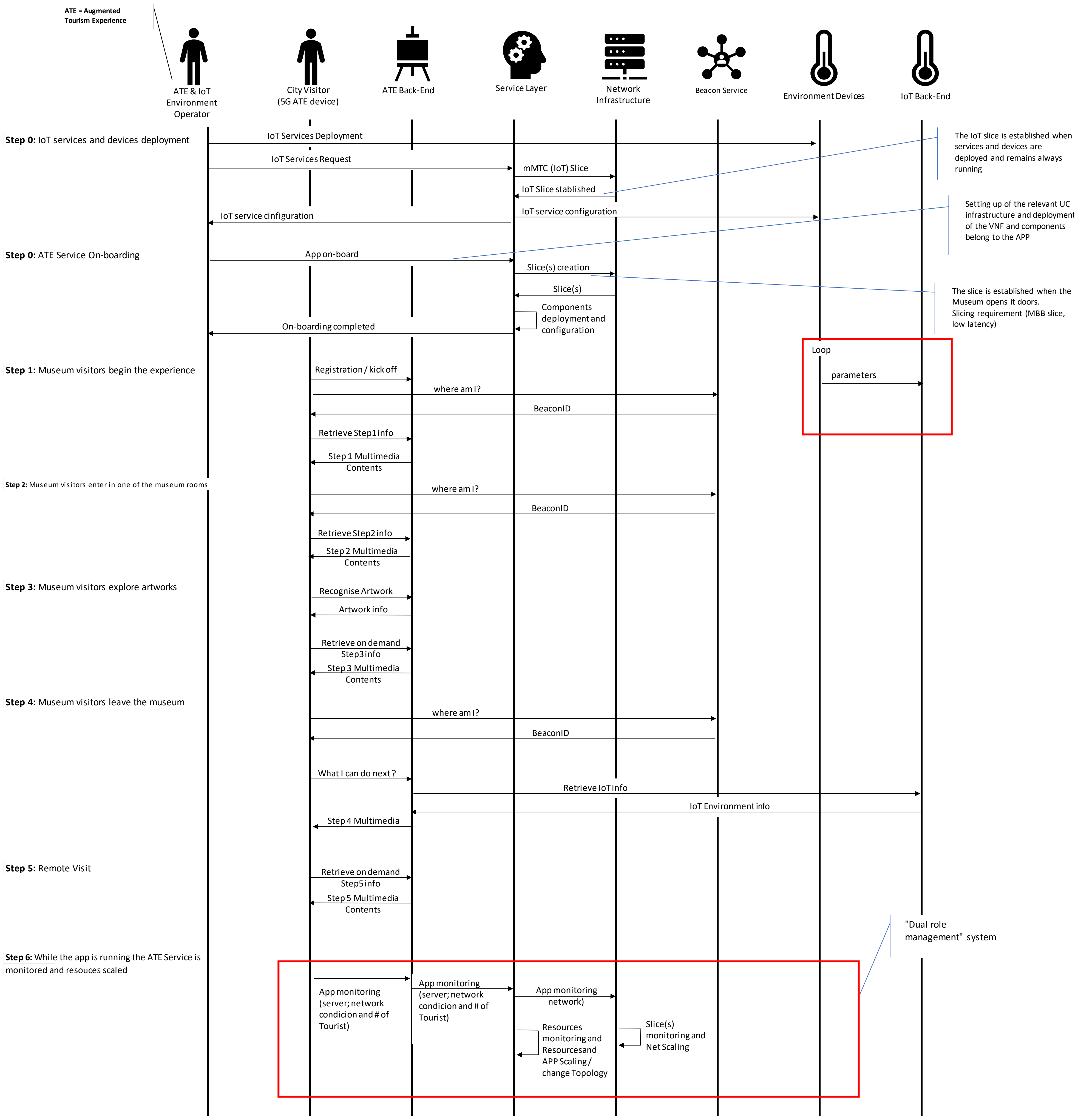


Figure 10: UC1a Augmented Tourism Experience Sequence Diagram

We partition this scenario into several steps, identified to the left of the sequence. The steps are required to include the following:

Step1: Retrieve useful info about the museum:

- possible tour to run,
- crowding in museum rooms,
- personalised tour,
- maps or the Museum,
- points of interests.

Step2: Receive general information about the room description and retrieve a map/picture of the room decorated with information about artworks placed over the room picture in a position which reflects the actual position of the artwork in the room. The User shall be able to “tag” artwork as a favourite so related multimedia content can be consumed afterword. In response to COVID-19 we are investigating the feasibility of enhancing information about the room to enable social distancing awareness in the UC. This is likely to involve indications about other rooms that are crowded or recommended inter-room routing based on lowest crowd flows.

Step3: As a visitor approaches the artwork, the application shall scan the artwork and, using a 3D Visual Search Service, recognise the target (the piece of art). Subsequently, the app shall be able to retrieve all of the multimedia assets related to the artwork: 3D models that represent the artwork, immersive videos, 2D Videos, photos, text written description in different languages, and audio guides. The application shall provide a menu detailing all the multimedia assets. By use of AR the user shall be able to:

- select the multimedia content to consume,
- interact with the 3D representation of the artwork (move, make it bigger to see hidden details of the artwork, rotate, etc.),
- select the artwork as favourite (in a basket), so the multimedia content can be consumed afterword.

Step4: At the end of the visit, the application shall suggest to the tourists further places of interest and several mobility solutions to travel to them (on foot, by bus, with car-sharing). The application shall therefore interact with "smart city services" that make use of information "from the city" based on open-data (bus lines, opening hours, information on museums, etc.) and also environment measurements (e.g. pollution, weather, traffic, availability of bike sharing, etc.). The environment measurements shall be carried out by an appropriate network of IoT sensors that will be installed in the Piazza Castello area. Visitors will be offered a series of places to visit, depending on their preferences and the time they can spend. After selecting the desired place, the application shall show the different ways to reach it:

- on foot, if the distance is not too long and current weather and pollution conditions allow it,
- by bicycle, showing the nearest bike sharing stations,
- by public transport, showing the stops closest to the journey times,
- by car, showing the nearest car sharing stations and any parking areas near the destination area.

Step5: At home or in other museums of the city, tourists shall be able to retrieve artworks previously stored or explore new realities not seen during the tour. This experience is VR-based and contents shall be consumable via interaction with other devices available in the home such as HMD or Oculus Quest.

3.3.1.2 UC specific User and Network Requirements

The end user interactions in the sequence diagrams shall be provided within the constraints of the following performance requirements (Table 3).

Table 3: User requirements for UC1 – Augmented Tourism Experience

	5G-Tours Use case name: UC1 - Augmented Tourism Experience			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes / 40**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**High**
	5	***Data Transmission (UL) :***	High/Medium/Low	**Low**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Walking-Running Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**High accuracy**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very Fast**
	9	**Reliability/Availability:**	high / medium / low	**99.99%**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Medium grade**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Substained High data rate (multimedia), Bursty medium (3d objects); Sporadic Medium msg/s (IoT)**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Medium Density / Medium**
Structural User Requirements	13	***Edge Computing :***	Yes/No	**No**
	14	***Edge Storage :***	Yes/No	**Yes**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Low**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated into the following Table 4, where the general/Specific vertical UC requirements for this UC are shown. We note that the user requirements regarding edge storage and computing shall be a topic for further research during delivery of the use case. The user expectation and the actual performance needs of the UC to provide a sufficient quality of experience to the end user shall be aligned in latter stages of the project.

During the network requirements gathering phase a strong desire (translated to a requirement) for reliability of the network was noted (99.9999%). We anticipate a reduction in this requirement, it is believed likely that a cost benefit analysis will indicate the UC is not commercially viable (too high cost) unless there is a relaxation of the requirement, this shall be researched in the latter stages of the project.

The corresponding radar charts of the three scenarios of general requirements against the 4G/5G networks capabilities of the three different kind of services provided in UC1 are shown in Figure 11, Figure 12, Figure 13.

Table 4: UC1 – Augmented Tourism Experience network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC1: Augmented tourism experience			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	20	50	100		20	100
2	**RAN** Latency (in milliseconds) - one way	msec	10	25	50		10	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	40	40	40		15	40
4	Reliability (%) - Min/Max	%	99,9999%	99,9999%	99,9999%		99.00%	#######
5	Availability (%) - Min/Max	%	99,99%	99,99%	99,99%		99.00%	99,99%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10	0	10		0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0.08	0.08	0.08		0.04	0.08
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	50	50	50		10	90
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y	Y			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	12	12	12		6	12
11	Device Density	Dev/Km^2	400	400	400		400	400
12	Location Accuracy	m	<1	<0,5	1		0.5	1
(*) Latency very low because there is some interactivity - tha same for RAN latency								
(**) A priori it will be people walking with which a very high value is not necessary								
(***) Especially for the topic of beacons no?								
Specific Vertical/Use Case Requirements								
Network	Number of End Points							
	Number (Range) of End Devices per End Point							
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)		15 ms					
	Highest Acceptable jitter (msec)		5 ms					
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Smartphone	IoT Sensors				
	Bitrate required (Kbps / Mbps / Gbps)		40 Mbps	1Mbps				
	Max Latency Allowable (in msecs)		10 ms	30 ms				
	Max Moving Speed (km/h, 0 if stationary)		10 km/h	0				
	IPv4 & IPv6 support (or both)		IPv4	both				
	Connnection of Device to End Point (Wired/Wireless)		Wireless	Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		WLAN	NB-IoT / WLAN				
	Authenication method (i.e. SIM, eSIM, Key..)		SIM / Key	SIM / Key				
(non-Network related Requirements)								
	i.e Battery life requirement		At least 2 hour:	At least one month				

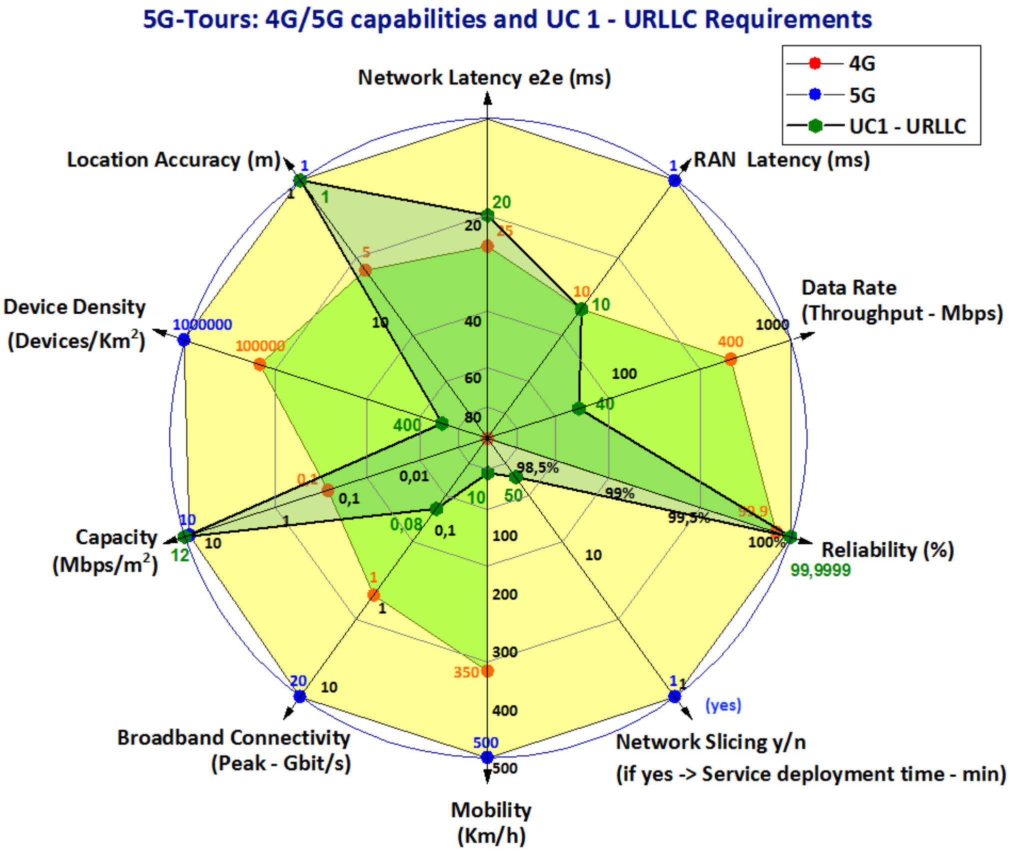


Figure 11: Radar chart for UC1 URLLC network requirements

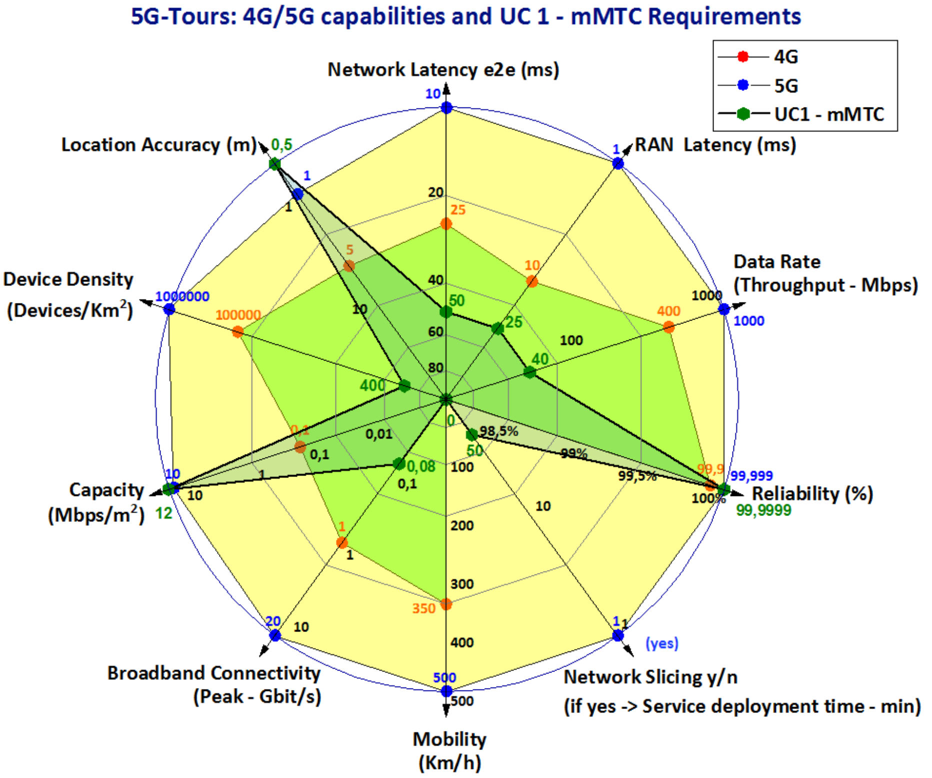


Figure 12: Radar chart for UC1 mMTC network requirements

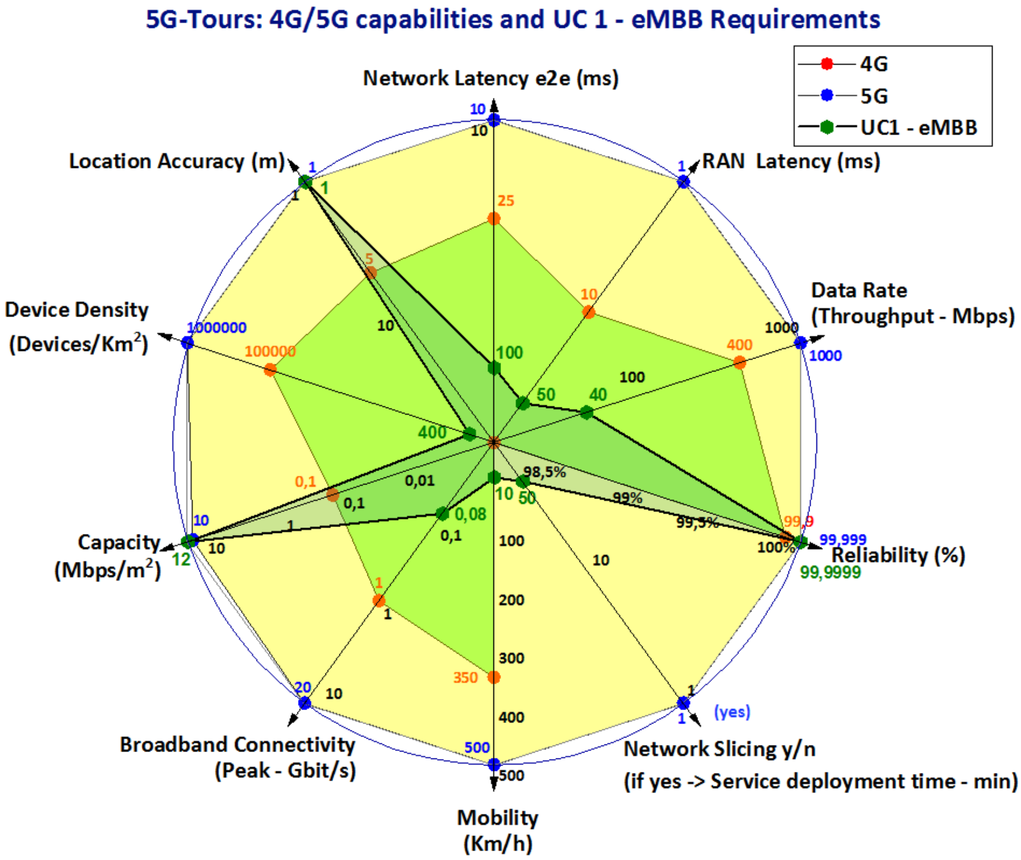


Figure 13: Radar chart for UC1 eMBB network requirements

The Augmented Tourism Experience UC shall utilise all three traffic types (namely URLLC, mMTC and eMBB communications). All three traffic types require the 5G network capabilities for providing the extra

a) Location Accuracy

b) Network Capacity and

c) High reliability

that the current 4G/LTE networks cannot deliver.

Furthermore, the URLLC traffic additionally (to the above 3) requires also an end-to-end Network Latency in the order of 20 msec that will better be delivered using the 5G network capabilities.

Finally, for the mMTC traffic, the Location Accuracy Requirement of 10cm, stretches the limits of 5G Networks. In order to achieve such accuracy with the mobile RAN, one would have to operate in higher frequencies and at the same time utilize other modalities like GPS (and more), in order to acquire the accurate position of the end user. Therefore, a multi-modal positioning algorithm shall be investigated to determine how to improve the accuracy that the 5G network will provide. Nevertheless, it is anticipated that sufficient quality of experience of the UC is possible with a significant reduction in this requirement, this shall be investigated in later stages of the project.

3.3.2 UC2 – Telepresence

Through a telepresence robot assisted experience, the users of UC2 shall:

1) gain the opportunity to enjoy a remote visit of the museum spaces (UC2a);
2) be enabled to participate to an educational gaming experience such as a remote treasure hunt (UC2b);
3) secure the museum through remote surveillance by security staff (UC2c). For example, this UC too, under the 5G-TORUS "enhanced virtual on-site experience" concept, may become of high importance and relevancy in the COVID-19 era, where the robot can help monitor, gamify and enforce social distancing.

The typical UC2 scenario shall comprise of this sequence of events:

- One or more visitors entering the telepresence room to use the service.
- The museum guide activates the service which performs a system request in order to allocate the necessary network resources.
- The guide pilots the robot using the telepresence application, moving it in the museum spaces to complete the guided tour, which is seen by visitors on a large screen in the same room. The visitor will be accompanied by a touristic guide providing information about the visited spaces and related artworks.
- At the end of the visit, the robot shall return to its base station, closing the session, and releasing the system resources.

The robot shall be piloted by trained personnel and not by end users. In the case of remote surveillance, security personnel shall be trained to pilot the robot, for use during museum closing times.

- The scenario represented by the diagram below is the most complex one, where both the visitor(s) and the guide are in a virtual remote visit room, so both have to interact with the Telepresence Service. As previously mentioned, both actors could also be in a remote visual room physically enabled at the museum. The application of this kind of installation is to allow access to certain spaces in the museum to, for example, disabled people.
- Museum visitor gets access to the remote visit room and asks for a telepresence visit.
- The Museum guide is the person who will drive remotely the robot through the museum space.
- The guide shall always control the telepresence session; the visitor shall be able to participate connecting to an already established session.
- The audio/video streamed by the robot is received in the remote virtual visit room where both the Guide and the Visitor are.

3.3.2.1 UC Sequence diagrams

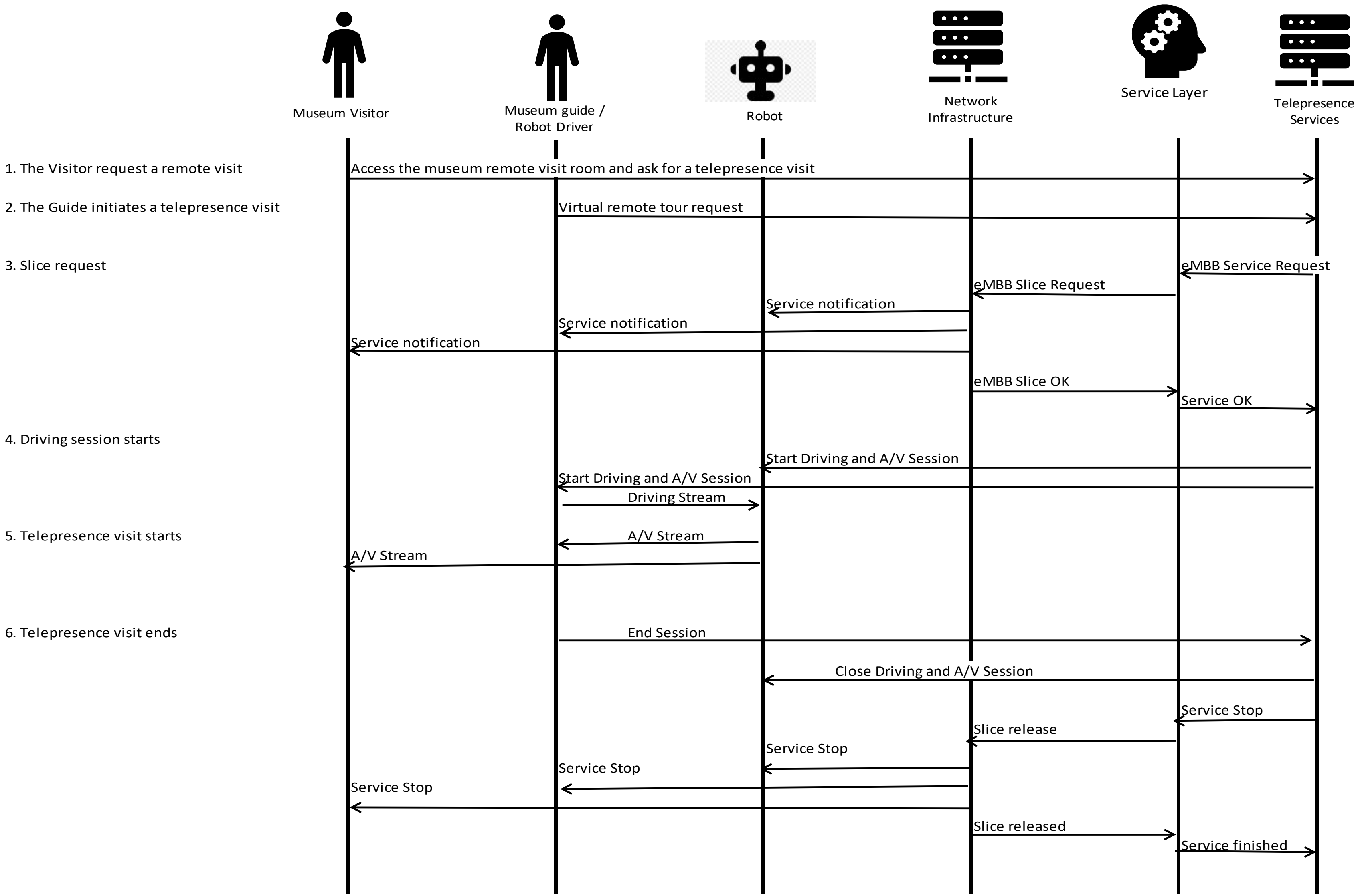


Figure 14: UC2a Telepresence Sequence Diagram

The same diagram can be easily adapted to cover UC2.b and UC2.c previously described. The adaptation to the remote surveillance scenario is represented below:

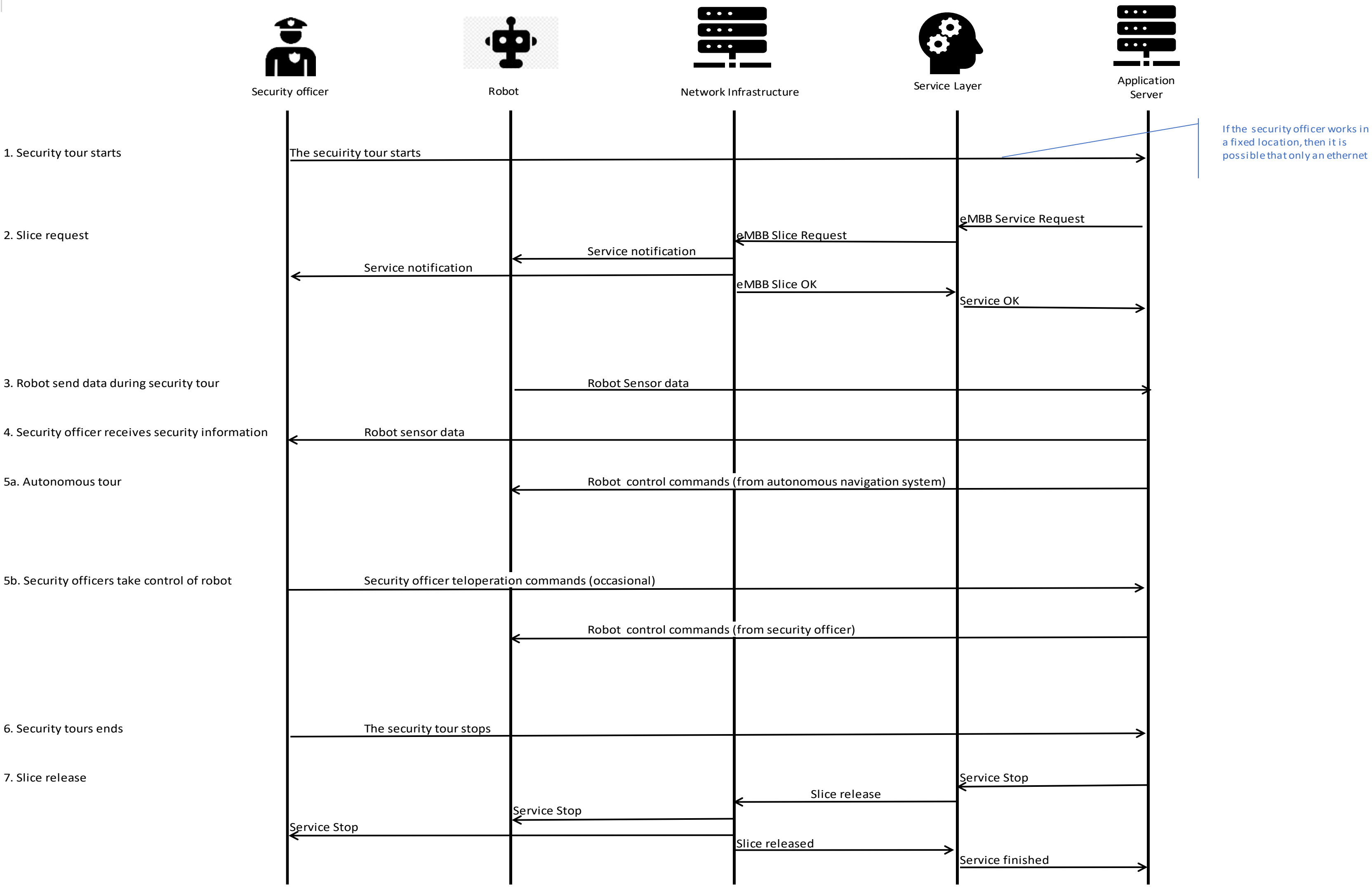


Figure 15: UC2c Telepresence Sequence Diagram

Key points with respect to capabilities of the vertical actors:

- The application server shall receive data streams from the robot and coordinates robot movements. It performs autonomous navigation and vision recognition tasks, computing robot trajectories during the security tour.
- The security officer receives data processed by the vision system running on the application server, not directly via the robot. The movements of the robot are normally controlled by the autonomous navigation system. The security officer shall be able take control of the robot (teleoperation) at any time. In this case, its commands are sent to the controller running on the application server, processed, and finally sent to the robot, overriding the commands normally generated by the autonomous navigation system.

3.3.2.2 User and Network requirement analysis

For the implementation of this UC the following requirements from the user perspective are needed (see Table 5):

Table 5: User requirements for UC2 – Telepresence

	5G-Tours Use case name: UC2 - TELEPRESENCE			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes / 2**
	2	**Video Transmission:**	Yes/No no of Channels	**Yes / 2**
	3	**Voice Communication:**	Yes/No	**Yes**
	4	**Data Reception (DL):**	High/Medium/Low	**Low**
	5	***Data Transmission (UL) :***	High/Medium/Low	**Low**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Walking-Running Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**Yes / High accuracy**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very Fast**
	9	**Reliability/Availability:**	high / medium / low	**Medium**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Baseline**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sustained / medium (video) (UC2a,b,c)** **Sporadic / high (controls) (UC2a,b)** **Sustained / low (controls) (UC2c)**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Medium density / Medium**
Structural User Requirements	13	***Edge Computing :***	Yes/No	**Yes**
	14	***Edge Storage :***	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**N.A.**
	16	***other***	User specified	**N.A.**

The mapping of the above user requirements into network requirements are illustrated into the following Table 6, where the general/Specific vertical UC requirements for the UC2 are shown. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 16 below.

Table 6: UC2 – Telepresence network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC2 – Telepresence			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	2			High	1	10
2	**RAN** Latency (in milliseconds) - one way	msec	1			high	1	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	30			High	~10	~30
4	Reliability (%) - Min/Max	%	99,9999%				99,000%	99,9999%
5	Availability (%) - Min/Max	%	99,9999%				99,000%	99,9999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	1				0,1	1
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,1					0,1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y (30)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	30				~10	~30
11	Device Density	Dev/Km^2	5				1	5
12	Location Accuracy	m	0,1				0,1	0,5
Specific Vertical/Use Case Requirements								
Network	Number of End Points		1					
	Number (Range) of End Devices per End Point		1					
	Density of End Devices (per sq. meter)		1					
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**							
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)							
	IPv4 & IPv6 support (or both)							
	Connnection of Device to End Point (Wired/Wireless)							
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)							
ic (non-Network related Requirements)								
	i.e Battery life requirement							

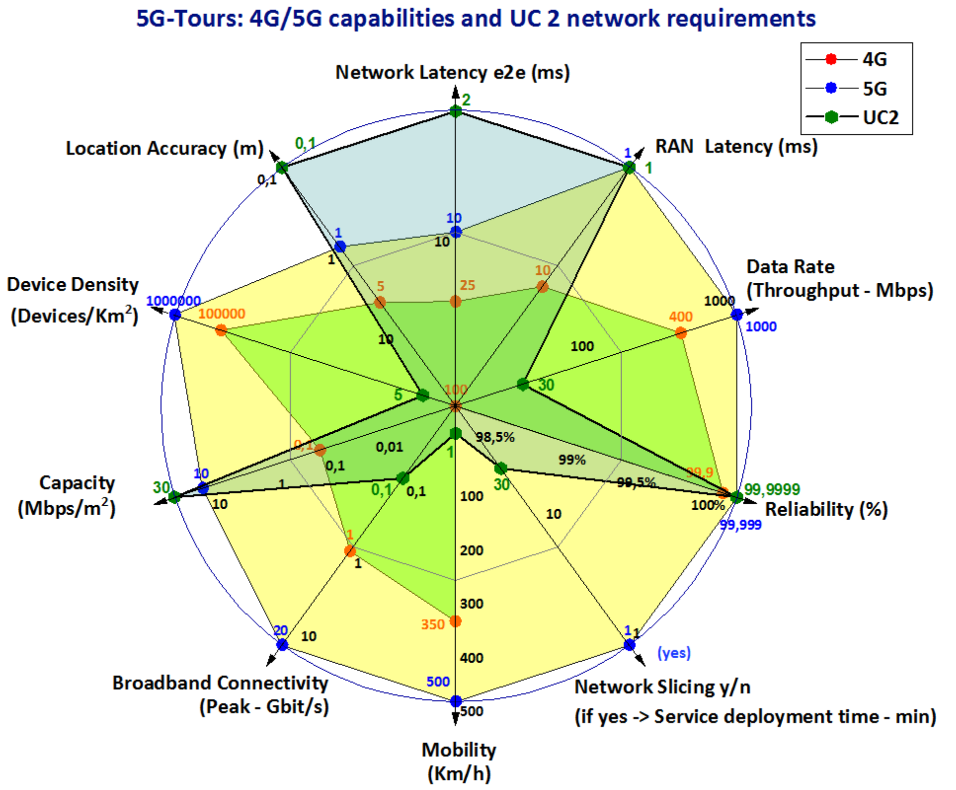


Figure 16: Radar chart for UC2 Telepresence network requirements

The Telepresence UC needs a 5G network order to achieve the required

- Capacity;
- Network Latency;
- RAN Latency;
- Location Accuracy;
- Reliability and
- Slicing (Service deployment time).

For the Network Latency (round trip), even the capabilities of the 5G technologies are stretched to the limit based on these requirements. The 2 msec that is required is a LAN type latency and not the Access+Core Network Latencies. Therefore, either this capability shall be relaxed, or provisioning of Edge Storage/Computing shall be established. The latter case (support of Edge Cloud) would make the implementation of the Service more costly for perhaps limited user experience gain. We anticipate that a 10msec latency is more than sufficient for this requirement, this shall be verified during the latter stages of the project.

The Location Accuracy Requirement of 10 cm also stretches the limits of 5G Network capabilities. Achieving such accuracy using only the capabilities of the 5G network is difficult. One would have to operate in higher frequencies and, at the same time, utilize other modalities like GPS in order to acquire the accurate position of the end user/device. Therefore, the provisioning of a multi-modal positioning mechanisms in order to improve of the location accuracy over and above the 5G network may be considered.

3.3.3 UC3 - Robot-assisted museum guide

This UC foresees the use of robotics to provide an enhanced museum visit experience. A humanoid robot shall provide basic information about collection highlights and temporary exhibitions as well as assist visitors during queuing time at the ticket desk; guide visitors moving through the museum and describing the artworks. This guided tour shall be performed autonomously by the robot following a precomputed path. Human intervention will be required only in emergency situations.

3.3.3.1 UC Sequence diagram

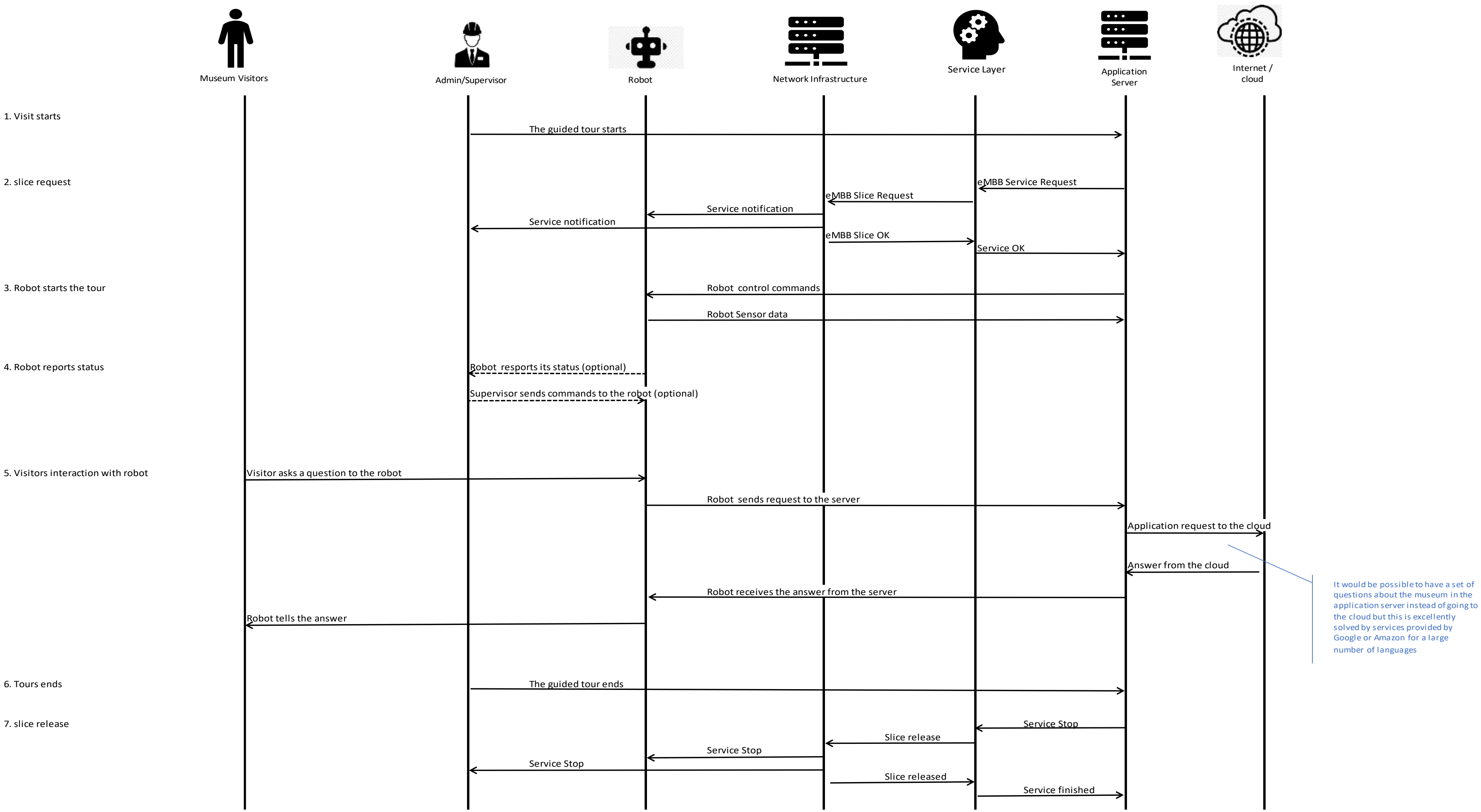


Figure 17: UC3 Robot-assisted Museum Guide Sequence Diagram

Key stages in the sequence of events are:

- At the beginning of the tour, the supervisor checks if the group of visitors is ready to start the visit and then starts the application.
- During the tour, the application server receives data stream from the robot and coordinates robot movements. It performs autonomous navigation and vision recognition tasks, computing robot trajectories during the guided tour.
- The periodic status report provided by the robot to the supervisor is not part of the guided tour application. Nevertheless, due to the prototypical nature of the application, it is essential to monitor its status during the operation.
- During the tour, the robot navigates autonomously between different waypoints, describing the museum artworks to the visitors. The visitor may interrupt the robot for a question, which will be processed by the application server, eventually connecting to a cloud service.
- At the end of the tour, the supervisor stops the application and takes the visitors to the exit.

3.3.3.2 User and Network requirement analysis

For the implementation of this UC the following requirements, from the user perspective are needed (Table 7).

Table 7: User requirements for UC3 – Robot-Assisted Museum Guide

	5G-Tours Use case name: UC3 - Robot-Assisted Museum Guide			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes (1 x 15Mbps)**
	2	**Video Transmission:**	Yes/No no of Channels	**Yes (1 x 15Mbps)**
	3	**Voice Communication:**	Yes/No	**Yes**
	4	**Data Reception (DL):**	High/Medium/Low	**Medium**
	5	***Data Transmission (UL) :***	High/Medium/Low	**Medium**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Walking-Running Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**High**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very fast**
	9	**Reliability/Availability:**	high / medium / low	**Medium**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Baseline**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sustained medium**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Sparse High**
Structural User Requirements	13	***Edge Computing :***	Yes/No	**Yes**
	14	***Edge Storage :***	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**N/A**
	16	***other***	User specified	**N/A**

The mapping or the above user requirements into network requirements are illustrated into the following Table 8, where the general/Specific vertical UC requirements for the UC3 are shown. We have identified a high user expectation in terms of the latency. We anticipate that this requirement can be relaxed with no detrimental impact on the quality of experience of the UC. This will be verified in the latter stages of the project. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 18.

Table 8: UC3 – Robot-Assisted Museum Guide network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC3: Robot-assisted museum guide and monitoring			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	2			High	1	10
2	**RAN** Latency (in milliseconds) - one way	msec	1			high	1	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	30			High	~10	~30
4	Reliability (%) - Min/Max	%	99,9999%				99,0000%	100,0000%
5	Availability (%) - Min/Max	%	99,9999%				99,0000%	100,0000%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	0,5				0,1	0,5
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,1					100Mbps
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y (30)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	30				~10	~30
11	Device Density	Dev/Km^2	1				1	1
12	Location Accuracy	m	0,1				0,1	0,5
Specific Vertical/Use Case Requirements								
Network	Number of End Points		1					
	Number (Range) of End Devices per End Point		1					
	Density of End Devices (per sq. meter)		1					
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**							
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)							
	IPv4 & IPv6 support (or both)							
	Connection of Device to End Point (Wired/Wireless)							
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)							
ic (non-Network related Requirements)								
	i.e Battery life requirement							

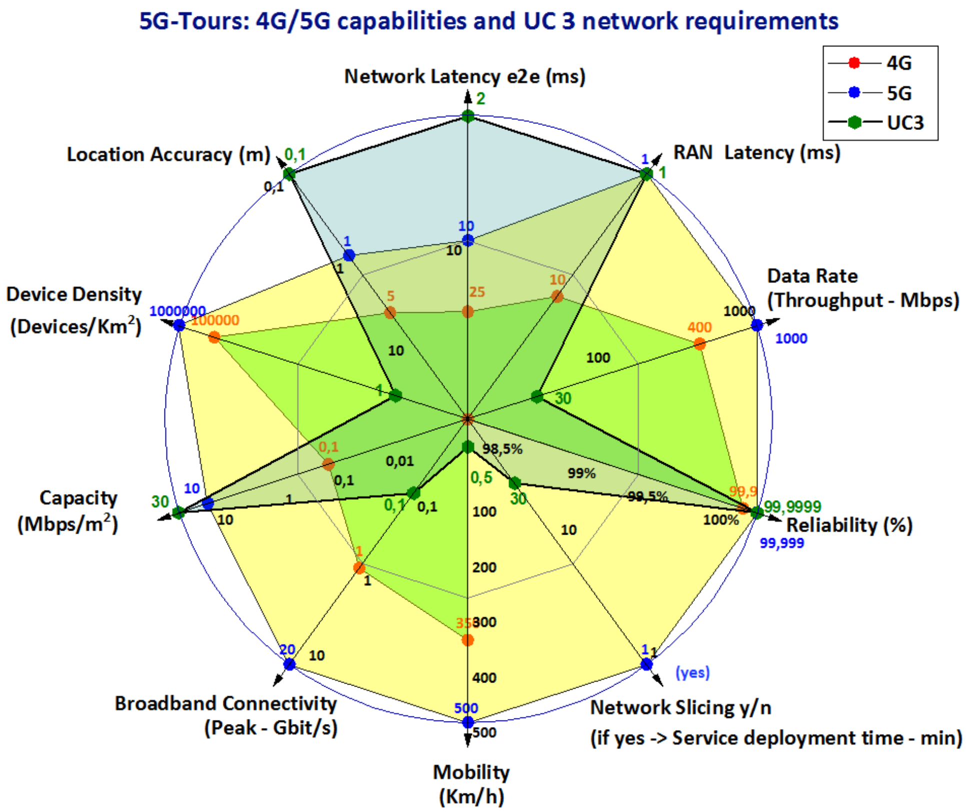


Figure 18: Radar chart for UC3 Robot-Assisted Museum Guide network requirements

Very similar to the previous UC, the Robot-assisted museum guide requires Network Latency (round trip) that even the capabilities of the 5G technologies are stretched to their limit. The 2 msec that is required is LAN type latency and not Access+Core Network Latencies. Therefore, either this capability should be relaxed to approx. 10 msec, or provisioning of Edge Cloud capabilities should be investigated. The latter case (Support of Edge Computing and/or Storage) would make the implementation of the Robot-assisted museum guide service expensive.

Furthermore, the Location Accuracy Requirement of 10 cm, also stretches the limits of 5G Network capabilities. In order to achieve such accuracy either the RAN would have to operate in higher frequencies and, simultaneously, other modalities like GPS (or location beacons for indoor) should also assist for acquiring the accurate position of the end user/robot. Therefore, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

Additionally (to the Network Latency and Location Accuracy)

- Capacity,
- Slicing,
- Reliability and
- RAN latency requirements,

dictate the use of a 5G Network for successful implementation of this UC.

3.3.4 UC4 - High quality video services distribution

This UC targets the distribution of enhanced high-quality video and immersive services for tourists to enhance the user experience when visiting a city. Users will be able to use their smartphones, tablets or VR devices to receive educational and informative content during their visits to either a city or museum. In the specific 5G-TOURS project implementation, video sources, which can be either professional 4K-HDR or 360º videos, will be produced in collaboration with the RAI Television Production Centre. This audio/video (A/V) product will serve as promotional activities about the city and its culture at the same time. UC4 is divided in three sub-use cases:

(i) transmission of mixed unicast/broadcast services using TIM’s laboratory network,

(ii) use of 5G broadcast delivery services using RAI’s broadcasting network, and

(iii) development of a 5G core multicast component in UPV’s laboratory.

It is anticipated that for the purposes of executing the use case a commercially available for core accessible from the TIM network will be sufficient; however, as additional capability a lab based 5G core will be made available for testing of UC functionality beside the deployed and in situ UC to be trialled by the users.

The UC sequence is on the following page:

3.3.4.1 UC Sequence diagram

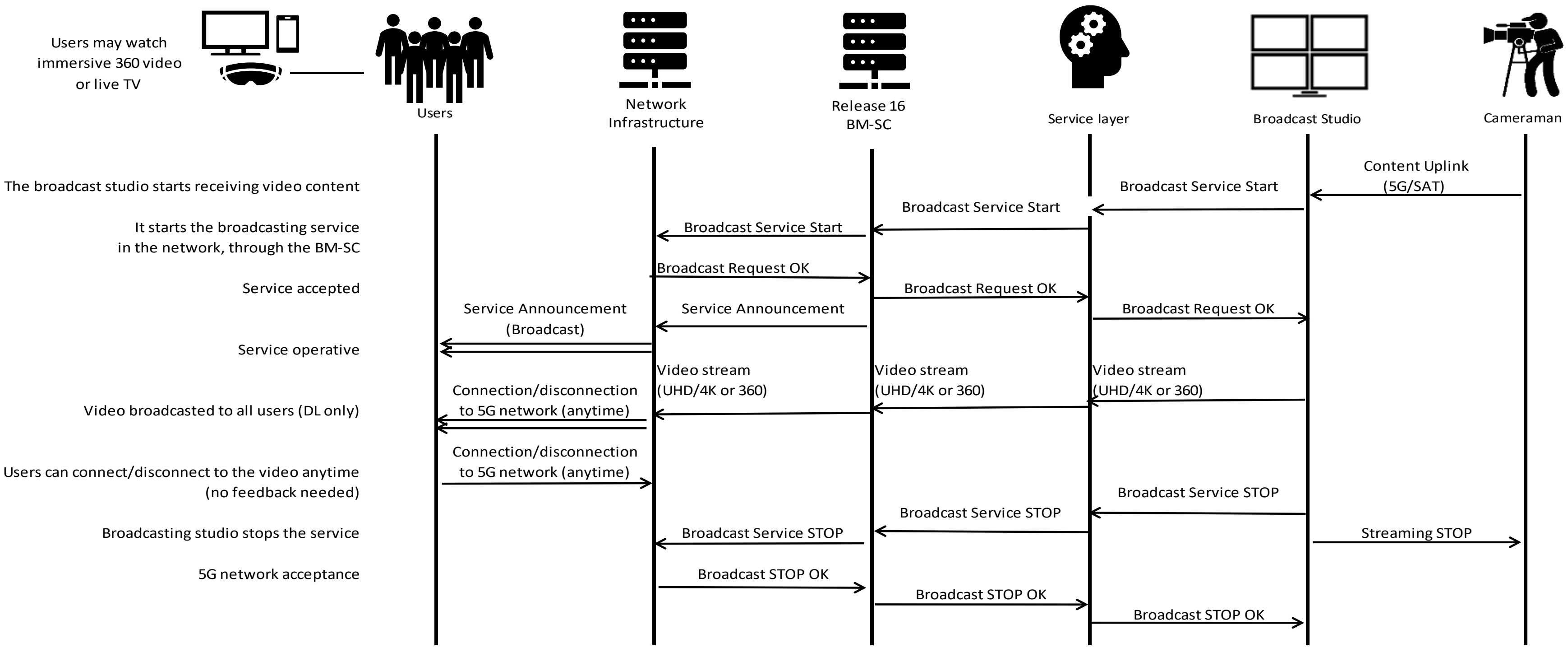


Figure 19: UC4 High Quality Video Service Distribution Sequence Diagram

3.3.4.2 Evolution of the UC

Compared to deliverables (5G-TOURS, 2019a) and (5G-TOURS, 2019), there are differences in the way UC4 is divided into sub-use cases. The two main lines of work are still divided into (i) UC4a: Mixed unicast/broadcast services in cellular networks; and (ii) UC4.b: 5G Broadcast delivery to massive audiences. The work to be done in UC4a was initially divided into three phases of development (5G-TOURS, 2019a):

- LTE with enhanced Multimedia Broadcast Multicast Service (eMBMS) capabilities;
- 5G non-standalone with eMBMS capabilities;
- 5G standalone with broadcast capabilities.

The decision was to take the last stage of UC4a as a separate UC4c, related to the development of 5G core multicast capabilities. The current status for each of the sub use cases is defined below.

Since UC4 is divided into three sub-UCs, Figure 19 provides a generic approach, where there is no uplink from the users to the network (i.e. UC4b like). Slight modifications would be needed to describe a specific sub use case. Some key aspects of the diagram:

- The broadcast service can be either the cameraman real-time video or offline inserted video.
- In any case, the cameraman uplink video is continuously transmitted, with a permanent connexion.
- Users are not always connected to the 5G broadcast service (or network). They need to establish a connection and can be disconnected any-time as well. The service will still be broadcasted.
- The use of network slicing will depend on the sub use-case. On a general basis, no network slicing is needed, since the service is ensured by the use of a different channel (MCH/PMCH), specified in 3GPP for EnTV services.
- Users can connect and disconnect to the broadcast service freely (no uplink, downlink only). The broadcast service is operative regardless of the number of users.
- The type of content can be either UHD video for smartphones/TVs, or immersive 360 video for VR glasses/smartphones.

The current UC4 sequence diagram may require refinement to more precisely differentiate between multi-cast and broadcast requirements. UC analysts shall resolve this aspect of the specification in the latter stages of the project.

UC4a: Mixed unicast/broadcast services in cellular networks

TIM has defined a roadmap and has progressed in the internal activities to evaluate LTE eMBMS service activation and related network deployment aspects. This UC will not use 5G-EVE's network, since multicast/broadcast capabilities are needed and are not provided by 5G-EVE. Instead, it was decided to use TIM's laboratory network.

The network, although located in a laboratory, has the same capabilities that the commercial network deployed by TIM in Italy and is generally used to test new functionalities before these are implemented on field. However, currently there are no eMBMS capabilities implemented in the commercial network. According to the current internal information, the eMBMS capabilities and functionalities should be part of the next software release that will be installed in the commercial network during the second half of 2020. Plans for enabling of eMBMS service on the commercial network are in place, this will be also reflected in the laboratory network so that it will be possible to perform the UC4a activities.

UC4b: 5G Broadcast delivery to massive audiences

This UC will be divided into two phases of demonstration:

- **Phase-1** (end 2020): partners will use 3GPP EnTV Rel-14 equipment with fixed reception, used in some previous demonstrations outside the project. Some minor updates in both the content and the technical aspects will be included.
- **Phase-2** (2021): the transmitter and receiver equipment will be updated to EnTV Rel-16. Immersive services in a mobile in-car environment will be showcased in this phase to highlight the capabilities of the 5G network in terms of bandwidth resources.

The available radio-frequency channel for the trial in Torino is the VHF 11 (216-223 MHz, centre frequency 219,5 MHz) in vertical polarization. There will be one transmitter located in Torino Eremo (the main RAI transmitting site for Torino), placed on a hill at about 650 m above sea level and 4 km away from Palazzo Madama and Rai CPTO studios (city centre). The area covered by the signal will be the whole town of Torino. Despite the available frequency is not intended for 5G broadcast, the results of the trials could anyway be useful to show the potential of this technology and to give important outcome regarding the network implementation.

UC4c: 5G core multicast

5G Core Multicast development shall be required for UC4c. Validation and testing shall be carried out by development (UPV) in a lab and then migrated as an all-in-one solution into TIM experimental laboratory housing 5G-EVE. Two new Network Functions (NFs) shall be provisioned, one Service Based Architecture (SBA)-based in the Control Plane and the other one located in the User Plane and interfaced with the multimedia server or the Content Delivery Network (CDN). Multicast as a feature enables one-to-many communications at the transport network. This terminology based on 3GPP concepts, where multicast is provisioned to verticals for support of Mission Critical communications. The design shall align with latest Rel-17 3GPP work.

The development will be done in UPV premises, specifically, on the VLC-Campus-5G infrastructure for 5G validation

3.3.4.3 User and Network requirement analysis

For the implementation of this UC, the following requirements come from the user perspective (see table 16).

Table 9: User requirements for UC4 – High quality video services distribution

	5G-Tours Use case name: UC4 - High quality video services distribution			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes (up to 15 x 25-100 Mbps)**
	2	**Video Transmission:**	Yes/No no of Channels	**Yes (up to 15 x 25-100 Mbps)**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**High**
	5	***Data Transmission (UL)* :**	High/Medium/Low	**Low**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Medium + walking running speed + stationary**
	7	**Location Information:**	High / Medium / Low Accuracy	**Low accuracy**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very fast**
	9	**Reliability/Availability:**	high / medium / low	**Medium**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Baseline**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sustained high data rate**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Medium low**
Structural User Requirements	13	***Edge Computing* :**	Yes/No	**Yes**
	14	***Edge Storage* :**	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Medium**
	16	***other***	User specified	**N/A**

We anticipate potential for a relaxation of the response time user requirement which is likely to be over specified for the needs of this use case. For the purpose of the use case demonstration a walking pace mobility requirement is deemed sufficient. However, for full commercial offerings of this use case it is likely to benefit from support of a higher mobility for vehicle-based users, the feasibility of supporting higher mobility will be researched during the latter stages of the project.

The mapping of the above user requirements into network requirements are illustrated into the following Table 10, where the general/Specific vertical UC requirements for the UC2 are shown. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 20.

Table 10: UC4 – High quality video services distribution network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC4: High quality video services distribution			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			10 ms	Medium	10 ms (bi-directional)	None (broadcast)
2	**RAN** Latency (in milliseconds) - one way	msec			5 ms	Low		
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			25	High	25 Mbps	-
4	Reliability (%) - Min/Max	%			99,9999%	High	99,999%	99,9999%
5	Availability (%) - Min/Max	%			99,90%	Medium		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			100	Medium	10	100
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,1	-	0,05	0,1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N			Y (60)	Medium	60 min	120 min
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N	-		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			-			
11	Device Density	Dev/Km^2			N/A (multicast/broadcast)	Low		
12	Location Accuracy	m			-	-		
Specific Vertical/Use Case Requirements								
Network	Number of End Points				1 In the trial.	Medium		
	Number (Range) of End Devices per End Point					Medium	10	50
	Density of End Devices (per sq. meter)				Multicast / broadcast	Low		
	Bitrate needs per end point (Kbps,Mbps, Gbps)					High	10 Mbps (5 MHz channel)	-
	End -to-end Latency (msecs)					Low	10 ms (multicast)	None (broadcast)
	Highest Acceptable jitter (msec)				-			
	Number of Class of Service / QoS (1-8, more)				-			
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**				Smartphones, AR and TV			
	Bitrate required (Kbps / Mbps / Gbps)					High	10 Mbps (5 MHz channel)	-
	Max Latency Allowable (in msecs)					Low	10	None (broadcast)
	Max Moving Speed (km/h, 0 if stationary)				100	Medium		
	IPv4 & IPv6 support (or both)				IPv4			
	Connection of Device to End Point (Wired/Wireless)				Wireless			
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)				Ethernet and FO			
	Authenication method (i.e. SIM, eSIM, Key..)							
fic (non-Network related Requirements)								
	i.e Battery life requirement				-			
5G-EVE Site Services USER REQUIREMENTS								
	City	Turin						
	Address & End Tel. Number[1]							
	Competent, Tel. Number, FAX							
	Type of Service[2]	Broadband						
	Speed/Capacity[3]							
	Access Protection[4]							
	PRIMARY / BACK UP[5]							
	EXTRANET[6]							
	Broadband Access Line[7]							
	Existing Access[8]							
	Number of DIAL-UP Users							
	Minimum Duration of Service	60 min						
	Class of Service[9] (Silver/Gold/Premium)							

It is anticipated that the user has over specified reliability needs for this UC. As reliability comes at a cost premium it is intended to research the perhaps relax this requirement during UC quality of experience analysis.

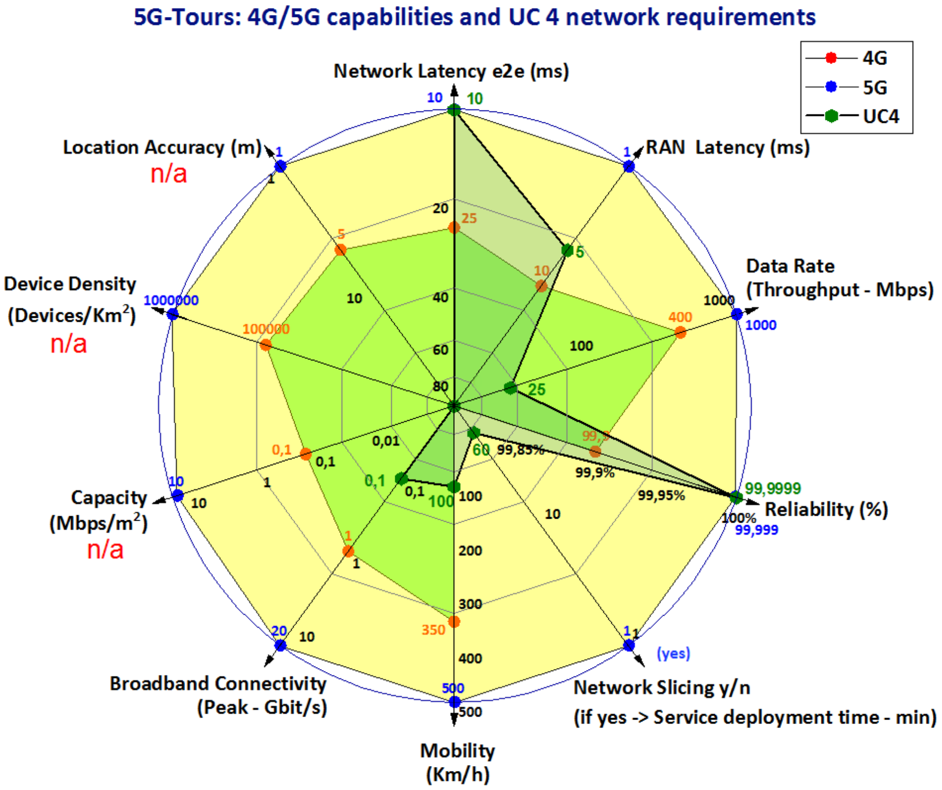


Figure 20: Radar chart for UC4 High quality video services distribution network requirements

Based on the above analysis the user and network requirements expectations of users of the system are high. We anticipate that several of the requirements for this use case are over specified; this will be verified and in the latter stages of this project. However, based on the stated requirements for UC4 for the delivery of high-quality video distribution the above brings to the fore the following features of a 5G network.

- RAN Latency,
- Network Latency and
- Reliability are the ones that need a 5G Network.

The most important part of this UC is the need of broadcast support, which needs to be implemented in the 5G network as an additional functionality.

3.3.5 UC 5 - Remote and distributed video production

This UC focuses on remote television production. In a distributed TV video production context, the content needs to be produced by mixing local and remote audio and video contributions in the TV studio. The remote contributions are thus delivered to the main editing site via the 5G network in real time.

3.3.5.1 UC Sequence diagram

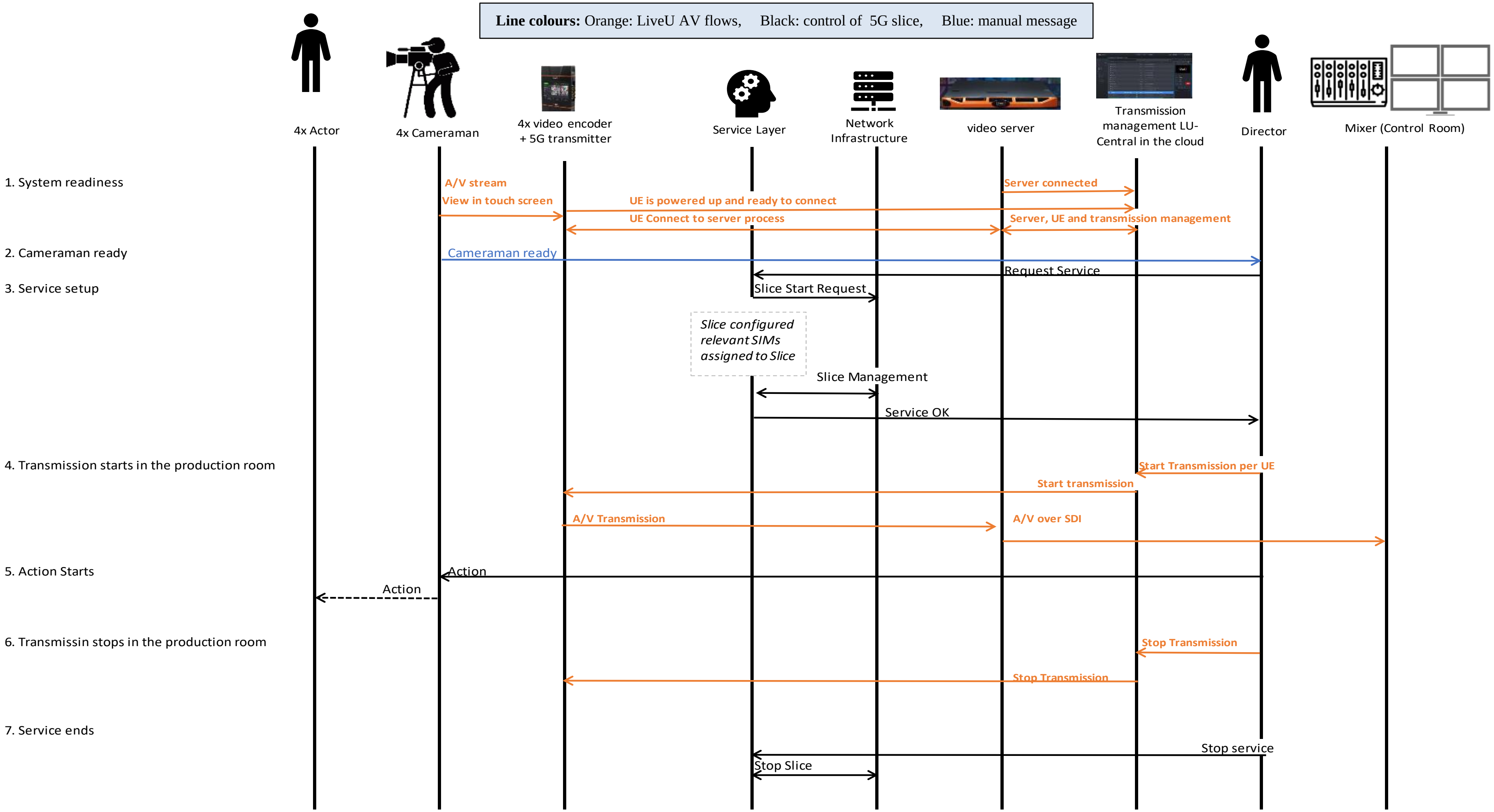


Figure 21: UC5 Remote and Distributed Video Production Sequence Diagram

The UC has “n” players in the field, each having its own transmitting unit, cameraman, etc., so the “n” video streams are uplinked simultaneously. They all have to get the same strict QoS/service and be synchronized in time to the same latency.

These are the main steps shown in the diagram:

1. LiveU video server is powered on, connects to its LiveU LU-Central management system in the cloud and announces its address and readiness; could be days or minutes in advance.

2. Cameramen power up their LiveU field units; the units connect with their LiveU cloud management, announce readiness and are given the address details of their LiveU video server.

3. The cameramen connect their A/V equipment to the LiveU field unit and inform the director that they are ready (via regular smartphones).

4. The director asks the 5G platform to bring-up the service; could be done in advance or automatically without director intervention.

5. The service is brough up including the relevant slice; the field units SIMs are moved to that slice;

6. Cameramen or remote director start the transmission from the field units to the video server in the production room in Palazzo Madama.

7. The video is outputted out from the video server and into the production system.

8. The director instructs the cameramen via the production intercom system over the return IFB channel in the LiveU solution.

9. The director instructs the cameramen to stop transmission when the event or their specific part ends; alternatively, the director stops or starts transmission of each unit from remote via the LiveU cloud-based management system.

10. Transmission stops, video output from the server stops.

11. Director instructs the 5G platform to stop the service.

12. Service stops, slice is freed-up.

3.3.5.2 User and Network requirement analysis

For the demo implementation of this UC the following requirements from the user perspective are needed (Table 11):

Table 11: User requirements for UC5 – Distributed video production

	5G-Tours Use case name: UC 5 - Distributed video production			
	a/a	**User Requirements Description**	**Metrics**	**values and Units**
Content User Requirements	1	**Video Reception:**	No	
	2	**Video Transmission:**	Yes , 4 x uplink (UL) transmissions	**at least 4x 20 mbps UL continous/stable (the 15 mbps channel is ok if must, but 20mbps or hugher is better)**
	3	**Voice Communication:**	Optionly Yes (not as part of the test itself but perhaps for operational needs), 4x DL (into the field cameraman);	**4x 128 kbps, DL**
	4	**Data Reception (DL):**	Low	**0**
	5	***Data Transmission (UL)* :**	High - video transmission, see above; no additional UL data transmission is foreseen	
Functional User Requirements	6	**Mobility:**	Walking-Running Speed / Stationary	
	7	**Location Information:**	Low Accuracy	
	8	**Fast Response (Low Latency):**	Very Fast. Important to have fixed/guaranteed latecy maintained for the duration of the fulll tranmsission (~2 hours), and very low latency so to allow video processing more time and synchronized multi-audio	**1. known/guaranteed/same latency for 2 hours 2. TBD low UL latency**
	9	**Reliability/Availability:**	high	**Stable, avilable in all the course of the music playetrs from A to auditoriu and inside**
	10	**Security / Privacy:**	Baseline	
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High data rate	**continuos UL video tranmissions for at least 2 hours**
	12	**Interactivity & Space Dependency:**	Dense High	**The transmissions take place from congested places (with multiple other users);**
Structural User Requirements	13	***Edge Computing* :**	Yes	**TBD on TiM installation; We may want to install the LiveU video servers in the Edge and run them there so to have shorter UL latency; otherwise sending the video to the E11Liveu video servers in the auditorium via the public internet/ISP may add latency**
	14	***Edge Storage* :**	TBD, if at all then Edge computing, not just Edge storage	**If we do test as VNF on the Edge computing, then some storage is needed. E.g. few GBs only/**
Service Specific (Examples)	15	***Battery Life:***	Not very important	**Liveu devices have bigger batteries**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements derives the following Table 12, where the general/Specific vertical UC requirements for the UC5 are shown. The corresponding radar charts (URLLC and eMBB) of general requirements against the 4G/5G networks capabilities is shown in Figure 22, and Figure 23.

Table 12: UC5 – Distributed video production network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC5 – Distributed video production			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10		<50	Med	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	1		1	Low	1	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	180		100	High	50	200
4	Reliability (%) - Min/Max	%	99,9999%		99,9999%	High	99,0000%	99,9999%
5	Availability (%) - Min/Max	%	99,9999%		99,9999%	Med	98,0000%	99,9999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	3		3	Med	0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,25					
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y (5)		Y	Low	5	15
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y		Y	Low		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	360		360	Medium	180	900
11	Device Density	Dev/Km^2	12		12	hi	12	15
12	Location Accuracy	m	n.a.		n.a.	n.a.	n.a.	n.a.
Specific Vertical/Use Case Requirements								
Network	Number of End Points							
	Number (Range) of End Devices per End Point							
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)				5		1	8
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**	modems inside Liveu bonding video device						
	Bitrate required (Kbps / Mbps / Gbps)	per the above, 4x 25 mbps UL						
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)	200 km/hr						
	IPv4 & IPv6 support (or both)	both						
	Connnection of Device to End Point (Wired/Wireless)	wireless						
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)	SIM					12	
fic (non-Network related Requirements)								
	i.e Battery life requirement							

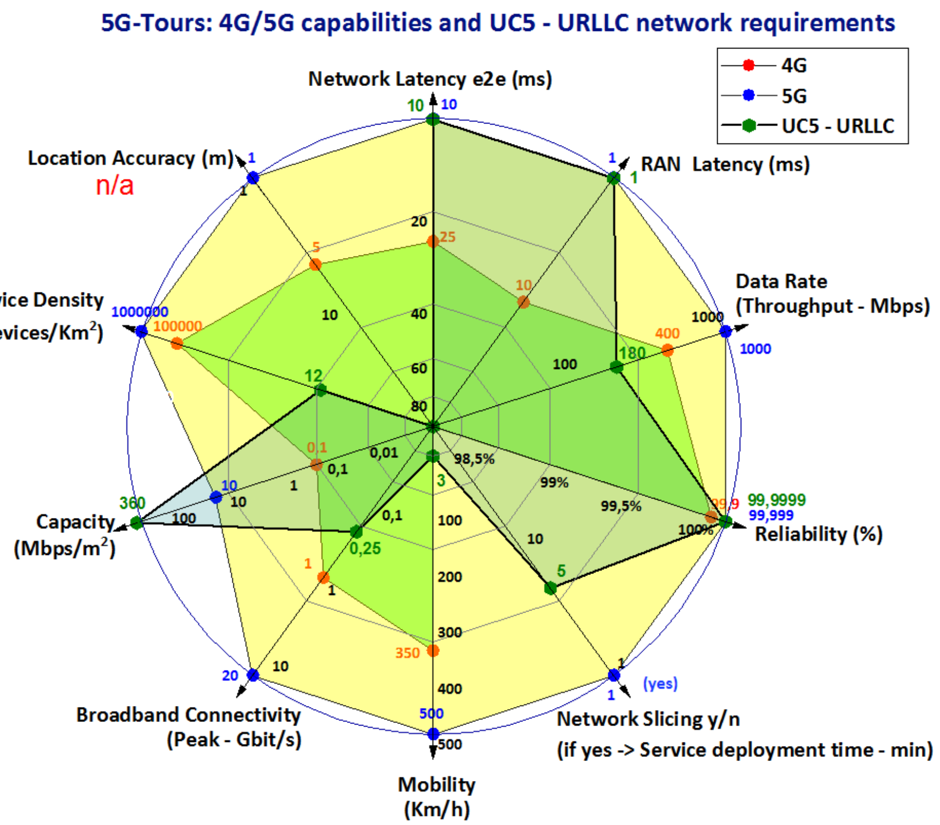


Figure 22: Radar chart for UC5 URLLC - Distributed video production network requirements

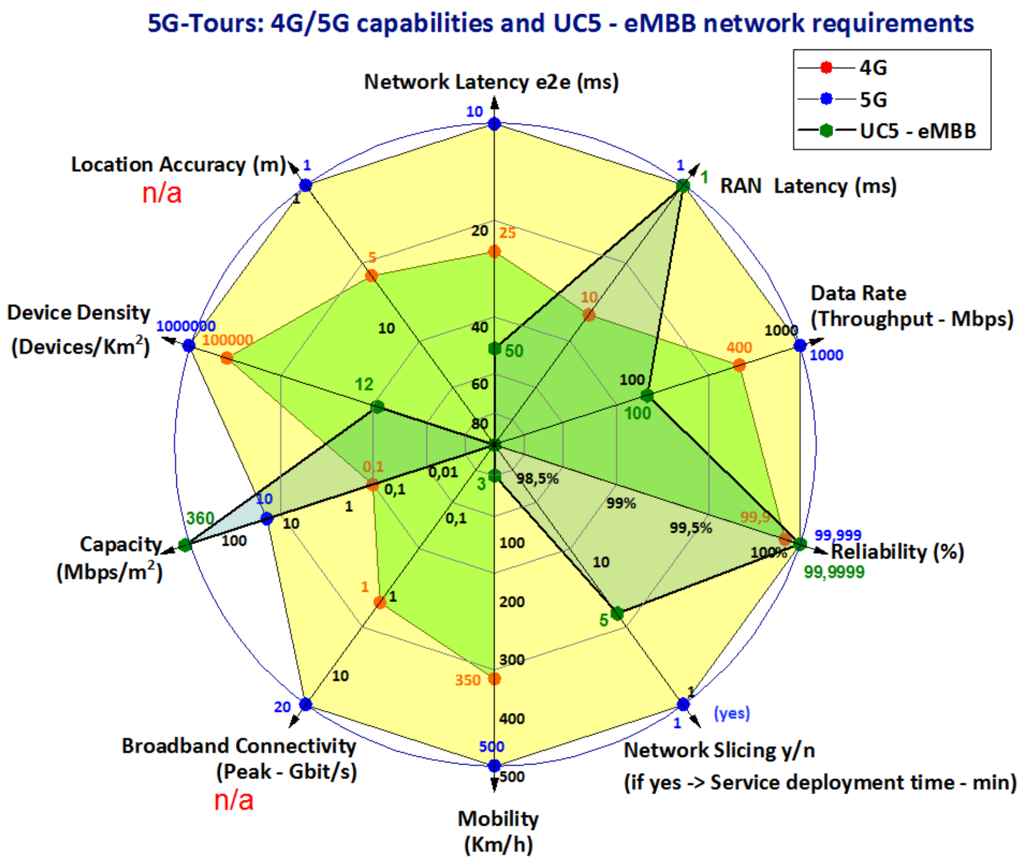


Figure 23: Radar chart for UC5 - Distributed video production network requirements

The UC needs 5G network capabilities due to the required

- RAN Latency (1 msec);
- Network Latency (15 msec);
- Reliability (99.9999%);
- Slicing and
- Capacity of 360 Mbps/m^2.

Nevertheless, even for 5G Network implementations, the Capacity Requirement appears high, and it can be satisfied as long as the number of end users in each cell are kept within predefined limits. The provisioning of such high Capacity requires careful Radio Access Network Planning and Careful Resource allocation in the Core and Transport Network.

4 The Safe City Platform

Within the constraints of the unified analysis methodology and functional entity constraints as set out in Section2 we have developed an initial view of the Safe City Platform. As a reminder, we seek to define key functional and performance requirements that uniquely define the platform, the machine and human interactions and thus by extension the potential business opportunities, aspects that are to be investigated further and refined during future WP2 activities.

4.1 The Platform

This platform shall support 4 UCs; Remote health monitoring and emergency situation notification, Teleguidance for diagnostics and intervention support, Wireless operating room and Optimal ambulance routing. By reviewing the functional connectivity of users and mandated functional entities across the supported UCs a priority list or dominant functionality and feature view emerges and is captured in a context diagram (Figure 24).

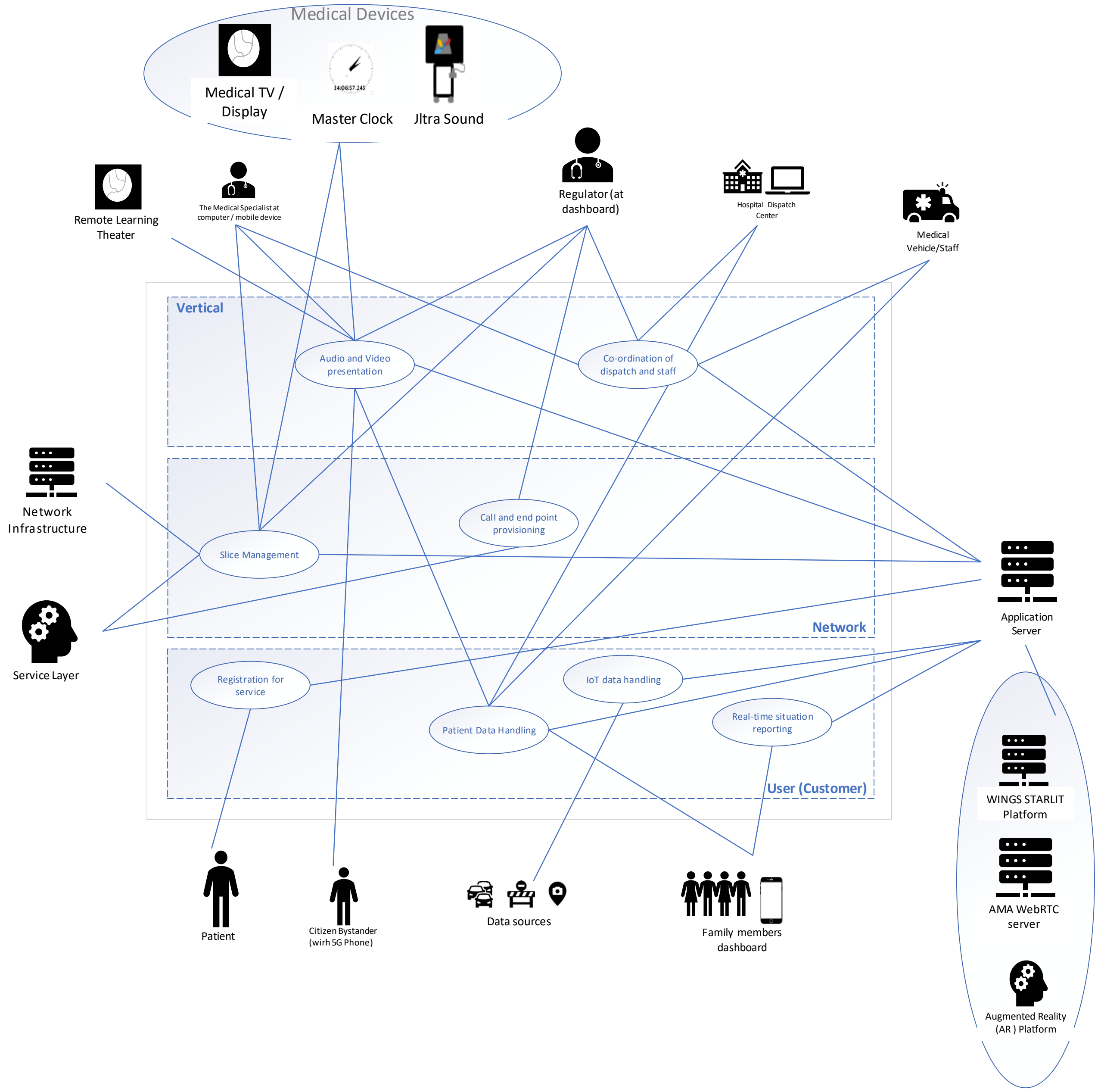


Figure 24: The Safe City Platform Context Diagram

Notable features that are emergent from this platform are:

- **The central role of a "regulator" vertical user**. Via appropriate mechanism they must be able to intervene in the operation of the 5G-TOURS enabled services and request on demand the creation of slices. This points to a dynamic slicing property of this platform.
- **Patient data handling**. Video of potential a highly traumatic nature and patient records are passing over this platform with interactions of a number of practitioners that may be remote to the medic centre and video from bystanders.
- **The 5G Citizen**. The concept of a citizen in the city that through their standard 5G device (and perhaps equipped with a special app) is able to become a critical part of the service provision by supply of video from their device to vertical users.
- **Central role of the application server**. A simple visual inspection of the connectivity of the application server into vertical and user functional needs shows that this is a critical component in the successful realisation of value in the UCs supported by this platform.

4.2 Deployment Considerations

The planned network deployment for the Rennes based safe city is depicted in Figure 25.

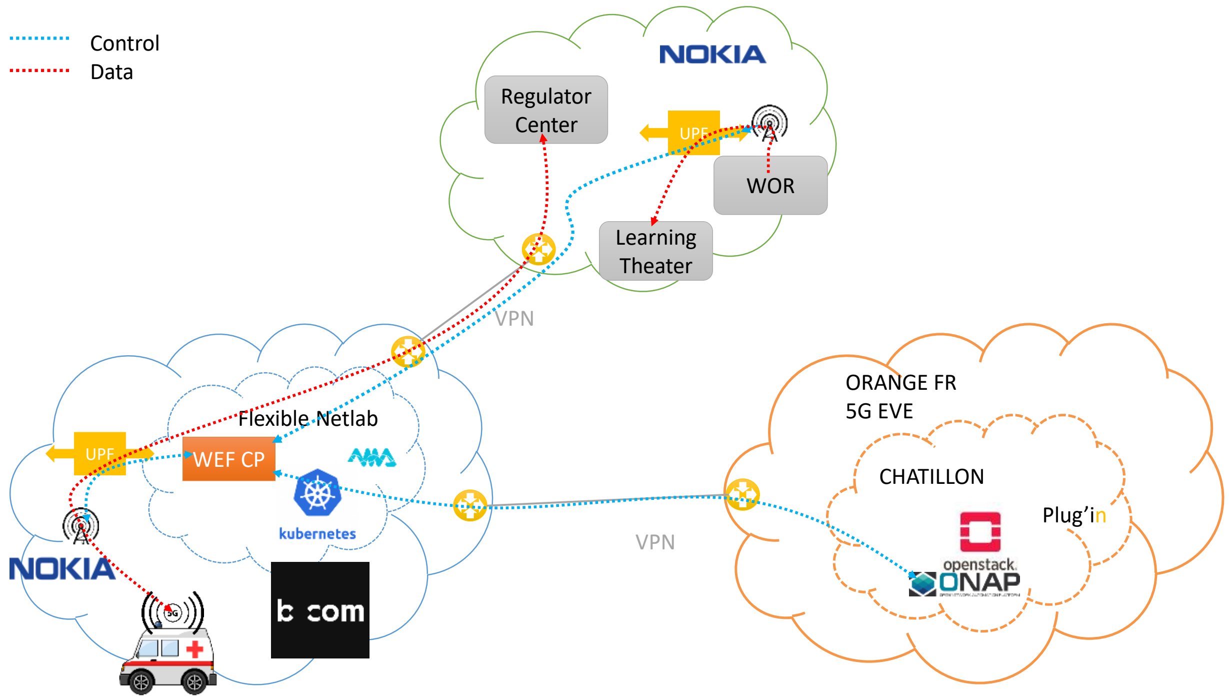


Figure 25: Overall network deployment of network equipment and functions

During the WP2 co-ordination with the UC and platform analysts it has become necessary for WP2 to be informed on rather more of the implementation details than are needed for the other platforms so that WP2 can plan further analysis activities. Complications such as hybrid network realisation based on a mixture of commercial and experimental network deployments and phasing of capabilities necessitates further explanation. 5G-TOURS respects the fact that during COVID-19 the Health sector is under extreme pressure and UC realisation in such an operational context is going to be challenging and so to accommodate this fact additional flexibility and contingency planning is built in.

The platform´s physical network is split across three main sites, two in Rennes and one in Châtillon near Paris, as the 5G-EVE node has been built within the scope of that project. As an extension of the Safe City UCs that will be trialled in Rennes, the existing commercial mobile network infra-structure of Orange will be used. This infrastructure currently supports a 4G LTE network for mobile broadband (MBB) communication, as well as a LTE-M network for machine type communication (MTC) for IoT devices used for remote patient monitoring and custom built extensions to the existing architecture at the offices of BCOM and CHU Rennes, using an experimental 5G network which is being created to be used in the URLLC UCs. This is described in more detail in the following subsections.

4.2.1 Indoor and Outdoor Coverage

The commercial 4G/LTE-M mobile networks of Orange that will be used for UC6 and UC9 has full coverage of Rennes including the main sites and corridor between. This is a temporary solution, because of the lack of a 5G mMTC experimentation network in Rennes. Once this becomes available (preferably a 3GPP Release-15 compliant 5G mMTC network), UC6 and UC9 will start using this network. There are no guarantees to date that such a network will be available within the time frame of the 5G-TOURS project although it can be expected assuming no further impact of COVID-19 on rollout.

There will also be two deployments of 5G NR wireless coverage:

- Outdoors: at the BCOM premises, for the connected ambulance, as shown in Figure 26. A suitable 5G NR antenna will be installed on the roof of the BCOM building, using primarily the 26 GHz frequency band.
- Indoors: at the Wireless Operating Room at CHU Rennes to provide high-speed, low-latency wireless access for medical imaging equipment, using licensed 26 GHz for data transmission and 2.6 GHz as the anchor frequency band (Figure 26). The anchor frequency band refers to the 4G frequency used to carry the control messages in a 5G Non-Stand Alone (NSA) network. We have currently no plans to deploy a 5G Stand Alone network in the scope of 5G-TOURS.

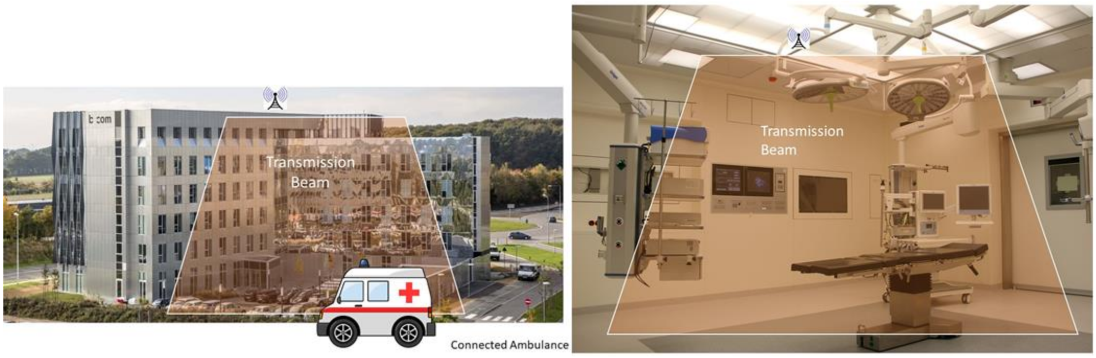


Figure 26 : 5G TOURS 5G NR NSA/SA wireless coverage at BCOM and 5G NR at CHU Wireless Operating Room

At the BCOM premises, there will be a 5G base station with a local virtual User Plane Function (UPF), part of the so-called "Wireless Edge Factory" (WEF). Similarly, there will be a WEF UPF at the hospital that connects to the WEF core network hosted in the BCOM datacentre through a dedicated VPN backbone. This will enable the setting of end-to-end network performance KPIs and the prioritization of data traffic between the ambulance and the hospital to guarantee the required quality of service. Furthermore, the WEF Core Network deployed in BCOM datacentre will manage the WEF UPF at the hospital to connect the 5G terminals of the Wireless Operating Room.

In addition, for the non-critical overall network orchestration and automatic deployment of the WEF core network, Orange provides an ONAP orchestrator in their Châtillon datacentre as part of their 5G-EVE infrastructure. ONAP enables the user or the experimenter to deploy and configure the WEF Core Network on demand. It could also be used to deploy the user plane part of the WEF.

The Orange datacentre has already been connected to the BCOM datacentre in the scope of the 5G-EVE project.

4.2.2 Phase 1

The network equipment for phase 1 (where applicable) is described below in three sections: control plane (CP), user plane (UP), and radio access network (RAN) equipment.

4.2.2.1 Control plane network equipment

The control plane is a virtual 4G Core Network compatible with the 5G NSA standard. The Control Plane is part of the WEF solution developed by BCOM. It is deployed as a set of Docker containers managed by a

Kubernetes cluster. This cluster is hosted on the Flexible Netlab platform in the BCOM datacentre. The Control Plane is deployed and orchestrated by an instance of the ONAP orchestrator hosted by Orange.

4.2.2.2 User plane network equipment

The user plane equipment provides connectivity between the RAN equipment and the data network (Internet). The main component is the User Plane Function (UPF) component of the WEF provided by BCOM. Two instances of the UPF will be deployed as part of 5G TOURS.

The first instance will be a VNF (i.e. a purely virtual UPF) deployed in BCOM datacentre as a virtual machine hosted on an OpenStack[5] cluster provided by Flexible Netlab. This virtual machine hosts an OpenVSwitch[6] (OVS) virtual switch that acts as a tunnel endpoint for the GTP tunnels coming from the RAN equipment deployed at BCOM for UC7. It is used to connect this RAN equipment to the Rennes CHU through a dedicated VPN. The WEF Control Plane manages the virtual switch under control of the OpenDaylight[7] SDN controller that is deployed in the control plane. The second instance is a PNF (i.e. an appliance built from a COTS network switch and a COTS mini-ITX PC). The PC is a KVM[8] hypervisor that hosts an OVS-based virtual machine similar to the one deployed in Flexible Netlab. It will be installed in the technical room of the Rennes CHU and will interconnect the RAN equipment deployed there with the various components required by UC8. The same WEF Control Plane will manage this switch through the VPN established between BCOM and the CHU.

4.2.2.3 RAN equipment

Phase 1 integration tests for UC8 will be done in a mock-up built in the BCOM showroom due to availability issues with 26GHz equipment in the early phases of the project as required by the French Regulator ARCEP. Therefore, initially this will be done with an Amarisoft Classic Callbox RAN equipment[9]. This equipment uses the 3.5GHz band and is also compatible with 5G NSA mode. It does limit the initial bandwidth available however it allows integration testing to begin in a timely manner while full 26GHz equipment is being sourced.

All the medical equipment that requires 5G wireless connectivity will connect to this RAN equipment through 5G CPE component. The exact model is not determined yet though due to the issues raised above, the project strives to acquire suitable equipment before phase 1 completes.

4.2.3 Phase 2

In the second phase, the plan is to switch from Amarisoft and use Nokia Small Cell technology as our RAN equipment. Two small cells will be deployed: one at the Rennes CHU to provide coverage for the Wireless Operating Room and one at BCOM premises to cover the outside area for UC7. Both will use the 26GHz/2.6GHz bands in 5G NSA mode. The Nokia RAN at BCOM will be deployed and operated by BCOM while the one at the CHU will be deployed and operated by Nokia.

Dependant on rollout as detailed above, we also hope to move UC6 and UC9 to 5G equipped sensors and move away from 4G/LTE-m equipment entirely.

[5] https://www.openstack.org/

[6] https://www.openvswitch.org/

[7] https://www.opendaylight.org/

[8] https://www.redhat.com/en/topics/virtualization/what-is-KVM

[9] https://www.amarisoft.com/products/test-measurements/amari-lte-callbox/

4.3 UCs

We now present the UCs as an outcome of the analysis team that was asked to finalise a flow of events and the interaction of key users and functions of 5G-TOURS using the unified across 5G-TOURS sequence diagram method.

4.3.1 UC6 - Remote health monitoring and emergency situation notification

This UC addresses solutions for remote health monitoring of people, especially when already diagnosed with a critical disease still compatible with home care (e.g. some form of cardiovascular disease, hypertension, diabetes, etc.). The main features offered by this UC involve: (a) remote health monitoring services, leveraging a variety of data sources, including (but not limited to) vital signs, air quality, weather conditions, site waiting times, transportation, traffic and location, and (b) quick, reliable notifications to nearby ambulances, medical professionals and family members in case of a health incident or a health emergency prediction.

The UC will leverage wearable devices and patches tracking a tourist's vital signs and having them aggregated inside an IoT based platform named STARLIT (Smart living platform powered by Artificial intelligence & robust IoT connectivity), where they will be processed in a combined fashion exploiting also various sources through open APIs (e.g. Open Data Platforms, Google Maps, Dark Sky API). STARLIT's outcome will be the identification or the prediction of a health-related emergency which will be followed by the immediate notification of the nearest emergency care dispatch centre.

The current coronavirus (COVID-19) pandemic has increased the incentives for efficient remote health monitoring. The pandemic has on one hand led to a reduction of on-site referrals for routine care due to the risk of contamination in clinical settings; on the other hand it has caused an increase in the need to continuously monitor the status of non-critically ill COVID-19 patients (quarantined at home or at dedicated venues such as hotels) (Behar, et al., 2020). Remote health monitoring requires foremostly clinician acceptance which depends, among others, on the service being perceived as efficient (Wade & Eliott, 2014) , (Smith & Thomas, 2020) . While this depends on various factors, at least from a technological perspective 5G offering high-speed, ultra-reliable low-latency communication is instrumental for efficiency of remote health monitoring (Kim, et al., 2020) , allowing it more than ever to become reality (Reichert, 2020) . In this current context the trial and validation activities planned in the scope of this use case within 5G-TOURS become more important than ever.

4.3.1.1 UC Sequence diagram

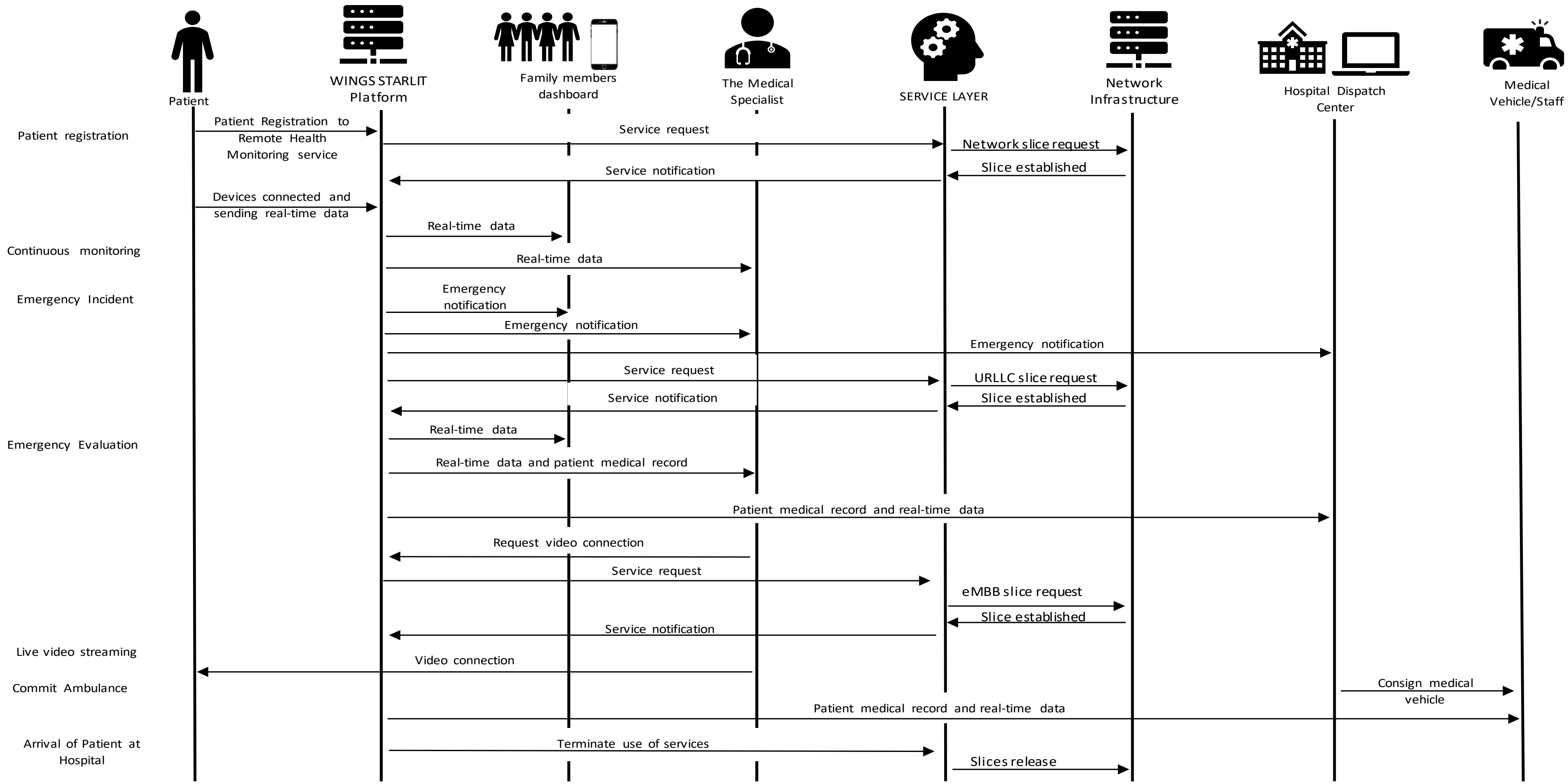


Figure 27: UC6 Remote health Monitoring Sequence Diagram

Key features of UC6:

1. A patient registers to the Remote Health Monitoring service of the WINGS STARLIT platform.
2. The WINGS STARLIT platform requests a minimum resource slice from the Service layer.
3. The slice is established on the 5G-TOURS infrastructure.
4. The wearable devices used for the monitoring of vital signs are connected and start sending real-time data to the STARLIT platform. These data are shared via suitable mobile apps and/or dashboards with family member and authorized medical specialists.
5. In case an emergency is identified by the STARLIT platform (e.g. due to one or more of the monitored vital signs or parameters exceeding a predefined threshold or indicating a problem), the WINGS STARLIT platform issues an emergency notification to the family members, the medical specialist and the Hospital Dispatch Centre.
6. Following the emergency identification, a URLLC slice is requested to the Service layer.
7. The URLLC slice is established on the 5G-TOURS infrastructure.
8. The patient data and medical record are sent to the medical specialist and the Hospital Dispatch Centre.
9. The medical specialist requests a video connection via the WINGS STARLIT platform.
10. The WINGS STARLIT platform requests an eMBB slice to the Service layer.
11. The eMBB slice is established on the 5G-TOURS infrastructure and is used for live video streaming and observation of the patient until an ambulance arrives.
12. The Hospital Dispatch Centre consigns an ambulance and the patient medical record and real-time data are sent to the ambulance as well via the WINGS STARLIT platform. Once the Ambulance has delivered the patient to the emergency department, the use of the network slices is terminated.

4.3.1.2 User and Network requirement analysis

For the implementation of this UC the following requirements from the user perspective are needed (Table 13).

Table 13: User requirements for UC6 – Remote health monitoring and emergency situation notification

	5G-Tours Use case name: UC6 - Remote health monitoring and emergency situation notification			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**No**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**Medium**
	5	***Data Transmission (UL) :***	High/Medium/Low	**Medium**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Walking Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**Medium**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very Fast**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**High**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sustained Medium**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Low Density Medium**
Structural User Requirements	13	***Edge Computing :***	Yes/No	**Yes**
	14	***Edge Storage :***	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Low**
	16	***other***	User specified	

The mapping or the above user requirements into network requirements is illustrated into the following Table 14, where the general/Specific vertical UC requirements for UC6 are shown. Reviews of user and derived network requirements show an anticipated performance of the system to support this UC which is higher than necessary. In particular the latency requirements are likely over specified for the types of data (vital signs and video) that are being carried over the network. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 28.

Table 14: UC6 – Remote health monitoring and emergency situation notification network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC6 –Remote health monitoring and emergency situation notification			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10	10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	1	1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps				High	10	50
4	Reliability (%) - Min/Max	%	99,9999%	99,9999%		High		
5	Availability (%) - Min/Max	%	99,99%	99,99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h				High	5Km/h	100 Km/h
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y		High	N/A	N/A
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N		Y		Medium	N/A	N/A
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium	N/A	N/A
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2					N/A	N/A
11	Device Density	Dev/Km^2					N/A	N/A
12	Location Accuracy	m		0,1		High		1m
Specific Vertical/Use Case Requirements								
Network	Number of End Points			2				
	Number (Range) of End Devices per End Point			5				
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)			82				
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**			Sensor/Wearable				
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)			30				
	IPv4 & IPv6 support (or both)			both				
	Connnection of Device to End Point (Wired/Wireless)			Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)			NB-IoT				
	Authenication method (i.e. SIM, eSIM, Key..)			SIM				
ic (non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City			Rennes				

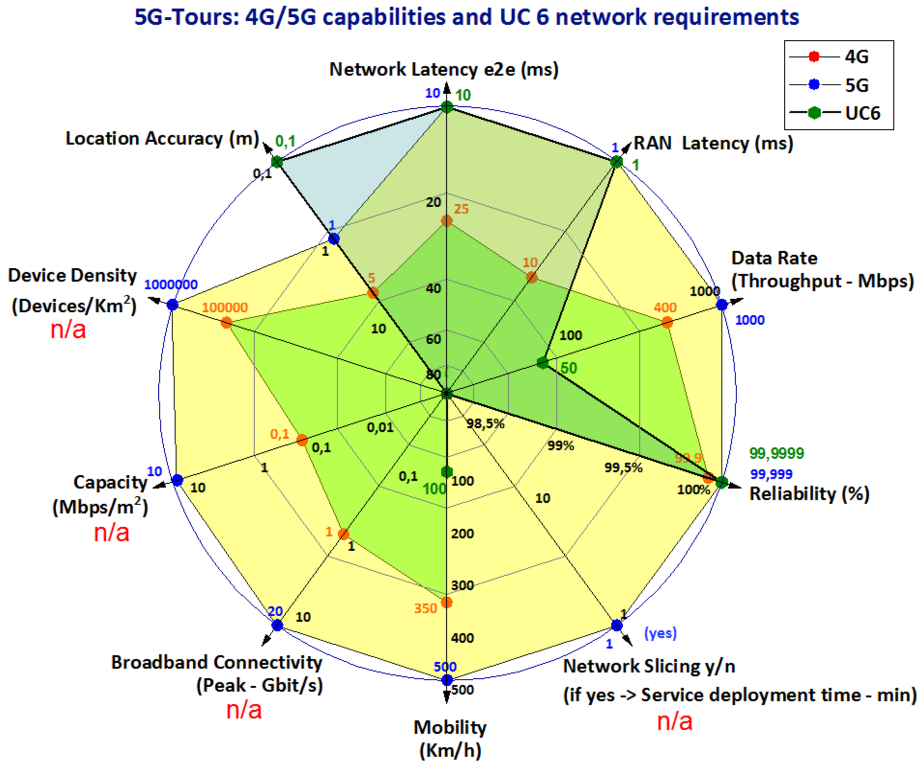


Figure 28: Radar chart for UC6 - Remote health monitoring and emergency situation notification network requirements

As already indicated the user and derived network requirements are to be verified as part of the evaluation of the performance of the UCs. Reliability and Location Accuracy are likely over specified and can be relaxed whilst maintaining an adequate quality of experience for the vertical and end user. However, at this time the requirements place the following three items as key system features to support the UC.

- Reliability of 6 nines (99,9999%),
- Low RAN and Networks Latencies and
- Ultra-high Location Accuracy,

are the primary requirements of the Remote Health monitoring UC that indicate the need of a highly Reliable 5G Network.

Furthermore, the ultra-high location accuracy requirement of 10 cm dictates the use of multi-modal positioning systems. Either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and, simultaneously, other modalities like GPS (for outdoors and location beacons or use of 26 GHz for indoor) should be utilized for accurate positioning of the end user/patient. Therefore, a multi-modal positioning algorithm could well be required to improve of the accuracy that the 5G network will provide. This aspect of the network is not going to be researched in the scope of 5G-TOURS as it is not deemed to be necessary once user requirements and verified to be eased.

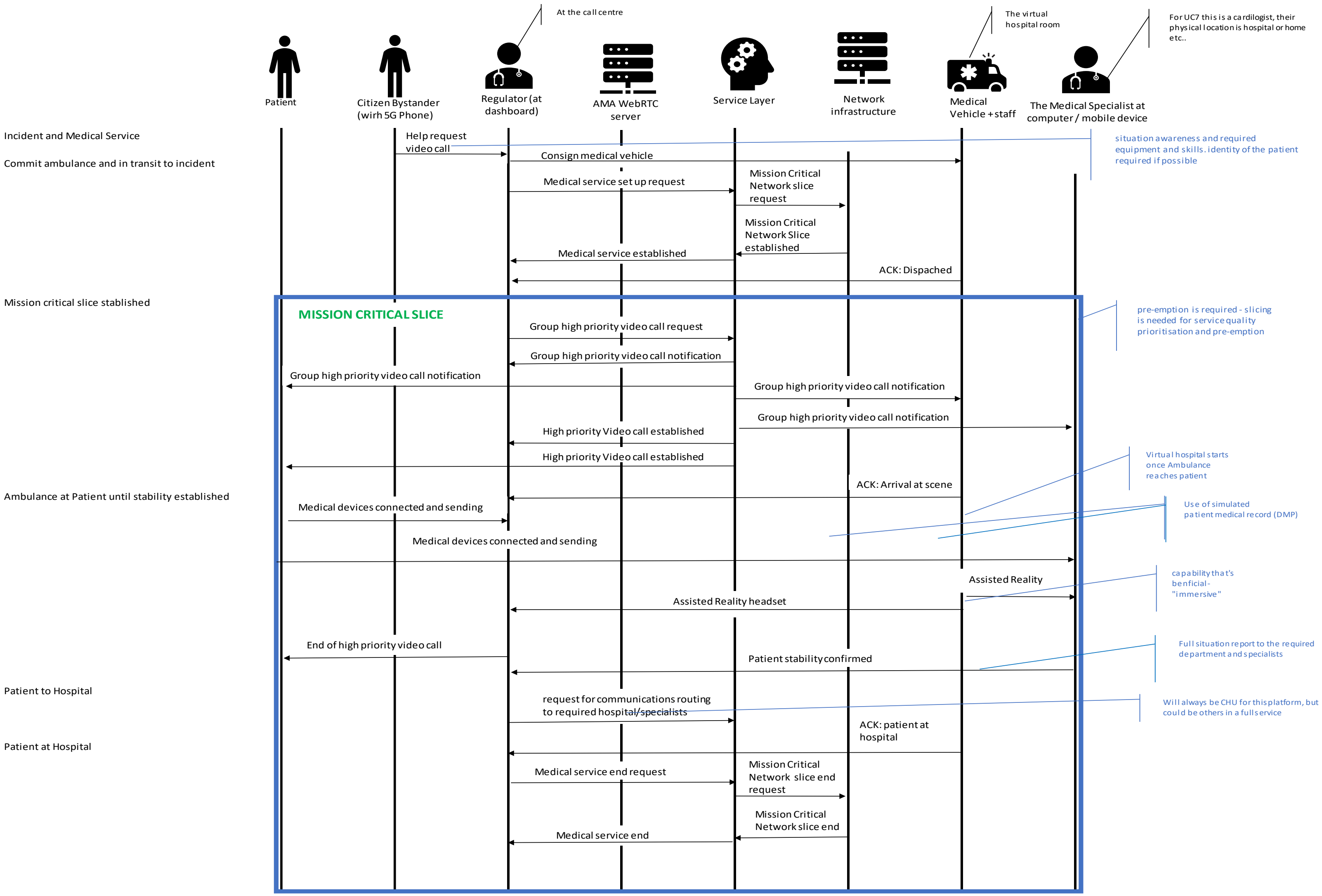
4.3.2 UC7 - Teleguidance for diagnostics and intervention support

The goal of the UC is to improve emergency care and, in particular, the communication between care givers in the ambulance / near the patient, the medical regulator, remote experts and emergency department staff to save the life of more patients , improve the outcome for patients on the short and longer term as well as their wellbeing, reduce the workload and stress for all care providers and improve their effectiveness, and, last but not least, reduce the overall cost of care on the short and longer term so that patients can participate fully in society again after a quick recovery.

To save lives and improve outcomes for patient, it is essential to realize fast and precise diagnosis of life-threatening conditions in order to be able to give patients the necessary lifesaving treatment as quickly as possible to reduce irreversible health damage as much as possible. Ultrasound is a highly versatile diagnostic tool in these cases, enabling rapid and quantitative examination of a variety of organs. Major drawback is that correct placement of an ultrasound probe is difficult, for the acquisition of images of diagnostic quality and for the interpretation of these images. Ultrasound has therefore limited usefulness without an expert doing the probe handling and the image interpretation. It is expected however that 5G technology will provide the key differentiating network KPIs for tele-sonography solutions that enable remote collaboration scenarios between care providers, where an expert guides a remote doctor or paramedic in performing an ultrasound exam or an ultrasound guided intervention.

The opportunity for 5G-TOURS approaches in UC7 like scenarios to assist in efficiency of Health service Operations in response to COVID-19 are apparent. As with any new to medical science illness the sector is going through a rapid process of learning regarding assessment of the appropriate primary care response to severely affected patients in home, or other locations, and what early treatment may be needed whilst transported to a medical centre. Medical experts having the opportunity for early intervention may be timely for patients in terms of their long-term recovery chances. These aspects shall be further researched with sector experts during the latter stages of the project.

4.3.2.1 UC Sequence diagram



DMP: Patient's personal file accessible to healthcare professionals according to the rights given by the patient. SAMU doctor can access directly to the DMP from a dashboard by identifying the patient.

Figure 29: UC7 Teleguidance for diagnostics Sequence Diagram

Key UC steps:

1. An incident occurs.
2. A bystander citizen call the emergency services.
3. A critical service, with traffic prioritization is then stablished.
4. The citizen is able to share a real-time video recorded with their own mobile phone with the regulator, who is able to more easily evaluate the situation.
5. An ambulance is consigned, and a virtual hospital starts once it reaches the patient.
6. Medical devices are connected to the patient and sending information.
7. A Medical Specialist at the hospital is able to support and advise the ambulance staff until the patient stability is achieved.
8. Then the patient is taken to the hospital, where the medical staff and devices are prepared for his/her arrival.

4.3.2.2 User and Network requirement analysis

For the implementation of this UC the following requirements, from the user perspective are needed (Table 15).

Table 15: User requirements for UC7 – Teleguidance for diagnostics and intervention support

	5G-Tours Use case name: UC7 - Teleguidance for diagnostics and intervention support			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception & Transmission:**	Yes 3 streams from ambulance to hospital 2 streams from hospital to ambulance	3 x 45 Mbps 2 x 45 Mbps
	2	**Video Transmission:**	Reception and transmission are reversed between ambulance and hospital	
	3	**Voice Communication:**	Yes	2 x 100kbps
	4	**Data Reception (DL):**	High: for AR type applications Medium for EMR transmission Low for live patient vitals duch as ECG	2 x 23 Mbps
	5	Data Transmission (UL):	Reception and transmission are reversed between ambulance and hospital	
Functional User Requirements	6	**Mobility:**	Medium Speed: driving ambulance Stationary: Ambulance at the point of incident	120 km/h
	7	**Location Information:**	Low Accuracy	50 m
	8	**Fast Response (Low Latency):**	Fast: for AR Medium: for hand-eye coordination when moving ultrasound probe	10 ms
	9	**Reliability/Availability:**	High	99.99999
	10	**Security / Privacy:**	Ultra-High grade	medical grade
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High data rate; video, AR Bursty Low: patient vitals, probe commands Sporadic High: EMR transmission	
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	
Structural User Requirements	13	***Edge Computing*:**	Yes/No: Edge could be relevant if located in the ambulance	
	14	***Edge Storage*:**	Yes/No: Edge could be relevant if located in the ambulance	
Service Specific (Examples)	15	***Battery Life:***	Low	
	16	***other***	User specified	

We note that again for this use case the user may be over specifying a requirement, in this case the bandwidth. It is believed that this may be due to a limited understanding of the performance of advanced encoders which significantly reduce network bandwidth requirements. The potential to relax this requirement shall be verified during the latter stages of the project.

The mapping of the above user requirements into network requirements are illustrated into the following Table 16, where the general/Specific vertical UC requirements for the UC7 are shown. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 30.

Table 16: UC7 – Teleguidance for diagnostics and intervention support network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC7 – Teleguidance for diagnostics and intervention support			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10				10	25
2	**RAN** Latency (in milliseconds) - one way	msec	2					
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	1000				150	1000
4	Reliability (%) - Min/Max	%	99,999%				99,00%	99,999%
5	Availability (%) - Min/Max	%	99,999%				99,00%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	120				0	120
7	Broadband Connectivity (peak demand)	Y/N or Gbps	1,5				1000	1500 Mbps
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y(1)				1	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y				Y	Y
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	6				150	6000
11	Device Density	Dev/Km^2	30				5	30
12	Location Accuracy	m	1				1	25
Specific Vertical/Use Case Requirements								
Network	Number of End Points		4					
	Number (Range) of End Devices per End Point		N/A					
	Density of End Devices (per sq. meter)		4					
	Bitrate needs per end point (Kbps,Mbps, Gbps)		40 Mbps					
	End -to-end Latency (msecs)		50					
	Highest Acceptable jitter (msec)		25					
	Number of Class of Service / QoS (1-8, more)		Max					
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Smartphone, CPE, Tablet					
	Bitrate required (Kbps / Mbps / Gbps)		40 Mbps					
	Max Latency Allowable (in msecs)		50					
	Max Moving Speed (km/h, 0 if stationary)		140					
	IPv4 & IPv6 support (or both)		Both					
	Connnection of Device to End Point (Wired/Wireless)		Wireless					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		5G					
	Authenication method (i.e. SIM, eSIM, Key..)		(e) SIM					
fic (non-Network related Requirements)								
	i.e Battery life requirement		1 hour					

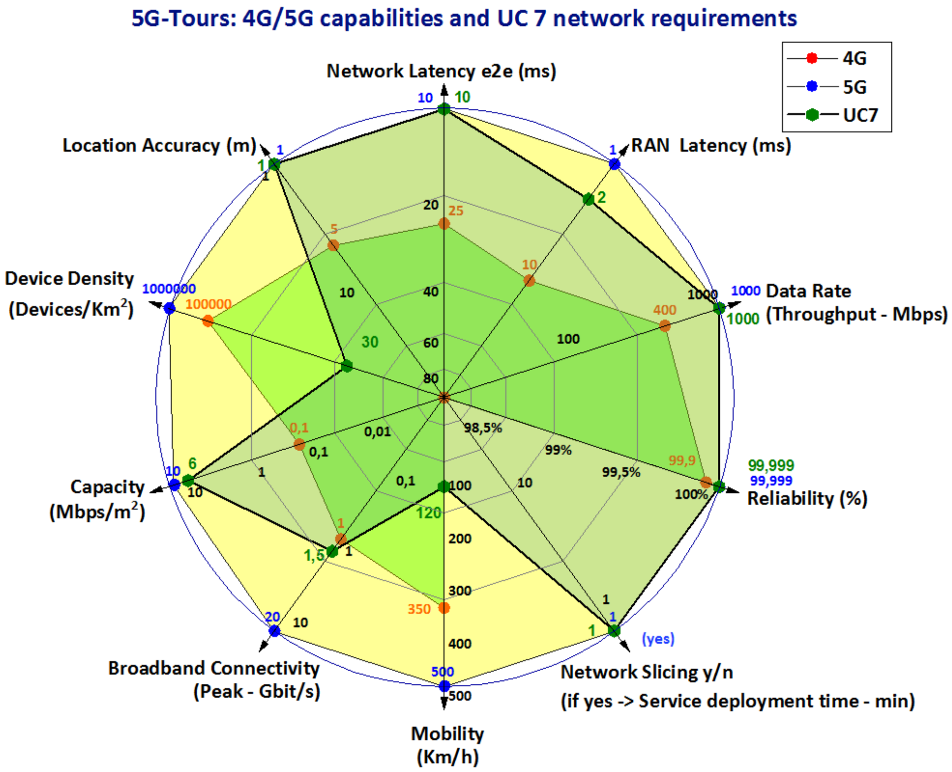


Figure 30: Radar chart for UC7 - Teleguidance for diagnostics and intervention support network requirements

From the 10 primary requirements of the Teleguidance UC, only the Device Density and the Mobility can be satisfied with 4G. All the rest (80%) namely:

- Broadband Connectivity;
- Capacity;
- Location Accuracy;
- Network Latency;
- RAN Latency;
- Reliability;
- Date Rate and
- Network Slicing

indicate that a 5G Network is needed to successfully implement the UC.

4.3.3 UC8 - Wireless operating room

This UC considers a situation where a patient has to go under a cardiac intervention procedure based on live, simultaneous X-Ray and ultrasound imaging. The interventional procedure starts with a 3D Angiography X-Ray acquisition enabling the doctors to obtain the 3D volume of the heart auriculum. Then, a radiofrequency ablation is performed, guided by fluoroscopy, complemented by doppler ultrasound to estimate the blood flow, and superimposed on the fluoroscopy image, using advanced segmentation and matching algorithms with an AR application that generates a guidance image displayed on a wireless tablet. The use of complementary imaging sources is justified to limit the use of X-Ray and contrast product at the minimum.

The tourist patient has been previously operated in his country, Italy, by a cardiologist who is so able to interact with his Rennes colleague to improve the quality of the procedure, via a teleconference performed using smart glasses. Finally, a HD camera captures the cardiologist's hands to help the scrub nurses to prepare the instruments and to enable students to follow the operation in the amphitheatre close to the TherA-Image room. All these video or live medical imaging are transferred as wireless video over IP, thanks to the recent DICOMRTV standard enabling synchronized real-time communication of video and associated metadata

4.3.3.1 UC Sequence diagram

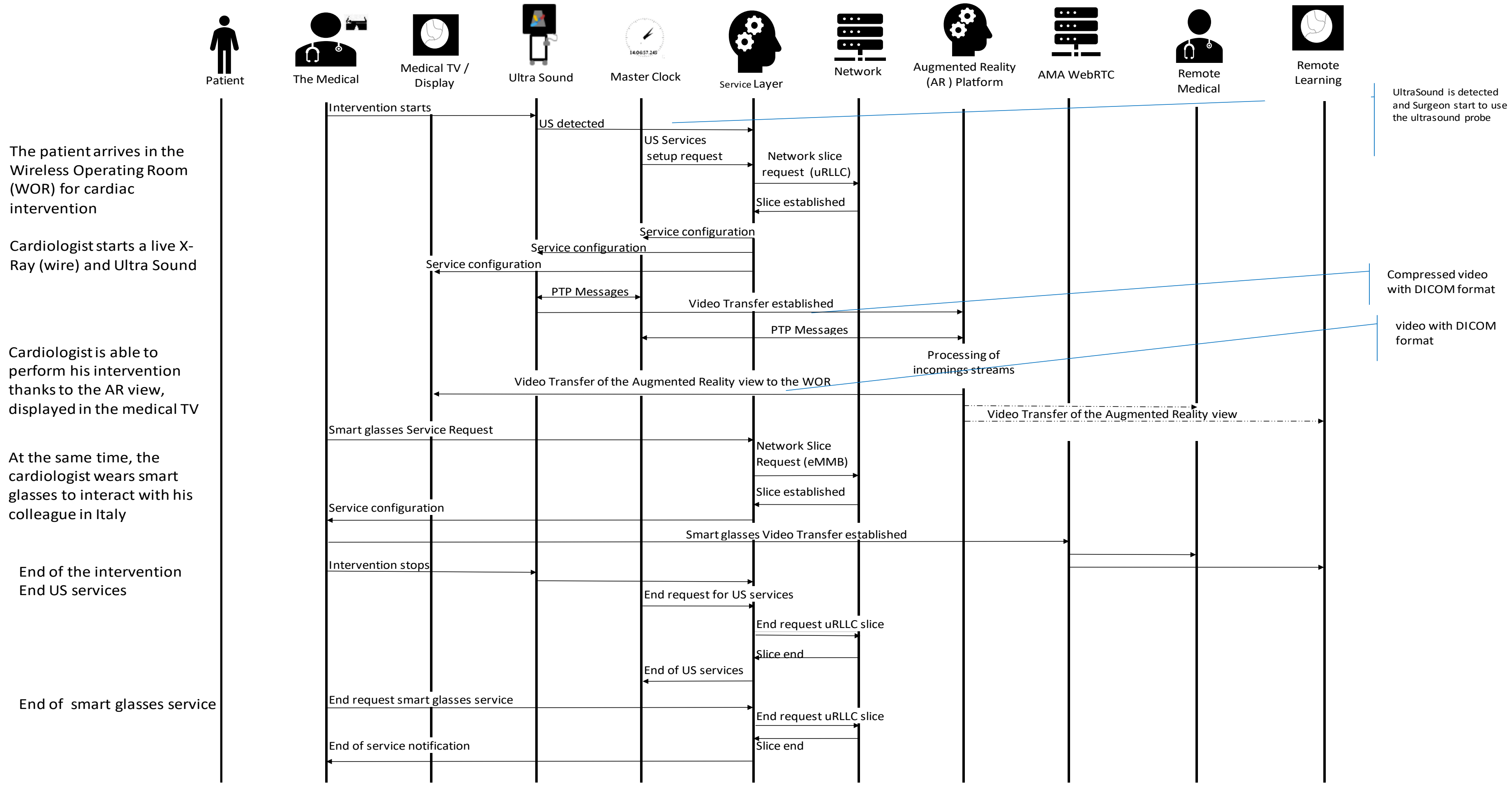


Figure 31: UC8 Wireless Operating Room Sequence Diagram

The major features of the sequence diagram:

1. Patient arrives in the WOR from the connected ambulance (trigger either be UC7 or UC9).
2. Medical Specialist (surgeon) is going to use the ultrasound probe and X-RAY device to carry out medical pictures.
3. uRLLC Slice is requested to the 5G-TOURS infrastructure through the Service Layer by the UltraSound and by the Master Clock to ensure synchronisation between all data flows (US, X-RAY with DICOM-RTV standard).
4. US stream is then transmitted to the AR platform through the 5G network, while the X-RAY stream is sent by wire to the same AR platform.
5. AR processes both the US and X-RAY streams and AR view is sent to the Display through 5G network.
6. Same AR view is transferred to remote doctors (through VPN) and remote learning theatre (by wire). Note that transfer of real time display to remote doctor could be limited due to VPN limitations.
7. Doctors (surgeon and remote doctor) can analyse the medical pictures.
8. After diagnosis, surgeon starts the chirurgical operation; he carries smart glasses.
9. Smart glasses are connected through the 5G network to AMA XpertEyes application, which transfer smart glasses video to the remote doctors and learning theatre.
10. Doctors end the operation and all slices and connections are released.

4.3.3.2 User and Network requirement analysis

For the implementation of this UC the following requirements from the user perspective are needed (Table 17).

Table 17: User requirements for UC8 – Wireless operating room

	5G-Tours Use case name: UC8 - Wireless Operating Rooms			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes	Ceiling Camera showing physician's hands: HD 8bits at 60fps: 150 Mbps (compressed)
	2	**Video Transmission:**	Yes	Smart glasses video to remote physician: 1280x720 3colors 8bits at 30 fps: 30 Mbps (compressed)
	3	**Voice Communication:**	Yes	WebRTC voice communication with remote physician: 128 kbps
	4	**Data Reception (DL):**	None	
	5	***Data Transmission (UL) :***	None	
Functional User Requirements	6	**Mobility:**	Stationary	
	7	**Location Information:**	None	
	8	**Fast Response (Low Latency):**	Slow	No specific constraint here. Latency on AR glasses flows shall allow for a smooth interaction between the surgeon and the remote physician: 100ms one-way latency
	9	**Reliability:**	high / medium / low	MTBF: > 1 Month
	9	**Availability:**	high / medium / low	99,99%
	10	**Security / Privacy:**	High	Integrity protection and Ciphering shall be supported
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	Continuous traffic, see bitrate values above
	12	**Interactivity & Space Dependency:**	Medium Density Low	Few devices packed in an operating of ~100m2 Interaction between surgeon and remote physician
Structural User Requirements	13	***Edge Computing :***	No	
	14	***Edge Storage :***	No	
Service Specific (Examples)	15	***Battery Life:***	Low	AR Glasses are connected to a battery powered 5G smartphone
	16	***other***	User specified	

The mapping or the above user requirements into network requirements are illustrated into the following Table 18 where the general/Specific vertical UC requirements for the UC8 are shown. The user requirement shows an anticipated performance of the video transmission and reception can be lowered by usage of advanced HEVC technology. The possibility to relax these user requirements will be verified in the latter stages of the project. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 32.

Table 18: UC8– Wireless operating room network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC8 – Wireless Operating Room			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	20				10	30
2	**RAN** Latency (in milliseconds) - one way	msec	5				2	7
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	800				600	7000
4	Reliability (%) - Min/Max	%	99,99999%					
5	Availability (%) - Min/Max	%	99,99999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	0					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,8					
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	N					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	N/A					
11	Device Density	Dev/Km^2	N/A					
12	Location Accuracy	m	N/A					
Specific Vertical/Use Case Requirements			1					
Network	Number of End Points		4				3	6
	Number (Range) of End Devices per End Point		N/A					
	Density of End Devices (per sq. meter)		10					
	Bitrate needs per end point (Kbps,Mbps, Gbps)		800 Mps				600 Mps	7 Gbps
	End -to-end Latency (msecs)		critical for PTP synchronization					
	Highest Acceptable jitter (msec)		3				2	4
	Number of Class of Service / QoS (1-8, more)		US probe, X-Ray eqt, Smart glass, Pro TV					
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		800 Mbps				20 Mbps	3 Gbps
	Bitrate required (Kbps / Mbps / Gbps)		5 ms					
	Max Latency Allowable (in msecs)		N/A					
	Max Moving Speed (km/h, 0 if stationary)		IPv4				IPv4	both
	IPv4 & IPv6 support (or both)		Wireless+Wired					
	Connection of Device to End Point (Wired/Wireless)		WLAN+Ethernet					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		N/A (LAN)					
	Authenication method (i.e. SIM, eSIM, Key..)							
fic (non-Network related Requirements)			Only for smart glasses					
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS			Rennes					
	City		CHU de Rennes					

The desirable reliability requirements coming from the vertical and end user perspective indicate an extremely high expectation that challenges the bounds of feasibility and certainly cost. This requirement shall be investigated during the latter stages of the project to determine the possibility of relaxation.

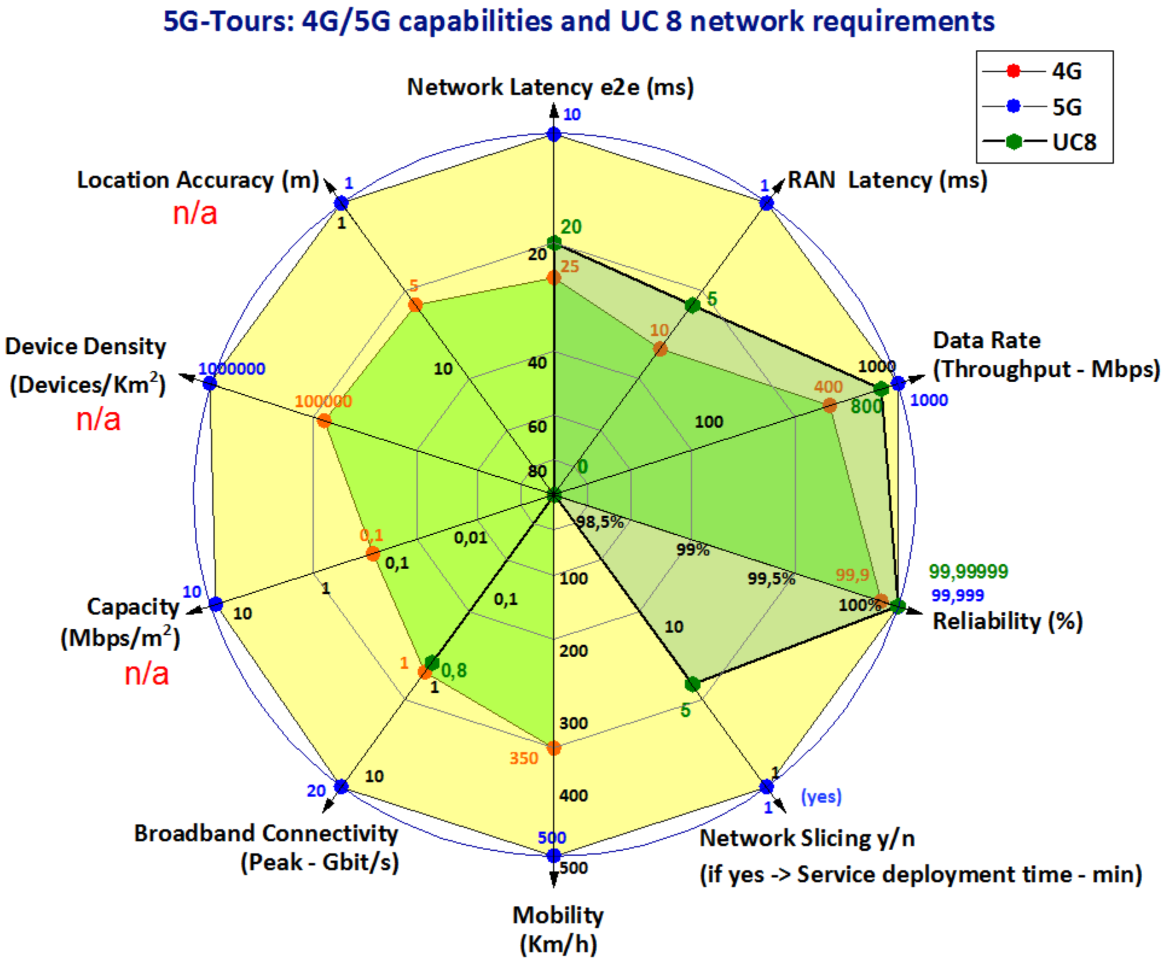


Figure 32: Radar chart for UC8 – Wireless operating room network requirements

The Wireless Operating Room UC focuses primarily on the Ultra High Reliability of 7 nines (99.99999%). This together with the

- Network Latency;
- RAN Latency;
- Data Rate

Along with demand for one or more dedicated Network Slices, clearly indicate the need for a 5G-Network infrastructure.

4.3.4 UC9 - Optimal ambulance routing

As the next step following the health monitoring UC6, this UC shows how city sources can be exploited towards real-time vehicle navigation taking into consideration the live status of the city, especially a touristic one with lots of cultural events being organized. This UC addresses real time navigation of the ambulance, both to the site of the emergency, to ensure that medical help will be provided as quickly as possible, as well as from the site of emergency to the hospital, as soon as possible once the patient has been stabilized on the emergency location.

4.3.4.1 UC Sequence diagram

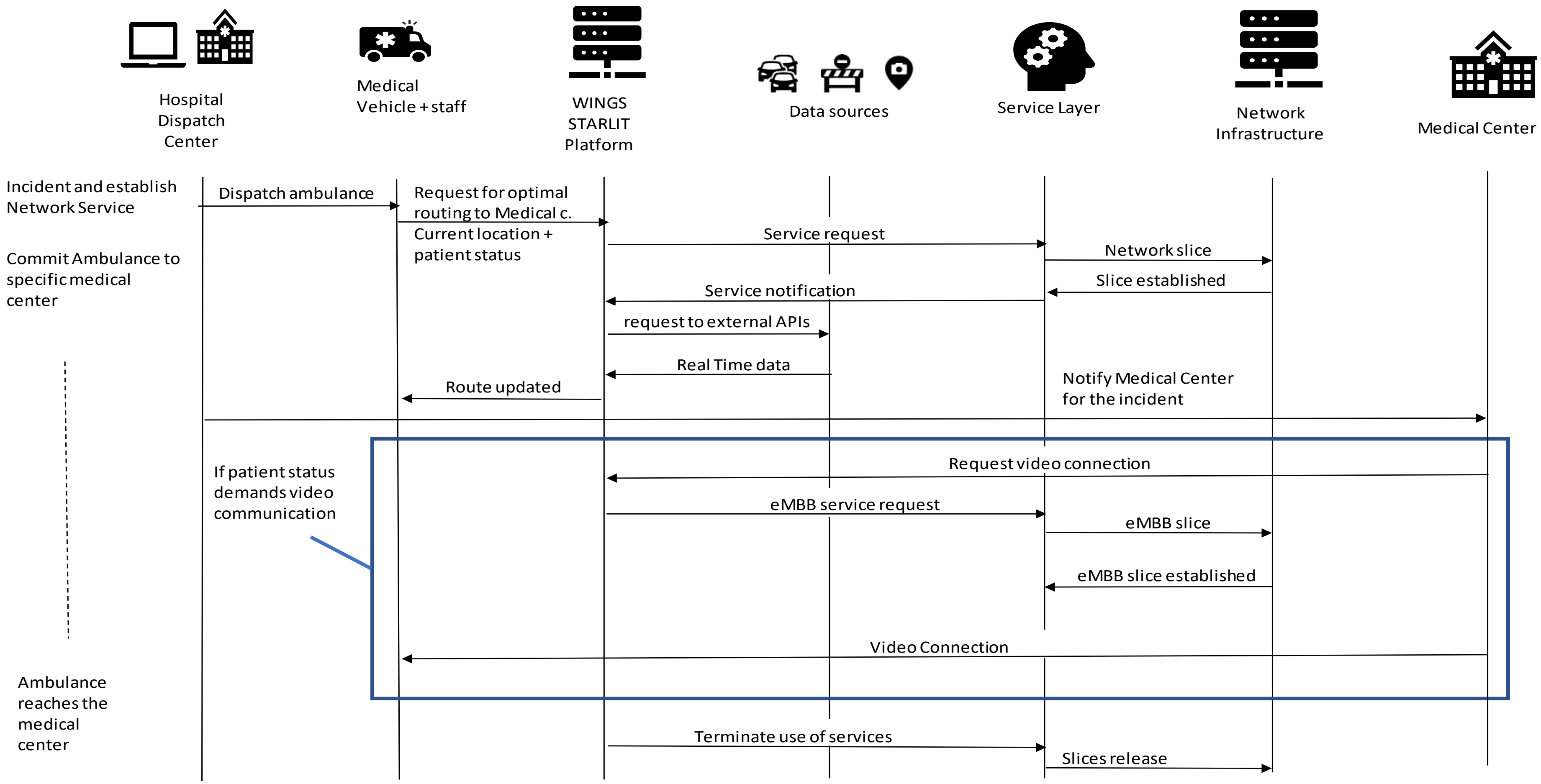


Figure 33: UC9 Optimal Ambulance Routing Sequence Diagram

Key steps of the sequence:

1. An incident occurs (e.g. accident, patient with stroke) and an Ambulance is dispatched.
2. Ambulance personnel requests for optimal routing to the patient location and from the patient location to the Medical Centre. The current location of the patient and the ambulance as well as the patient status are sent to the WINGS STARLIT platform.
3. The WINGS STARLIT platform requests a network slice from the Service layer.
4. The slice is established on the 5G-TOURS infrastructure.
5. The WINGS STARLIT platform obtains data on traffic and potential route issues (e.g. road closures) from external APIs.
6. Based on the retrieved data the WINGS STARLIT platform continuously calculates and updates the optimal route for the ambulance.
7. The medical centre is notified of the incident and receives updates on the estimated time of arrival of the Ambulance.

4. If the medical status of the patient merits intervention of a the medical specialist a video connection via the WINGS STARLIT platform shall be established, and the following sequence shall be followed. The triggering event is from the skilled practitioners in the medical centre which is in contrast to earlier UCs on this platform.
5. The WINGS STARLIT platform requests an eMBB slice from the Service layer.
6. The eMBB slice is established on the 5G-TOURS infrastructure and is used for live video streaming and observation of the patient until the ambulance arrives at the medical centre.
7. Once the Ambulance has delivered the patient to the emergency department, the use of the network slices is terminated.

4.3.4.2 User and Network requirement analysis

For the implementation of this UC the following requirements from the user perspective are needed (see Table 19):

Table 19: User requirements for UC9 – Optimal ambulance routing

	5G-Tours Use case name: UC9 - Optimal ambulance routing			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**No**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**Medium**
	5	***Data Transmission (UL)* :**	High/Medium/Low	**Medium**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Medium**
	7	**Location Information:**	High / Medium / Low Accuracy	**Medium**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very Fast**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Medium**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sustained Medium**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Low Density Medium**
Structural User Requirements	13	***Edge Computing* :**	Yes/No	**Yes**
	14	***Edge Storage* :**	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Low**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated into the following Table 20, where the general/Specific vertical UC requirements for the UC9 are shown. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 34.

Table 20: UC8– Optimal ambulance rooting room network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC9 – Optimal Ambulance Routing			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99,9999%		High		
5	Availability (%) - Min/Max	%		99,99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		>=100Km/h		High		
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y (1)		High		
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N		Y (1)				
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		n/a				
11	Device Density	Dev/Km^2		n/a				
12	Location Accuracy	m		0,1		High		
Specific Vertical/Use Case Requirements								
Network	Number of End Points			2				
	Number (Range) of End Devices per End Point			2				
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)			3				
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**			Smartphone/Tablet				
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)			100				
	IPv4 & IPv6 support (or both)			both				
	Connnection of Device to End Point (Wired/Wireless)			Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)			NB-IoT				
	Authenication method (i.e. SIM, eSIM, Key..)			SIM				
ic (non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City			Rennes				

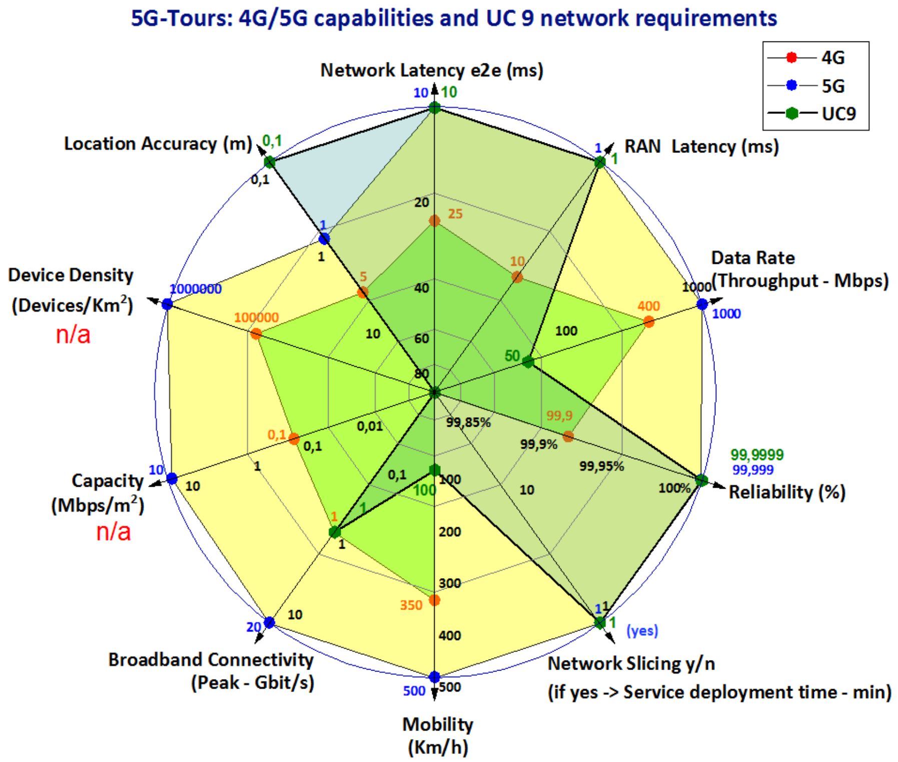


Figure 34: Chart for UC9 – Optimal ambulance rooting network requirements

50% of the Requirements for the Optimal-Ambulance Routing UC can be fulfilled by currently available 4G Network but the other 50% namely:

- Location Accuracy;
- Network Latency;
- RAN Latency;
- Reliability and
- Dedicated Network Slice

indicates the need for 5G technology.

Additionally, the ultra-high location accuracy requirement of 10 cm dictates the use of multi-modal positioning systems. Such high accuracy should be justified since an ambulance with size of a few meters should be routed optimally. Nevertheless, if this is the case and sub-meter accuracy is needed, either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and, simultaneously, other modalities like GPS/GNSS (for outdoors and positioning beacons or use of 26 GHz for indoor) should be exploited for accurate positioning of the “target”. In conclusion, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

5 The Mobility Efficient City Platform

Within the constraints of the analysis methodology and functional entities constraints as set out in Section2 we have developed an initial view of the Mobility Efficient City Platform. As a reminder, we seek to define key functional and performance requirements that uniquely define the platform, the machine and human interactions and thus by extension the potential business opportunities, aspects that are to be investigated further and refined during future WP2 activities.

5.1 The Platform

This platform shall support 4 UCs; Smart airport parking management, Video-enhanced ground-based moving vehicles, Emergency airport evacuation and Excursion on an AR/VR-enhanced bus. By reviewing the functional connectivity of users and mandated functional entities across the supported UCs a dominant functionality and feature view emerges and is captured in a context diagram (Figure 35).

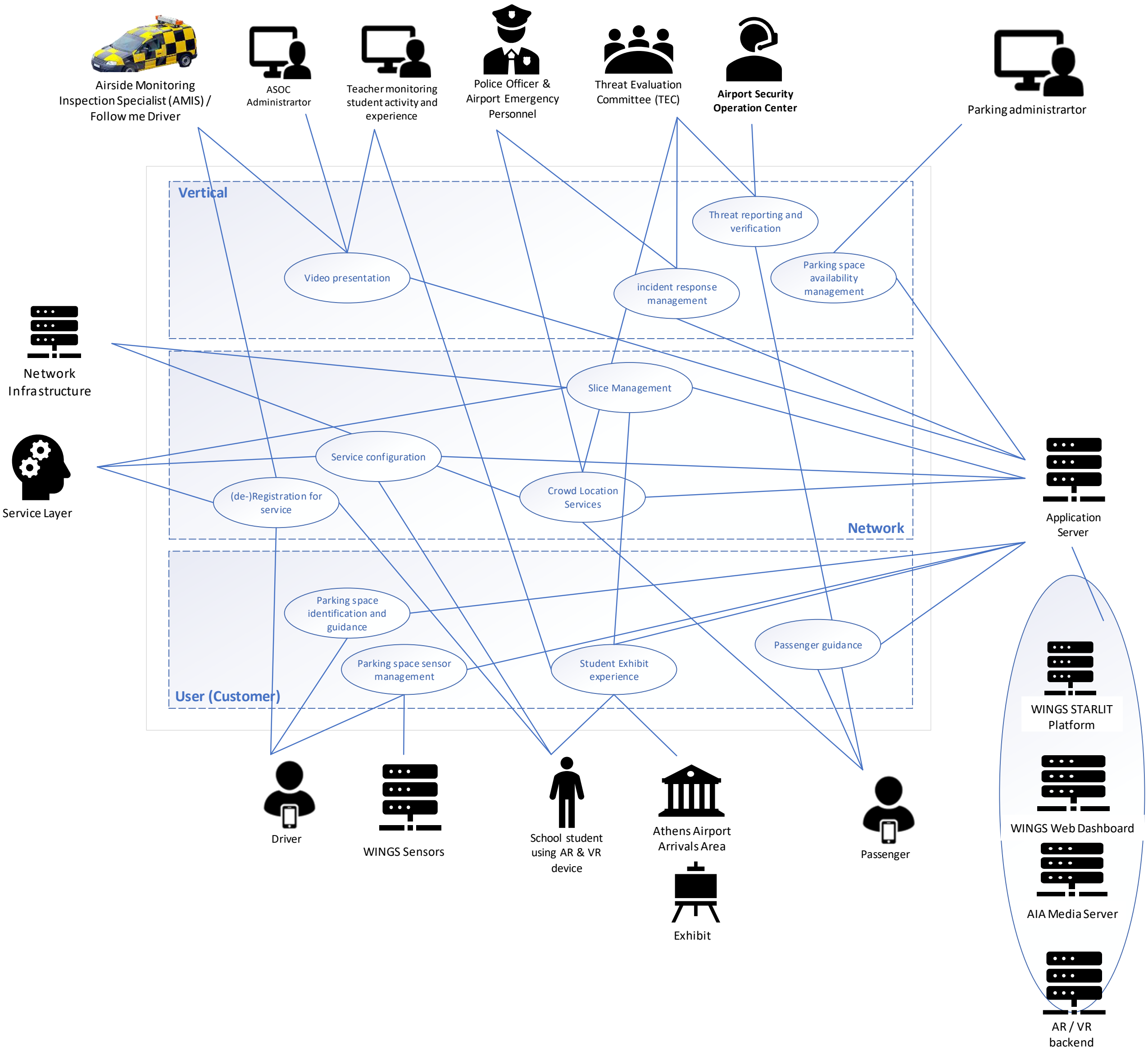


Figure 35: Mobility Efficient City Platform Context Diagram

Features that are emergent from this platform are:

- **The end user interaction with the vertical**. Both the passenger in the safety case and the driver are interacting with the platform based on location-based functionality, both indoor and outdoor, which tracks and guides the user. This has to be a trusted platform especially in the case of the guidance in a security threat scenario.

- **Application servers highly integrated with the Service layer**. To realise a number of functional areas in the platform.
- **Authority figures in the vertical overseeing**: For the threat response there are multiple layers of interaction between passengers, a committee structure and officers in location. This again points the need for vertical users to fully trust the platform as it is integrated into the mission critical operations. For the student the teacher is able to review what students have experienced, this is for evaluation of learning experience rather than safety issues but could also potentially be for safeguarding reasons.
- **Dynamic slicing capability**: In the event of this platform being deployed in a commercial environment whereby these use cases are running at scale in a city the nature of the slicing required leads to a useful stretching of the capability of the network potentially justifying investment in the networks.

5.2 Deployment Considerations

The deployment of the Mobility Efficient City platform at the Athens node is depicted in Figure 36.

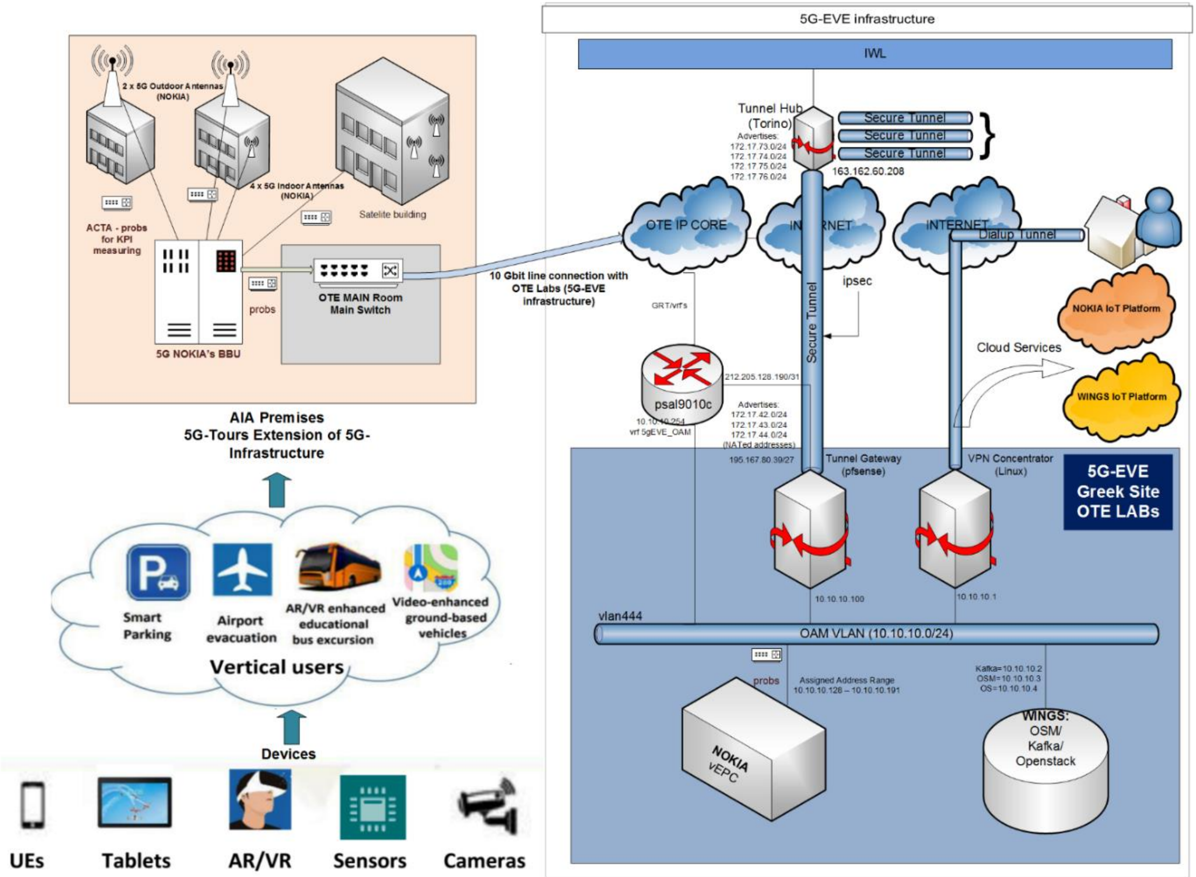


Figure 36: Mobility Efficient City Platform

The implementation of the 4 UCs relies partly on 5G-EVE Greek Site infrastructure, and on an extension that is implemented at the Athens International Airport (AIA) premises as part of the 5G-TOURS project. The different network components of the Athens Node that have been implemented within the currently running 5G-EVE project are the following:

- A fully functional 5G network installed and configured by NOKIA-GR that is up and running.
- An Orchestrator (OSM) installed and configured by WINGS that is also up and running.
- The OSM Orchestrator is fully interconnected with the Interworking Layer (IWL) of the Turin 5G-EVE site through a secure tunnel.
- Furthermore, a Kafka bus server, for the needs of keeping the metrics of the KPIs, is installed and configured and so the interconnection of the Kafka with the central Kafka server.

- Additionally, the interconnection of the NOKIA's 5G platform with the orchestrator is in a final phase of implementation.
- Finally, there is also an interconnection with the NOKIA's and WINGS IoT platforms.

For the needs of 5G-TOURS the following components shall be installed at the AIA premises.

- 2 outdoor and 4 indoor antennas. During the 1st phase of implementations, these antennas will use the 4G/LTE spectrum band of 2700-2800MHz.
- All the antennas will be connected via optical fiber with the NOKIA's Baseband Units (BBU)s at the airport, which through an OTE L2/L3 switch will be interconnected to the OTE IP Core in order, using a 10 Gbit capacity line, to interconnect to the 5G-EVE Greek site infrastructure located at OTE Labs in Psalidi-Attika.
- For the implementation needs of the 4 5G-TOURS UCs smart devices will be used, and specific innovative applications developed (Smartphones, tablets, AR/VR headsets, IP-cameras, IoT chipsets, and various sensors, etc.).
- Also, KPI measuring probes will be installed between antennas and the BBU, as well as between the BBU and OTE's Core-switch (at AIA). Finally, a probe will also be placed before NOKIA's platform (ePC) at OTE-Labs. These probes will be used for measuring network performance and service layer metrics in real time in order to validate KPIs of the network.

The implementation of the 4 UCs in the Athens´ node will follow 2 phases. During the **1st phase,** the interconnection of the devices will use directly the NOKIA's 5G antennas in order to have access to the 5G mobile network of the 5G-EVE Greek site infrastructure. During the **2nd phase** of implementation, blueprints and test cases for each one of the UCs will be implemented and used and the running of trials shall follow the 5G-EVE flow.

System Test Enhancement Requirements

5G-TOURS inherits capabilities from 5G-EVE with respect to KPI measurements to monitor MANO and Service Layer performance based on 24*7 network KPI measurement and analytics presentation; this will be supplemented by provision of Industrial probes provided by 5G-TOURS only at the Mobility Efficiency city platform in Greece. Details of how testing, verification and validation is provisioned shall be defined by WP7.

5.3 UCs

We now present the UCs as an outcome of the analysis team that was asked to finalise a flow of events and the interaction of key users and functions of 5G-TOURS using the unified across 5G-TOURS sequence diagram method.

5.3.1 UC10 - Smart airport parking management

In this UC, parking customers at the airport obtain real time information on available and occupied spaces through 5G-enabled parking sensors and are able to locate available parking spaces directly through a mobile application that guided them via the optimal route. This is a solution that relies on the mMTC capabilities provided by 5G. A large number of sensors installed at selected individual parking spots, will help keep track of available and occupied spots in real time, facilitating the parking process within an airport, as well as in any other controlled parking area. As a result, this will also add to the travelling efficiency of tourists through targeted parking spot suggestions.

5.3.1.1 UC Sequence diagram

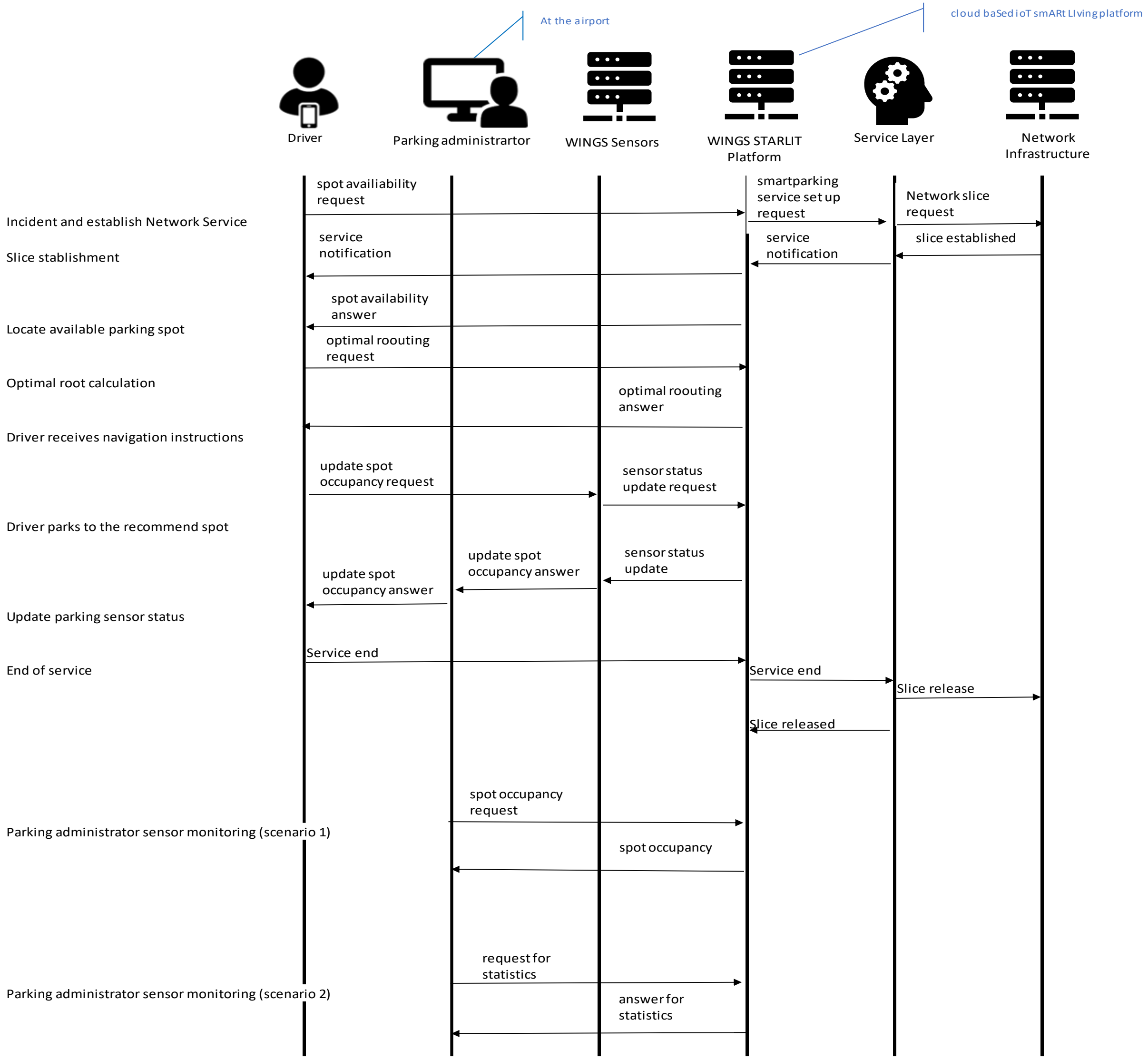


Figure 37: UC10 Smart Airport Parking Management Sequence Diagram

Key steps of the UC:

1. A driver inside AIA parking searches for an empty parking spot.
2. The driver requests the parking spot availability from the WINGS STARLIT platform via the WINGSPARK app.
3. The smart parking service is established and an mMTC slice established in the 5G-TOURS infrastructure.
4. The WINGS STARLIT platform calculates and returns the parking spot availability and the suggested spot based on the overall parking status.
5. A request for calculating the optimal route to the suggested spot is sent to the WINGS STARLIT platform via the WINGSPARK app.
6. WINGS STARLIT platform calculates the optimal route and returns the navigation instructions to the driver.
7. Driver parks at the suggested spot.
8. The sensor sends the change of its status to the WINGS STARLIT platform.
9. Parking sensor status and overall parking occupancy is updated.
10. Parking administrator requests the overall parking occupancy of the parking facility.
11. WINGS STARLIT platform calculates the overall parking occupancy at the desired granularity (day, month, year) and returns the information via the WINGSPARK dashboard.
12. Parking administrator requests statistics regarding parking events or occupancy either for a specific sensor, or a group of sensors, or all sensors for a specific time period.
13. WINGS STARLIT platform calculates the desired statistics at the desired granularity (day, month, year) and returns the information via the WINGSPARK dashboard.
14. The services ends and the mMTC slice released.

5.3.1.2 User and Network requirement analysis

For the implementation of this UC, the following requirements from the user perspective are needed (Table 21).

Table 21: User requirements for UC10 – Smart airport parking management

	5G-Tours Use case name: UC10 - Smart Airport parking management			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**No**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**Medium**
	5	***Data Transmission (UL)* :**	High/Medium/Low	**Low**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Medium Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**High**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Very Fast**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Baseline**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Sporadic Medium**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Medium Density Medium**
Structural User Requirements	13	***Edge Computing* :**	Yes/No	**No**
	14	***Edge Storage* :**	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Medium**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated into the following Table 22, where the general/Specific vertical UC requirements for the UC are shown. During the translation of user requirements to network requirements, the UC analysts identified that a justification for a 5G capability network is not fully apparent. The needs anticipated by the vertical user could potentially be addressed using a lower specification network, this specification issue has been identified as requiring resolution during the latter stages of the project. Requirements that are to be focused upon during the validation of requirements are the reliability, mobility and location accuracy performance expectations. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 27.

Table 22: UC10 – Smart airport parking management network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 10 – Smart parking management			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		5		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99,9999		High	99,9990	99,9999
5	Availability (%) - Min/Max	%		99,99		High	99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		30		High	5	30
7	Broadband Connectivity (peak demand)	Y/N or Gbps		1		High	0,01	0,1
8	Network Slicing (Y/N) - if Y service deployment time (m	Y/N		Y		Medium	1	3
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		0,1			0,1	0,1
11	Device Density	Dev/Km^2		100K		High	1K	100K*
12	Location Accuracy	m		<0,5		High	0,5	1
(*) 1 parking space = 10m^2 => 1 Km^2 = 100.000 parking spaces								
Specific Vertical/Use Case Requirements								
Network	Number of End Points			100				
	Number (Range) of End Devices per End Point			1				
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)						15	50
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)			2				
	Number of Class of Service / QoS (1-8, more)			1				
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**			Sensor				
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)			30				
	IPv4 & IPv6 support (or both)			both				
	Connnection of Device to End Point (Wired/Wireless)			Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)			NB-IoT				
	Authenication method (i.e. SIM, eSIM, Key..)			SIM				
non-Network related Requirements)								
	i.e Battery life requirement			3				
5G-EVE Site Services USER REQUIREMENTS								
	City		Athens International Airport					

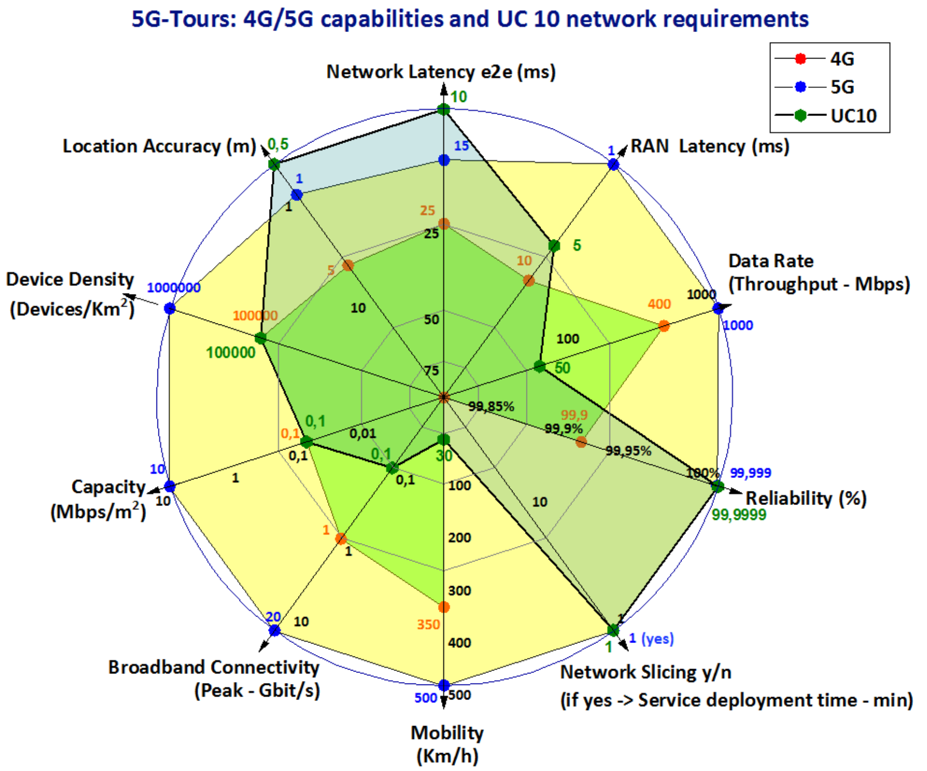


Figure 38: Radar chart for UC10 – Smart airport parking management network requirements

For the UC10 (Smart Parking), the 5G network capabilities will be required. Although with respect to the

- Throughput;
- Mobility;
- Peak Traffic Demand (Broadband Connectivity) and
- Capacity,

even existing 4G/LTE and 4G+ technology/network will suffice, when it comes to

- Device Density and
- RAN Latency,

a 5G network is a better fit due to the scalability of the capability.

Furthermore, for the case of E2E Network Latency and the Location Accuracy the UC10 requirements stretch the limits of 5G Networks. From the perspective of anticipated commercial realisation and with respect to the very low E2E latency, the possibility of Edge Computing and/or Edge Cloud architectures should be considered. This will reduce the overall latency at significant cost. There are two alternative approaches: either a Proof of Concept trial evaluating whether the 5G network offering E2E Latency of approximately 15ms is good enough for the Service, or performing a techno-economic analysis for using Edge Cloud/Computing architectures.

Finally, the desired Location Accuracy of 0.5 m indicates that hybrid location identification technologies could be utilised. For outdoor parking spaces, a combination of military grade GPS together with a 5G network location information should be more than sufficient. For indoor parking environments, a WiFi assisted 5G network together with other modalities should be utilised in order to provide 0.5 meters location accuracy. It is anticipated that it will be sufficient for the mobility efficient platform to establish an identity per end device that is associated with the specific location so that the system can correlate each identity with location and this would avoid the additional complexity of a fully dynamic system that is required to receive GPS location information from end device constantly.

5.3.2 UC11 – Video-enhanced ground-based moving vehicles

This UCs provides high definition cameras to the follow-me vehicles which lead aircraft to parking positions, monitor and oversee the activity at the Airport Airside area, and attend incidents, emergencies and critical events, improving day-to-day airport operations as well as response activities to emergencies.

The Follow-me vehicles shall have mobile units of the airport (follow-me cars) with high definition cameras, sending multiple live feeds to the Airport Operations Centers (AOCs) and other stakeholders. This solution will leverage 5G to enable multiple-simultaneous live streams of high-resolution video transport in real-time, thus allowing for instant situation awareness and more efficient guidance towards aircraft parking locations.

5.3.2.1 UC Sequence diagram

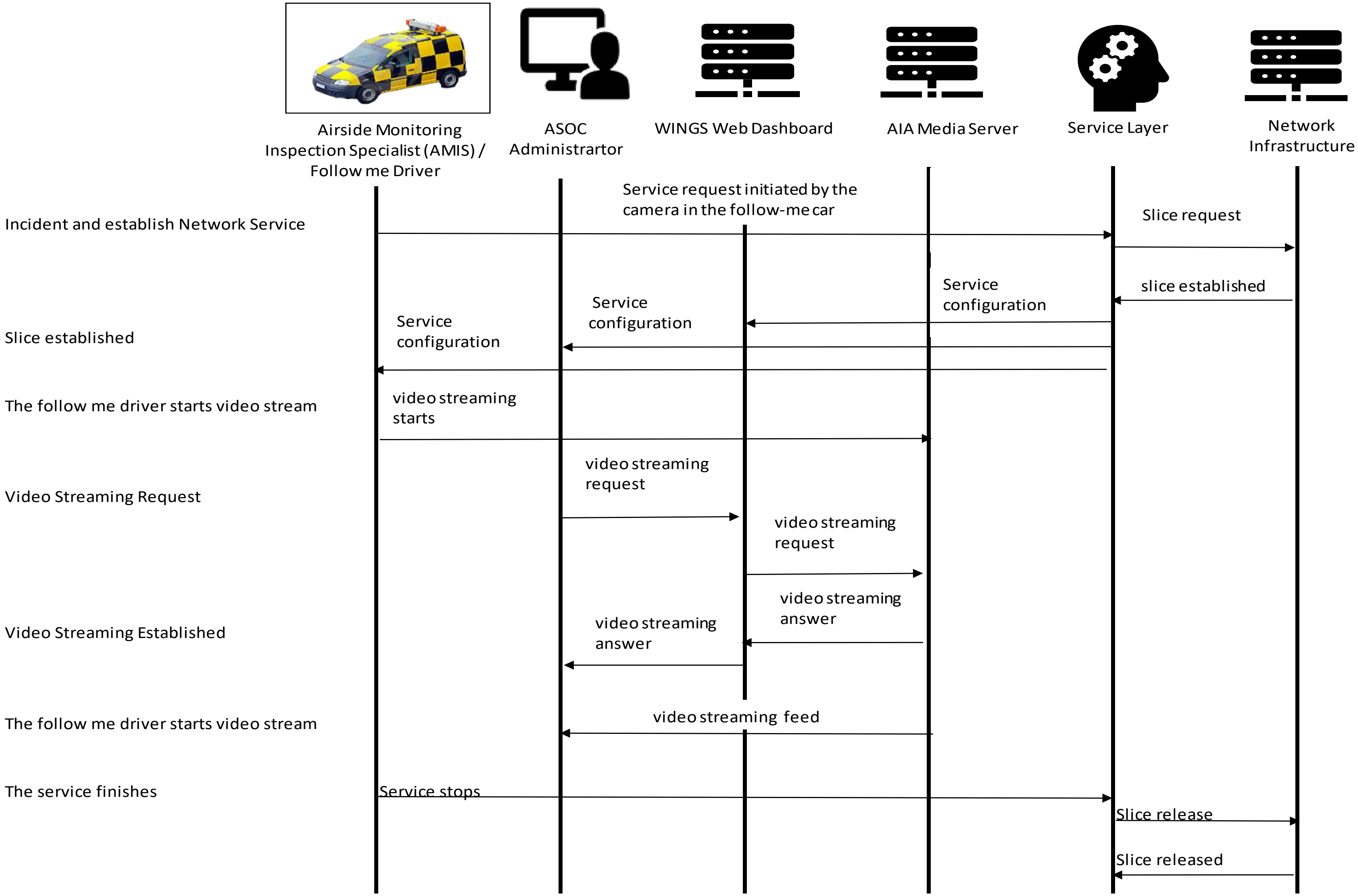


Figure 39: UC11 Video Enhanced Ground based vehicle Sequence Diagram

Key steps of the sequence diagram:

1. Airside Monitoring Inspection Specialist (AMIS) informs the Airport Security Operation Centre (ASOC) about an incident on Apron Area over TETRA.
2. ASOC requests the Follow-me driver (AMIS) to start the video and connects to see it.
3. The equipment installed on the vehicle is connected through 5G infrastructure to AIA Media Server. In more detail, the 5G router is connected through an IPsec VPN connection to AIA infrastructure and the streaming is routed to AIA Media Server.
4. A web client requests the stream from the Media Server.
5. The ASOC administrator has direct viewing capability of the area where the incident is taking place.

5.3.2.2 User and Network requirement analysis

For the implementation of this UC, the following requirements from the user perspective are needed (Table 23):

Table 23: User requirements for UC11 – Video-enhanced ground-based moving vehicles

	5G-Tours Use case name: UC 11 - Video Enhanced Ground Based Vehicles			
	a/a	**User Requirements Description**	**Metrics**	**values and Units**
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**Low**
	5	***Data Transmission (UL)* :**	High/Medium/Low	**High**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**High Speed**
	7	**Location Information:**	High / Medium / Low Accuracy	**High**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Fast**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**High**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Bursty High**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Sparse Medium**
Structural User Requirements	13	***Edge Computing* :**	Yes/No	**No**
	14	***Edge Storage* :**	Yes/No	**Yes**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**High**
	16	***other***	User specified	

The mapping or the above user requirements into network requirements is illustrated into the following Table 24, where the general/Specific vertical UC requirements for the UC are shown. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 40.

Table 24: UC11 – Video enhanced ground based moving vehicles network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 11 - Video-enhanced ground-based moving vehicles			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			50		50	100
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			50		10	50*
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,999		99,99	99,999
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			150		80	150
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,25		25 Mbps	250 Mbps
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N			30		60	30
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y		Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			0.00256		1 Gbps/Km^2	2,5 Gbps/Km^2 **
11	Device Density	Dev/Km^2			50		5	50 ***
12	Location Accuracy	m			1		5	1
(*) per vehicle 50 Mbps video stream is transmitted								
(**) assume 50 vehicles at 50 Mbps/vehicle in one Km^2 = 2,5Gbps/Km2 = 0,00256Mbps/m^2								
(***) 50 vehicles								
Specific Vertical/Use Case Requirements								
Network	Number of End Points		Follow me vehicles				2	3
	Number (Range) of End Devices per End Point						1 5G router & 1 IP Camera	
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)						Mbps	Gbps
	End -to-end Latency (msecs)						50	250
	Highest Acceptable jitter (msec)						15	30
	Number of Class of Service / QoS (1-8, more)						1	1
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**						Tablets	
	Bitrate required (Kbps / Mbps / Gbps)						Mbps	Gbps
	Max Latency Allowable (in msecs)						100	500
	Max Moving Speed (km/h, 0 if stationary)						80	150
	IPv4 & IPv6 support (or both)							IPv4
	Connnection of Device to End Point (Wired/Wireless)						Wireless-Tablet/Etherne	Wireless
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							WLAN/4G/5G/Ethernet
	Authenication method (i.e. SIM, eSIM, Key..)							eSIM, User application account
non-Network related Requirements)								
	i.e Battery life requirement						power from vehicle	
5G-EVE Site Services USER REQUIREMENTS								
	City							Athens
	Address & End Tel. Number[1]							Athens International Airport

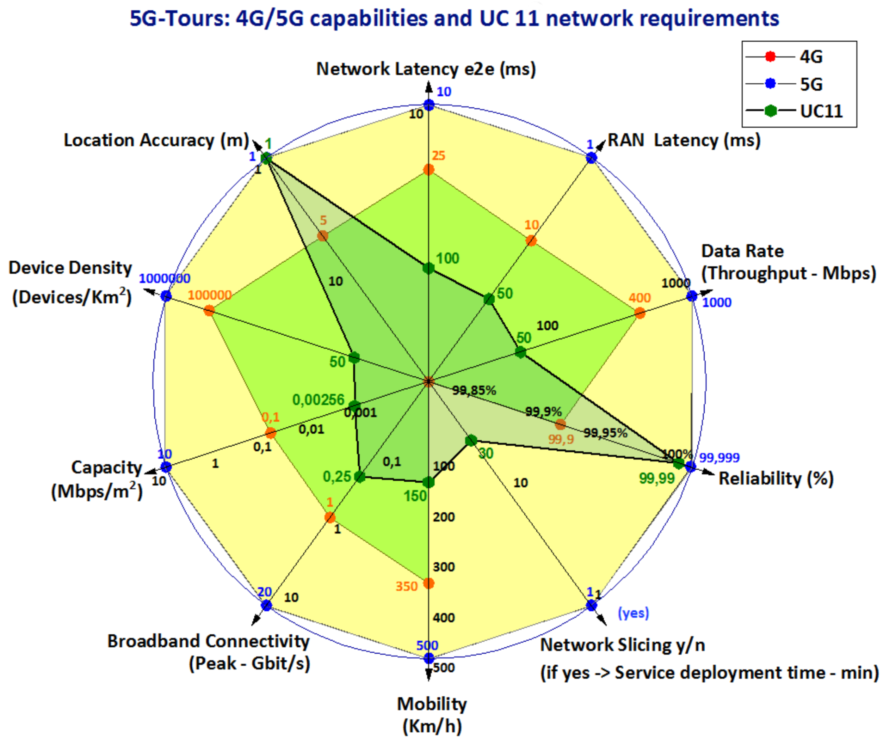


Figure 40: Radar chart for UC11 – Video-enhanced ground-based moving vehicles network requirements

Whilst similar User Experience could be achieved with a 4G Network based solution, it is anticipated that UC11 should benefit from the additional capabilities of 5G with regards to:

- Reliability;
- Location Accuracy and
- Network Slicing Requirements.

We caveat this preliminary view with the already identified latter project stages need for the validation process to further research the needs regarding network performance. If we take into account that the Reliability of 4G Networks is improving and that Location Accuracy (see also the Smart Parking UC10) can also be achieved by other means in outdoor environments, it is potentially only the implementation choice regarding Network slicing that necessitates 5G. This UC11 can potentially serve as an example of a utilisation of a service that although it does not strictly require 5G, verticals benefits from such deployed capabilities as a marginal cost increment for their high utility benefit.

5.3.3 UC12 - Emergency airport evacuation

This UC focuses on the evacuation of the airport in a quick and organized fashion in case of an emergency, providing automated guidance of emergency routes from the affected area up to the muster areas. There shall be monitoring of user location and provision of instructions, individual personalised messages shall be sent to users.

5.3.3.1 UC Sequence diagram

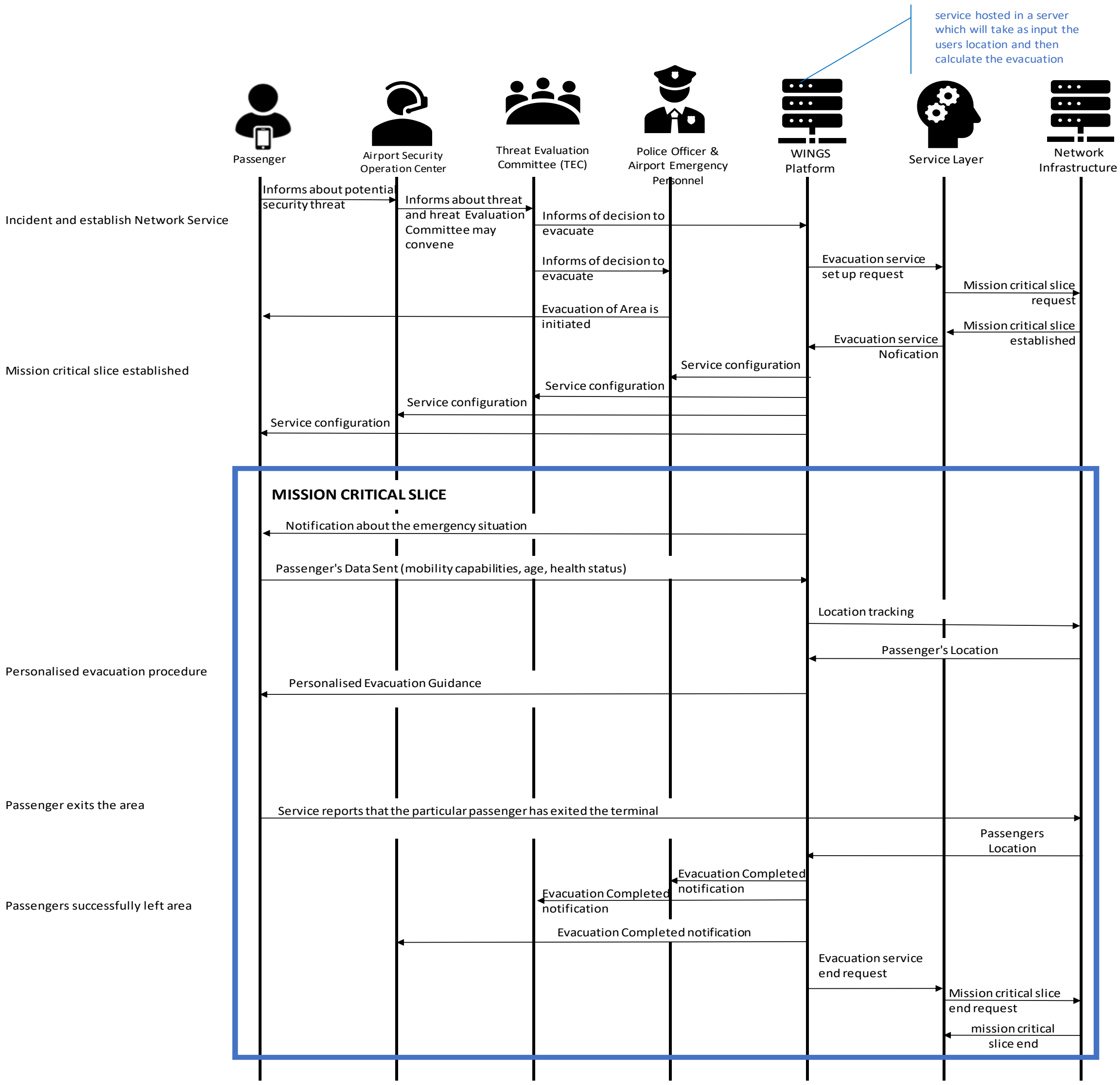


Figure 41: UC12 Emergency Airport Evacuation Sequence Diagram

There are various roles involved before reaching a decision about evacuation. These roles are mostly omitted in the sequence diagram for the sake of simplicity. Key steps of the UC:

1. Gate Attendant informs Airport Security Operation Centre (ASOC) about the threat.
2. ASOC informs the Security Duty Supervisor (SDS) and the Airport Duty Officer (ADO).
3. ASOC asks assistance from the Security Staff and the Police Officers at the area.
4. ADO informs the Threat Evaluation Committee about the threat.
5. Police Officer informs the Police Operations Centre about the evacuation necessity.
6. Police informs the Threat Evaluation Committee about the evacuation necessity.
7. The Threat Evaluation Committee decides to initiate the evacuation of the area.
8. A Mission Critical Slice is deployed. During the latter stages of the project the needs of the vertical user are to be validated with respect to their expectations regarding a "mission critical" aspect of a slice. The properties of a mission critical slice and how this required designation from a user translates based on their expectations into an end to end system implementation is critical to cost of commercial platform deployment and thus shall be investigated further.
9. A push notification about evacuation is sent from the WINGS platform to the passengers´ mobile phones.
10. Passengers' data collected (mobility capabilities, age, health status). It is essential that requirement validation processes clarify the data privacy and security implications of this UC requirement. Onerous requirements here will have a significant impact on the commercial realisation viability of the platform, so should be fully understood during the latter stages of the project.
11. Each Passenger's exact location is calculated based on the information collected from the 3 indoor cells - Still under discussion depends on the antennas´ installation.
12. Optimal, personalised evacuation route is sent to each passenger's phone.
13. Passenger's position monitored during evacuation.
14. Passengers (all of them!) successfully reached exit.
15. Mission critical slice is released.

5.3.3.2 User and Network requirement analysis

For the implementation of this UC, the following requirements from the user perspective are needed (see Table 25):

Table 25: User requirements for UC12 – Emergency airport evacuation

	5G-Tours Use case name: UC 12 - Emergency airport evacuation			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**No**
	2	**Video Transmission:**	Yes/No no of Channels	**No**
	3	**Voice Communication:**	Yes/No	**No**
	4	**Data Reception (DL):**	High/Medium/Low	**High**
	5	***Data Transmission (UL)* :**	High/Medium/Low	**No**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**Walking-Running**
	7	**Location Information:**	High / Medium / Low Accuracy	**High**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Fast**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**High**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Bursy High**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Dense Medium**
Structural User Requirements	13	***Edge Computing* :**	Yes/No	**No**
	14	***Edge Storage* :**	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Mediun**
	16	***other***	User specified	

The user's anticipated needs for battery life were noted by UC analysts. The motivation for a medium consumption may be derived from experiences of location based services on mobiles which can drain power from batteries and as the users mobile becomes critical for survival in this UC this could have translated into a desire to ensure batteries do not fail during evacuation. This requirement will be further validated during latter stages of the project. The translation of the above user requirements into network requirements results in Table 26, where the general/Specific vertical UC requirements for the UC are shown.

The immediacy of establishing a slice could be underspecified in the network requirements. This shall be refined once the operational procedures of evacuation constrained by legal and operational requirements at the Airport and how they impact the response needs of the platform have been refined in the latter stages of the project.

The corresponding radar charts (for URLLC and mMTC) which translate into the derived needs for the mission critical slice and mapping to general requirements against the 4G/5G networks capabilities is shown in Figure 42, and Figure 43.

Table 26: UC12 – Emergency airport evacuation network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 12 - Emergency airport evacuation			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15	25			15	100
2	**RAN** Latency (in milliseconds) - one way	msec	10	10			10	20
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	500	100			100	500 *
4	Reliability (%) - Min/Max	%	99,9999	99,9999			99,999	99,9999
5	Availability (%) - Min/Max	%	99,99	99,99			99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10	0			0	10**
7	Broadband Connectivity (peak demand)	Y/N or Gbps	10	10			1	10
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	1	1			1	1
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y			Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	20	20			2	20***
11	Device Density	Dev/Km^2	1000K	1000K			1000K	1000K*****
12	Location Accuracy	m	<1	<1			1	0,3
(*) Total per UE								
(**) 10 km/h running speed of a peson evacuating								
(***) 2 persons per m^2 at 10 Mbps/person								
(*****) 1 or 2 persons per m^2								
Specific Vertical/Use Case Requirements								
Network	Number of End Points						1	200
	Number (Range) of End Devices per End Point						1	3
	Density of End Devices (per sq. meter)						1	3
	Bitrate needs per end point (Kbps,Mbps, Gbps)		1	1			Mbps	Kbps
	End -to-end Latency (msecs)						low	extremely low
	Highest Acceptable jitter (msec)						15	20
	Number of Class of Service / QoS (1-8, more)						7	8
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**							Smartphone
	Bitrate required (Kbps / Mbps / Gbps)							Kbps
	Max Latency Allowable (in msecs)						15	100
	Max Moving Speed (km/h, 0 if stationary)						0	70
	IPv4 & IPv6 support (or both)							IPv4
	Connnection of Device to End Point (Wired/Wireless)						Wireless	Wireless
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					WLAN/4G/5G/Beacon/Zigbee		
	Authenication method (i.e. SIM, eSIM, Key..)					Sensor ID, User application account		
non-Network related Requirements)								
	i.e Battery life requirement						one year	five years
5G-EVE Site Services USER REQUIREMENTS								
	City	Athens						
	Address & End Tel. Number[1]	Athens International Airport						

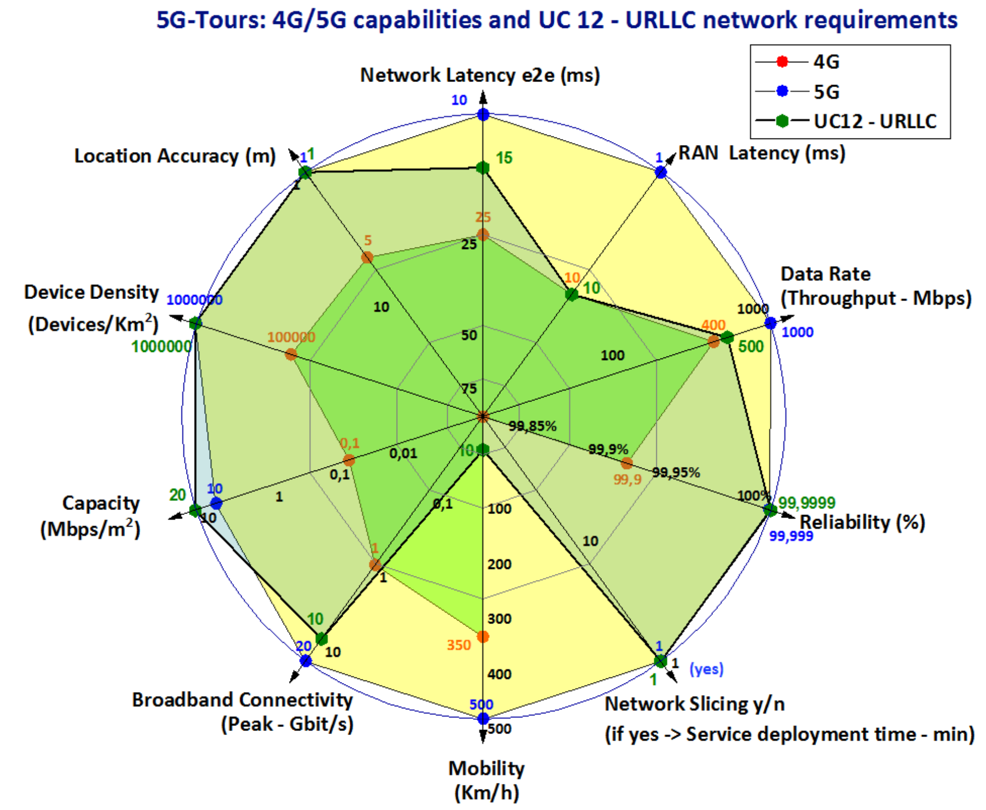


Figure 42: Radar chart for UC12 URLLC – Emergency airport evacuation network requirements

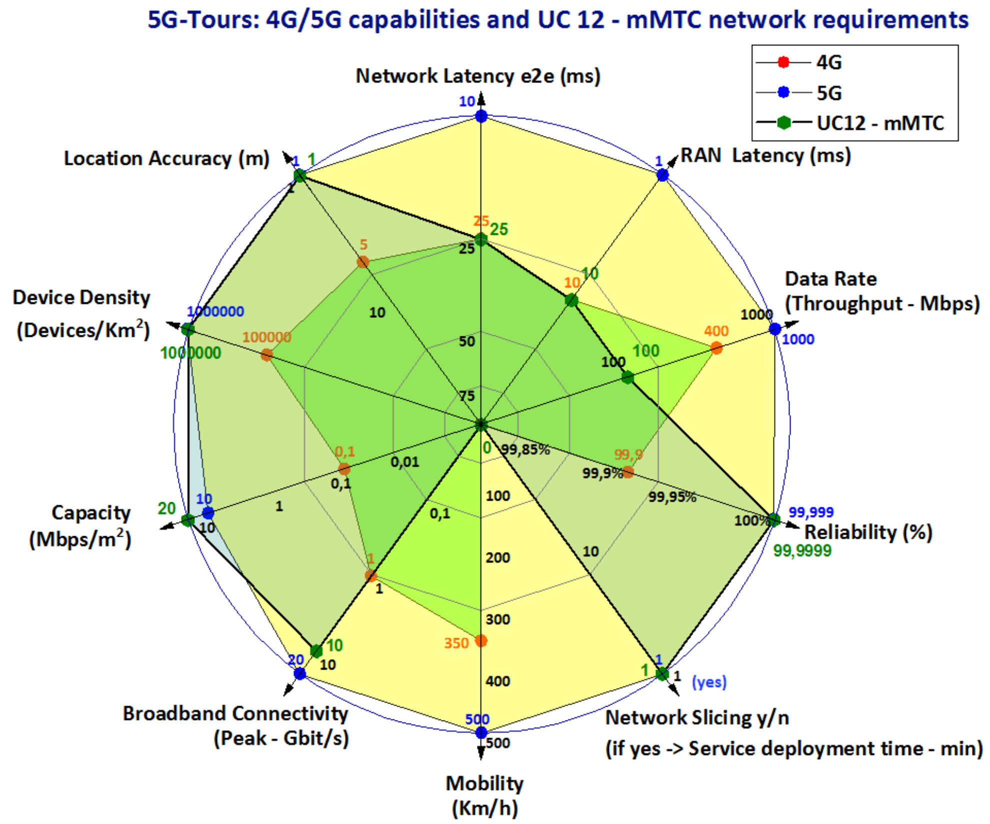


Figure 43: Radar chart for UC12 mMTC – Emergency airport evacuation network requirements

For UC12, a 4G/LTE network will only be able to satisfy the

- RAN Latency (only mMTC traffic but not for the URLLC) and
- Throughput Requirements

Advanced 5G Network should be well utilised with respect to

- Broadband Connectivity;
- Device Density;
- Reliability;
- Network Slicing;
- Latency and
- Location Accuracy.

It is interesting to observe that the UC12 Capacity requirements (for both mMTC and URLLC traffic) stretch the 5G Network requirements to the limit. Therefore, for a successful implementation of this UC, careful planning of the 5G NR gNBs and dimensioning of the Network resources should be performed. Since the required capacity should also be delivered in well-defined and confined spaces of the AIA, even the stringent capacity requirement can be achieved with 5G technology.

5.3.4 UC 13 - Excursion on an AR/VR-enhanced bus

The goal of this UC is to demonstrate the value offered by the use of 5G technology in cases when groups of people travel, e.g. on a bus, in order to visit a site of interest. The UC focuses particularly on the example of school students travelling to a destination of educational interest during a field trip or excursion. In the trials, a group of 20-25 students from the school of Ellinogermaniki Agogi (EA) will travel on a school bus to Athens International Airport (AIA) to visit an exhibit that will be hosted in the public space of the Arrivals area of the airport. The fast and reliable wireless connectivity offered by 5G and the smooth streaming of online content that can be enable will be utilized to generate good quality digital learning experiences both during the transportation to and from the destination, and during the visit of the exhibit.

More specifically, during the school bus ride transferring the students to the airport, students will be presented with rich informational and educational content preparing them for the visit of the exhibit in the airport, through the use of VR technologies on their 5G-enabled smartphones and headsets. Next, during the visit at the airport, the students will be able to interact with the exhibit using AR technologies on their 5G-enabled smartphones, to enhance the learning experience and overall enjoyment of the activity. Finally, during their bus ride back to school, students will interact with digital content relating to the visited exhibit through VR technologies on their 5G-enabled smartphones and headsets, as a wrap-up and follow-up to the learning experience of the visit.

5.3.4.1 UC Sequence diagram

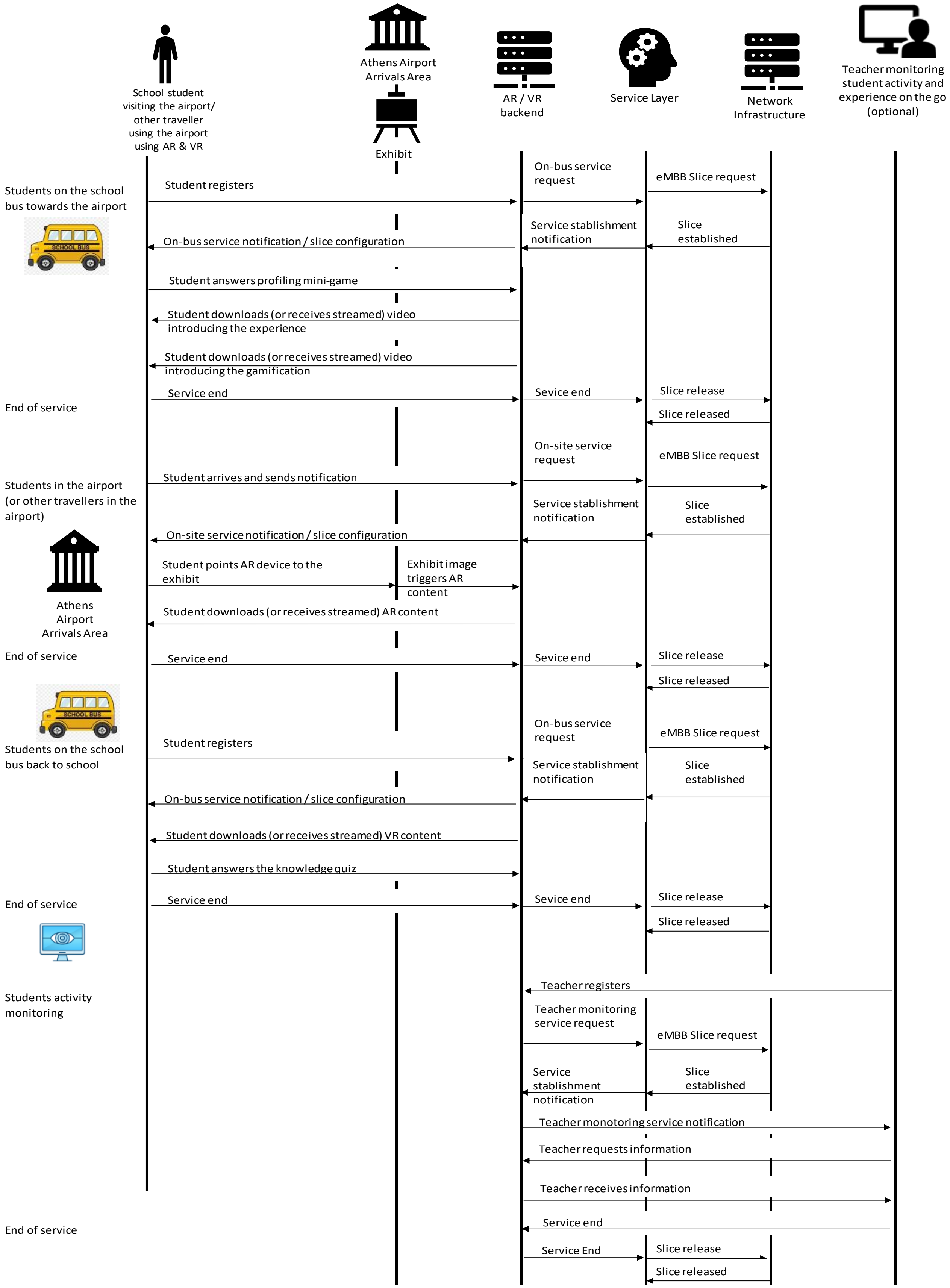


Figure 44: UC13 Excursion on an AR/VR Enhanced Bus Sequence Diagram

Key stages and steps of the sequence diagram:

Students travelling to the Athens Airport:

1. On a school bus, school students will be traveling to the Airport, where they will visit an exhibit in the arrivals area introducing Myrtis to the travellers arriving in Athens.
2. Students will use the end-user devices to enter a 3D VR space, where they will be able to explore the environment and select to interact with various digital assets.
3. Duration of the pre-visit VR experience: 5-10 minutes
4. The VR-enhanced pre-visit experience is comprised of the following parts:

a.i Profiling mini-game

1. Purpose: To offer personalized experiences to each student.
2. Each student will be asked 3-4 questions, which will be disguised in a mini game. The answers the user will give will affect the way the app will work for that user.

a.ii Video introducing the experience

1. The students will watch a video which will introduce them to what they will see and learn about during their visit to the Myrtis exhibit.
2. Duration of the video: 3-5 minutes

a.iii Video introducing the gamified aspects

1. In a short video, students will be informed that after the visit, during their bus journey back to school, they will participate in game-based testing of what they have noted and learned during their trip to the exhibit. The video will explain the purpose and rules of the game. It will encourage the students to be careful to collect information and evidence during the visit, so that can later prove their achievements and win relevant prizes/emblems.
2. Duration of the video: 1-2 minutes

Students in the Athens Airport: the AR-enhanced visit experience

1. In the public area of the Arrivals hall in Athens Airport, students will stand in front of the exhibit, i.e. a large banner introducing Myrtis to the travellers arriving in Athens.
2. Students will use the end-user devices to point to different parts of the banner and so trigger AR content on their screens. They will explore the different items represented on the banner and the information will be hidden, and they will be free to select to interact with any of the available digital assets.
3. The AR content offered to each user will be personalised on the basis of the input the user will have provided in the profiling mini-game.
4. Duration of the AR experience: 10-15 minutes
5. The AR-enhanced visit experience is comprised of the following parts:

.i Rich information on Myrtis and Athens through AR

1. A number of different areas with short texts and other visual elements will appear on the exhibit banner. Some of these items will act as triggers of AR experience, popping up a panel with additional information when looked through the end-user device.

.ii Gamified AR experience

1. “Note this”: While exploring the exhibit, at times students will receive alerts in the AR environment encouraging them to pay attention to some details or trivia that they will later on find useful in a knowledge quiz (in the post-visit experience).
2. The treasure hunt: The AR application will also organize a hunting game, in which the students will be asked to find certain items by following tips that will be given. Once a student finds the object, they will point their device to it, the app will recognise it, and register it on the student’s list. This will unlock the next tip leading to the next object.

Students travelling back from the Athens Airport: the VR-enhanced post-visit experience

1. On the school bus once again, school students will be traveling back to their school after their visit to the exhibit in the airport.
2. Students will use the end-user devices to enter a 3D VR space, where they will be able to explore the environment and select to interact with various digital assets.
3. Duration of the post-visit VR experience: 5-10 minutes

4. The parts VR-enhanced post-visit experience is comprised of the following parts:

i The knowledge quiz

- In the VR environment, students will participate in game-based testing of what they have noted and learned during their trip to the exhibit. This will be a knowledge quiz in the form of a "Who wants to be a millionaire?" game. Using the information and evidence they will have collected during the visit (including the trivia and hunted items from the AR experience), they will provide their answers to multiple-choice questions. To answer some of the questions, students will have to interact with digital assets, e.g. by exploring details of a 3D model or watching a short video.

ii Recognition of achievements

- After the completion of the knowledge quiz, the VR application will present each student with their achievements during the whole experience, in the form of prizes, badges, other emblems, etc.

5.3.4.2 User and Network requirement analysis

For the implementation of this UC, the following requirements from the user perspective are needed (Table 27):

Table 27: User requirements for UC13 – Excursion on an AR/VR-enhanced bus

	5G-Tours Use case name: UC13 - AR/VR enhanced excursion			
	a/a	User Requirements Description	Metrics	values and Units
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	**Yes (3D AR/VR content) - high**
	2	**Video Transmission:**	Yes/No no of Channels	**No (optionally, students visiting can transmit video to remote students, but not a basic requirement)**
	3	**Voice Communication:**	Yes/No	**No (optionally, students visiting can communicate with remote students, but not a basic requirement)**
	4	**Data Reception (DL):**	High/Medium/Low	**High**
	5	***Data Transmission (UL)*** **:**	High/Medium/Low	**Medium**
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	**VR on the bus Medium speed, of AR exhibition Walking-Running spped/Stationary**
	7	**Location Information:**	High / Medium / Low Accuracy	**Medium**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Fast**
	9	**Reliability/Availability:**	high / medium / low	**99.99%**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Medium - Restricted (children's personal data)**
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	**Bursty high for AR/VR 3D content**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Dense high 1-2 UE/m2**
Structural User Requirements	13	***Edge Computing*** **:**	Yes/No	**Yes**
	14	***Edge Storage*** **:**	Yes/No	**Yes**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**Low**
	16	***other***	User specified	

The translation of the above user requirements into network requirements is illustrated into the following Table 33, where the general/Specific vertical UC requirements for the UC are shown. During the mapping process the UC analysts have identified two requirements that should be validated during latter stages of the project; namely, Batter Life and Response Time. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 45.

Table 28: UC13 – Excursion on an AR/VR-enhanced bus network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	Use case 13 – Excursion on an AR/VR-enhanced bus			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			25		25	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			120		80	120
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,99		99,9	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			100		4	100
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,01		2	10 *
8	Network Slicing (Y/N) - if Y service deployment time (min	Y/N			Y		30	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			10		1	10 **
11	Device Density	Dev/Km^2			1000		10K	1000K***
12	Location Accuracy	m			>=1		<4	>=1
(*) 10 Mbps per VR device downstream = 0,01 Gbps								
(**) 1 device per m^2								
(***) 1 or 2 students per m^2 = 1000K devices (AR/VR gogles) per Km^2								
Specific Vertical/Use Case Requirements								
Network	Number of End Points							
	Number (Range) of End Devices per End Point						20	25
	Density of End Devices (per sq. meter)						1	2
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**							
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)							
	IPv4 & IPv6 support (or both)							
	Connnection of Device to End Point (Wired/Wireless)							
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)							
non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City	Athens						
	Address & End Tel. Number[1]	International Airport of Athens						

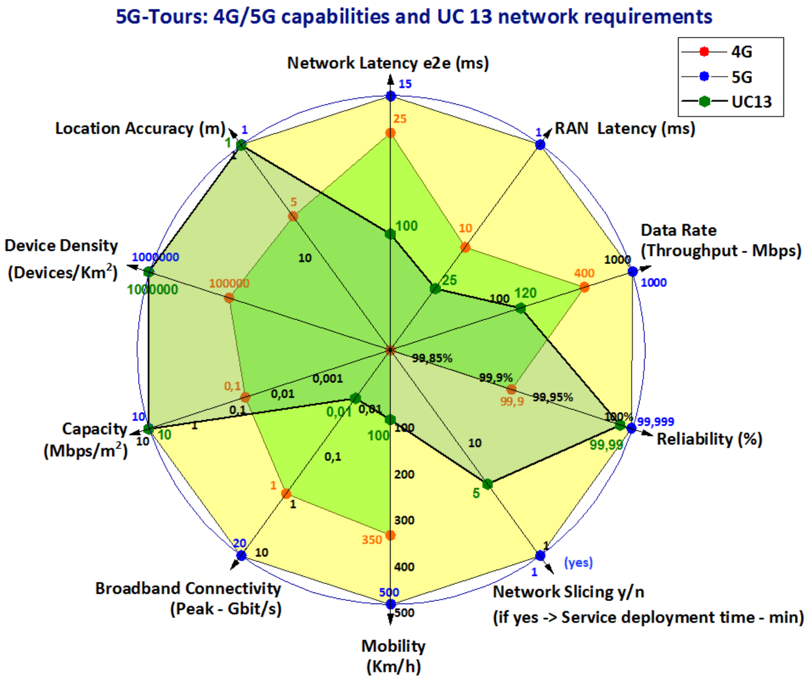


Figure 45: Radar chart for UC13 – Excursion on an AR/VR-enhanced bus network requirements

Half of 5G-TOURS UC13 requirements need a 5G network for the Service implementation. The following required 5G networks:

- Location Accuracy;
- Device Density;
- Capacity;
- Network Slicing and
- Reliability.

The remaining requirements can be currently implemented even with existing 4G/LTE. Nevertheless, as AR/VR devices acquire higher resolutions and quality the required Broadband Connectivity, Latency (both RAN and Network) as well as Throughput will stretch existing networks to their limits. It is only a matter of time before even rudimentary AR/VR Applications /Services will be unable to provide the expected User Experience over current 4G networks.

6 Identifying the opportunity for integrated multi-service solutions across platforms

The 5G-TOURS testbeds will verify the feasibility of delivering against the technical requirements set out per UC in sections 3, 4, and 5. The successful deployment of these UCs at scale will require efficient infrastructure solutions that bring deployment costs to a level where the benefits from these services outweigh the cost of deploying them. MNO enabled network slicing in 5G solutions claims to offer a cost-efficient, multi-service shared infrastructure solution. However, how much do the 5G-TOURS UCs lend themselves to being combined on shared infrastructure?

In this section, we:

- Recap on the motivation for multi-service, shared infrastructure in 5G networks;
- Revisit the technical requirements of the 5G-TOURS UCs jointly to understand areas of commonality and the overall requirements of a more efficient, shared, multi-service infrastructure set supporting combinations of UCs via network slicing;
- Consider the types of shared infrastructure deployment models that would be practical to deploy in the environments and coverage areas targeted by the UCs.

These observations will help to shape the business case model analysis being carried out in WP8 to understand the commercial viability of the proposed UCs.

6.1 Shared, multi-service infrastructure delivers cost efficiencies

The 5G-TOURS architecture is a virtualised architecture supporting network slicing. From a commercial and economic perspective, the two key drivers for network slicing are:

- Supporting new connectivity services to new user groups and hence unlocking new revenue models.
- Reducing the cost of infrastructure and equipment by delivering differentiated services from a single shared infrastructure (set rather than via multiple bespoke networks).

The second of the above points has been analysed in the EC 5G-NORMA (5G-NORMA, 2017) and 5G-MoNArch (5G-MoNArch, 2019) projects for a range of UCs in London and Hamburg respectively. These have shown that, in general, the wider the range of services and tenants accommodated on the same shared infrastructure set, the better the improvement in Return on Investment (RoI) for the service provider. For example, if an existing mobile network is repurposed to deliver one high reliability service, then the incremental cost of facilitating a second high reliability service tends to be less than for the first service as the initial repurposing of the network for high reliability has already been done.

With this in mind, we next examine the technical requirements of the 5G-TOURS UCs jointly to identify the potential for shared infrastructure and hence cost savings.

6.2 Technical requirements for multi-service infrastructure supporting the 5G-TOURS UCs

6.2.1 Service types / Slices

Table 29 categorises the use case analysts' views on the network service / slice types required per UC in terms of the three core slice categories of:

- URLLC,
- mMTC,
- eMBB.

This is also presented graphically in Figure 46. These both show that:

- All three dimensions of URLLC, mMTC and eMBB are required to support the 5G-TOURS UCs.
- There is no distinct bias in the joint requirements towards one of the three core slice types.

Table 29: Service types/slices for the 13 UCs of 5G-TOURS

	5G Tours Service types / slices			
Areas	***Use Cases***	***URLLC***	***mMTC***	**eMBB**
Touristic city	**Augmented Tourism Experiense**	√	√	√
	Telepresense	√	√	√
	Robot-Assisted Museum Guide	√		√
	High-Quality Video Services Distribution	√		√
	Distributed Video Production	√		√
Safe city	**Remote health Monitoring**	√	√	
	Teleguidance for Diagnostics and Intervention sup.	√		√
	Wireless Operating Room	√		√
	Optimal Ambulance Routing		√	
Mobility-efficient city	**Smart Parking Management**		√	
	Video Enhanced Ground Based Mov. Vehicle			√
	Emergency Airport Evacuation	√	√	
	AR/VR Enhanced Educational Bus Excersion			√
	total	**9**	**6**	**9**
		69,23%	**46,15%**	**69,23%**

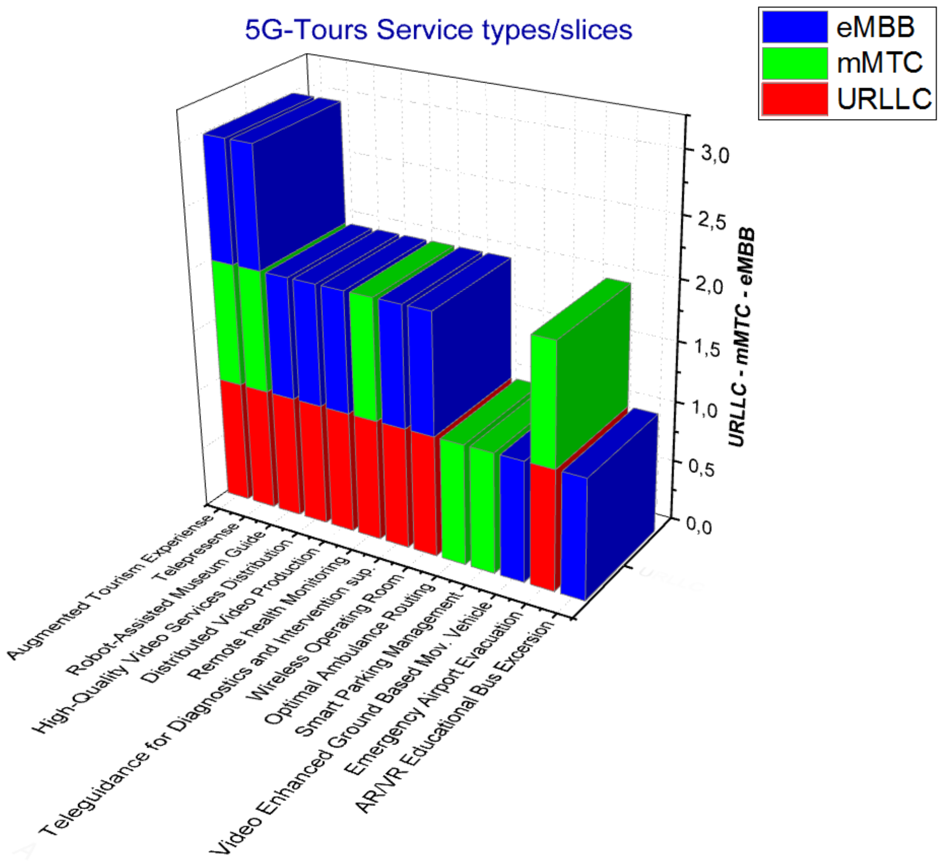


Figure 46: Service types/slices requirements per UC scenario

6.2.2 User requirements

In Table 30, the user requirements for all 13 5G-TOURS UCs are presented. This is derived from the more detailed assessment of each UC in sections 3, 4 and 5.

Table 30: Overall user requirements for the 13 UCs of 5G-TOURS

Areas	*Use Cases*	*Video Reception*	Video Transmission	Voice Communication	Data Reception (DL)	*Data Transmission (UL)*	*Mobility*	Location Information	Fast Response (Low Latency)	*Reliability/ Availability*	*Security / Privacy*	Service / Traffic Type	*Interactivity & Space Dependency*	*Edge Computing*	*Edge Storage*	*Battery Life*	*other*
Touristic city	Augmented Tourism Experiense	Yes	No	No	High	Low	Walking-Runnung speed	High	Very fast	low	Medium	St. High, Br.Medium, Sp.Medium	Medium Dencity /medium	no	yes	low	n/a
	Telepresense	yes	yes	yes	low	Low	Walking-Runnung speed	High	Very fast	medium	baseline	St.medium, Sp.high, St. low	Medium Dencity medium	yes	no	n/a	n/a
	Robot-Assisted Museum Guide	yes	yes	yes	medium	medium	Walking-Runnung speed	High	Very fast	medium	baseline	sustained medium	sparse high	yes	no	n/a	n/a
	High-Quality Video Services Distribution	Yes	yes	No	High	Low	Medium+walking running+stationary	Low	Very fast	medium	baseline	sustained high	Medium Dencity low	yes	no	medium	n/a
	Distributed Video Production	No	yes	Yes	low	High	Walking-Runnung speed / stationary	low	Very fast	high	baseline	sustained high	dense high	yes	yes	low	n/a
Safe city	Remote health Monitoring	No	No	No	medium	medium	walking speed	medium	Very fast	high	high	sustained medium	Medium density low	yes	no	low	n/a
	Teleguidance for Diagnostics and Intervention sup.	Yes	yes	yes	High	High	medium speed	low	fast	high	ultra-high	st. high, Br. Low,	n/a	n/a	n/a	n/a	n/a
	Wireless Operating Room	yes	yes	yes	none	none	stationary	none	slow	low	high	st. high	Medium density low	no	no	low	n/a
	Optimal Ambulance Routing	no	no	no	medium	medium	medium	medium	Very fast	high	medium	sustained medium	Medium density low	yes	no	low	n/a
Mobility-efficient city	Smart Parking Management	no	no	no	medium	Low	medium	high	Very fast	high	baseline	sporadic medium	medium density medium	no	no	medium	n/a
	Video Enhanced Ground Based Mov. Vehicle	yes	no	no	high	High	high	high	fast	high	high	Bursty high	sparse medium	no	yes	high	n/a
	Emergency Airport Evacuation	No	no	no	high	none	medium	high	fast	high	high	Bursty high	Dense medium	no	no	medium	n/a
	AR/VR Enhanced Educational Bus Excersion	yes	no	no	high	medium	Medium speed	no	fast	low	medium	Bursty high	dense high	yes	yes	low	n/a

Based on Table 30, Table 31 below reports the number of UCs for which each identified user requirement metric is important or not. Table 31 is presented graphically in Figure 47. This helps to identify common areas across the UCs and potential for infrastructure sharing. Common user requirements across the UCs include support for:

- Video transmission and reception, implying high bandwidth requirements for both uplink and downlink;
- Accurate location information;
- Fast response times, implying low latency connections (and potentially edge computing);
- Secure and reliable connections.

Table 31: Number of UCs per Requirement metrics

	Metrics					
User Requirements	n/a	Yes	No	High	Medium	Low
Video Reception		8	5			
Video Transmission		6	7			
Voice Communication		5	8			
Data Reception (DL)	1			6	4	2
Data Transmission (UL)	2			3	4	4
Mobility				1	6	6
Location Information	2			6	2	3
Fast Response (Low Latency)				8	4	1
Reliability/Availability				7	3	3
Security / Privacy				5	3	5
Service / Traffic type - Sustained				4	4	1
Service / Traffic type - Bursty				3	1	1
Service / Traffic type - Sporadic)				1	2	
Interactivity & Space Dependency - Dense				2	1	
Interactivity & Space Dependency - Medium					3	3
Interactivity & Space Dependency - Sparse				1	1	
Edge Computing	1	7	5			
Edge Storage	1	4	8			
Battery Life	3			1	3	6
other	13					

Then a histogram of the numbers of UCs for each one of the user requirements is illustrated in Figure 47.

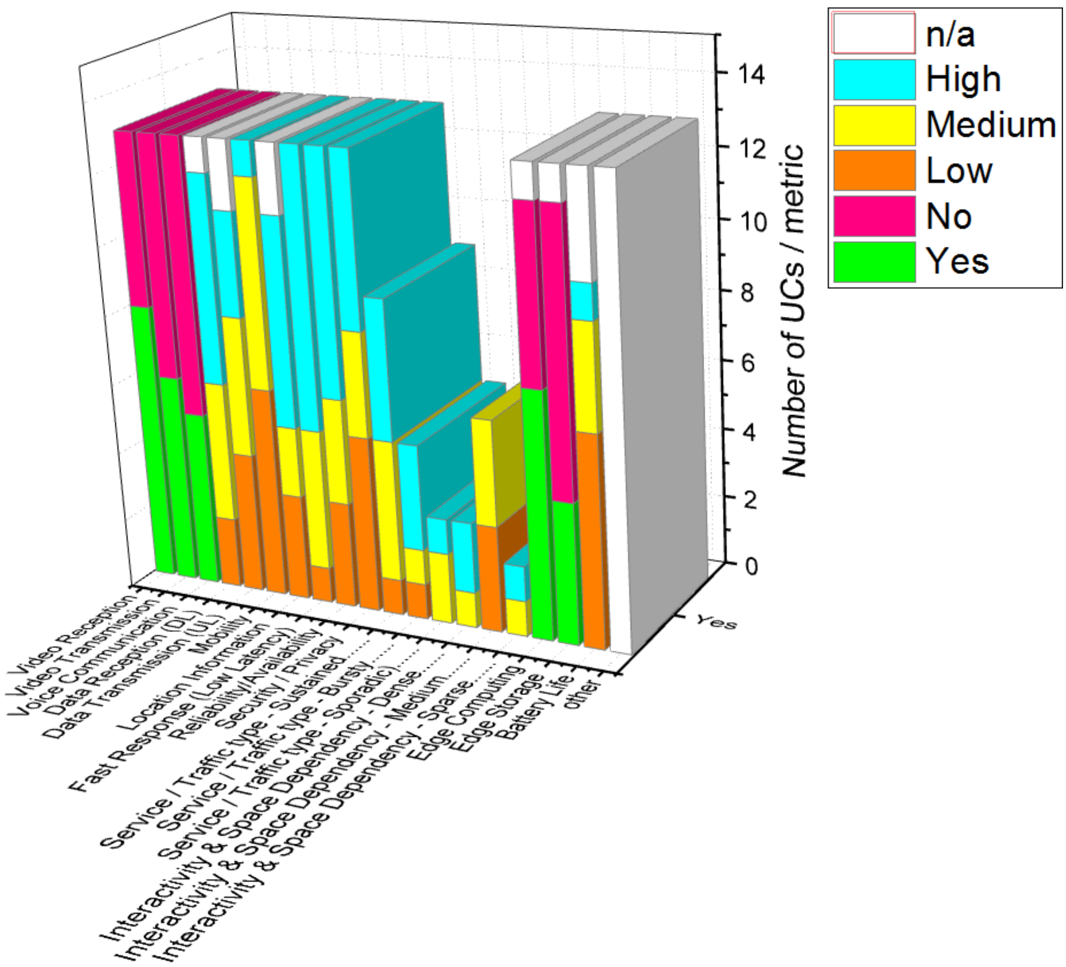


Figure 47: Number of UCs per user requirement matrix

6.2.3 Network Requirements

As a high-level feasibility analysis we survey the network features or requirements that are asserted the user and the implied service/slice requirements. In some UCs, the target performance level needed for particular network requirements is sufficiently covered by 4G technologies. In other cases, enhancements brought by the 5G-NR air interface and 5G network architecture are required to meet the target performance level. However, in some UCs, we have identified that a "standard" wide area commercial eMBB focused 5G network deployment would not be enough to meet the network requirements implied by the user and service/slice requirements. An aggregate view across each requirement category has been obtained (Table 32) by assessing requirements against the following criteria:

1. Within 4G capabilities (Covered by 4G);
2. Within a standard wide area commercial eMBB focused 5G network's capabilities (Need 5G);
3. Exceeding the capabilities of the standard 5G network above (Exceed 5G).

Not all UCs have an entry against a requirement category, thus some categories will not total 100% across "Covered by 4G" and "Need 5G". In the first instance the requirements are assessed against "covered by 4G" where they are not, they are allocated to "Need 5G". However, as has been identified in the individual UC analysis sections some user and derived network requirements are pointing to requirements potentially exceeding 5G. Thus, of those UC requirements that "need 5G" a percentage of those that are at risk of exceeding a benchmark 5G requirement is noted. Latency, Reliability, Capacity and Location accuracy emerge as requirement categories that should be carefully monitored in latter stages of the project during requirements validation.

Table 32: Percentage of network requirements covered by 4G or 5G or exceed 5G

Network Requirements	Covered by 4G	Need 5G	Exceed 5G
Network Latency (e2e)	35,3%	64,7%	11,8%
RAN Latency (one way)	41,2%	58,8%	0,0%
Throughput	82,4%	17,6%	0,0%
Reliability	0,0%	100,0%	82,4%
Network Slicing	0,0%	94,1%	0,0%
Mobility	100,0%	0,0%	0,0%
Broadband Connectivity	70,6%	17,6%	0,0%
Capacity	11,8%	64,7%	52,9%
Device Density	58,8%	17,6%	0,0%
Location Accuracy	0,0%	76,5%	35,3%

Figure 48 focuses on the network features where the 4G and "standard" 5G can address the target performance levels of the UCs. This highlights the typical network features where there is a clear requirement for evolving the existing 4G network to support these 5G features. Distinct 5G network features most required are reliability and network slicing.

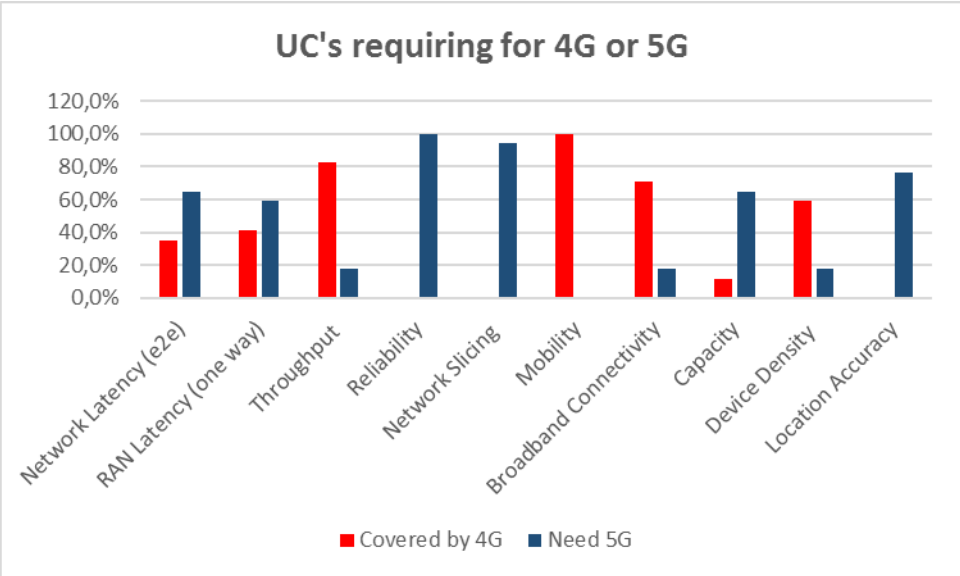


Figure 48: 5G-TOURS UCs requiring 4G or 5G

However, the target performance level in some network requirement categories for some of the UCs exceeds the expected performance levels of "standard" 5G network deployments. An analysis of these is presented in Figure 49. This helps to identify areas where standard multi-service 5G networks might be stressed by particular UCs and require some repurposing and additional network infrastructure resulting in higher cost. The network requirements potentially exceeding "standard" 5G network capabilities identified are:

- Capacity;
- Location Accuracy;
- Reliability and finally
- Network Latency.

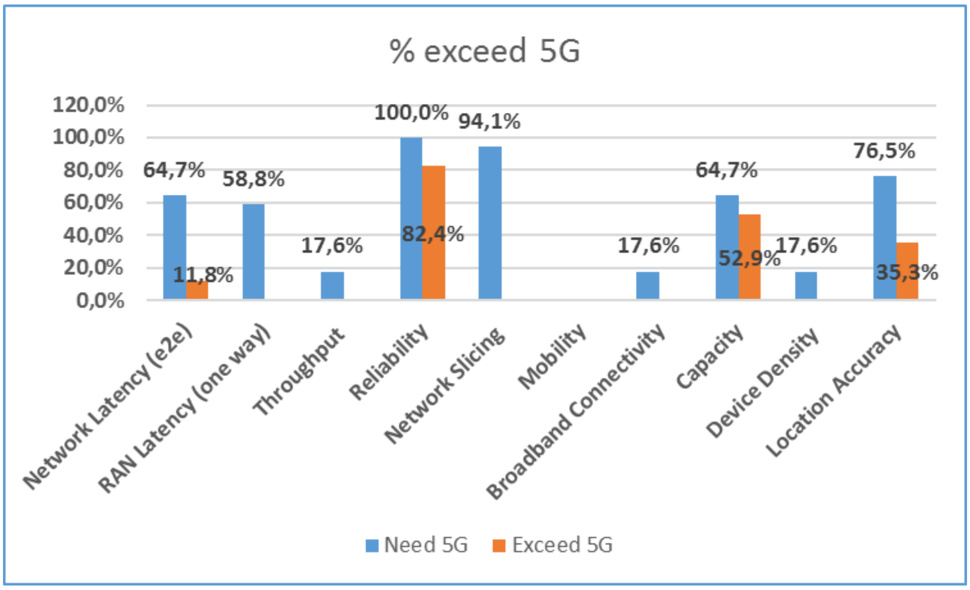


Figure 49: Percentages of UC's requirements that need 5G or exceed 5G

Each of these can be mitigated by additional infrastructure or technologies, with related cost implications, as follows:

- To satisfy additional Capacity requirements careful planning of the Radio Access Network and expansion of the Network throughput Resources (via additional frequency bands, densification of sites, higher orders of MIMO etc.) is usually applied.
- To provide the ultra-high Location Accuracy other positioning modalities need to be considered. This solution is complicated, however, when mobility is also required.
- Extra Reliability can be addressed by planning redundancy in resources and installing fully (in every aspect) redundant passive and active equipment / components & infrastructure so the requested reliability is achieved at the expense of cost and potentially passed on prices.
- Network Latency can be improved at a cost by making use of edge computing. This, however, imposes limits on the location and distance between the actors of certain UCs (such as the distance between the Operator and Machine).

The analysis here provides valuable insight into the features that 5G Network technology developments should focus on and how this should be done in order to better serve the needs of the end-users. Even though it appears that some UC requirements cannot be met easily by 5G technology, one should keep in mind that first time users/deployment tend to over specify requirements in order to have a large enough safety margin for successful delivery. Usually after first deployment some requirements can be relaxed or even corrective action can be taken so services can be implemented without straining the network resources to their limit, or making implementation costly.

6.3 Opportunity for shared infrastructure deployment models for the 5G-TOURS UCs

Finally, we consider the types of shared infrastructure deployment models that would be practical to apply in the environments and coverage areas targeted by the 5G-TOURS UCs. The commercial constructs or business models are in the domain of WP8 to investigate. However, based on the sequence diagrams, user and network requirements, we can form initial views regarding the type of network deployment. To do this, we consider the physical locations and coverage areas of the services identified under each UC. If different UCs require service coverage in distinctly different and spatially separated geographic locations, then sharing infrastructure amongst these UCs will not be practical.

Figure 50 considers the service coverage areas required by each of the 5G-TOURS UCs. This shows that:

- Some UCs are focused on very **localised and mostly indoor locations**. These include:
    - The wireless operating theatre which is only applicable in clinical facilities;

    - Tele presence and robot-assisted museum guide and monitoring which will be limited to within the museum building;
    - Smart parking management, airport evacuation and video enhanced follow-me cars which will be limited to the airport campus (a mix of indoor and outdoor but localized area).
- Some UCs will require service over a relatively **large outdoor coverage area**. These include:
    - Augmented tourism experiences which will require city wide coverage to take in all outdoor points of interest and attractions;
    - High quality video services distribution and remote and distributed video production which might be roll out in regions initially and eventually required on a nationwide or wider basis;
    - Optimal ambulance routing and teleguidance for diagnostics and intervention support will be required wherever ambulances serve and so will need national coverage eventually. Similarly, remote health monitoring and emergency situation notification will want to reach patients in all parts of the country eventually;
    - AR/VR enhanced smart buses will require outdoor coverage over a wide enough area to incorporate the route from educational facilities to the points of interest being visited. This implies at least city wide if not nationwide coverage.

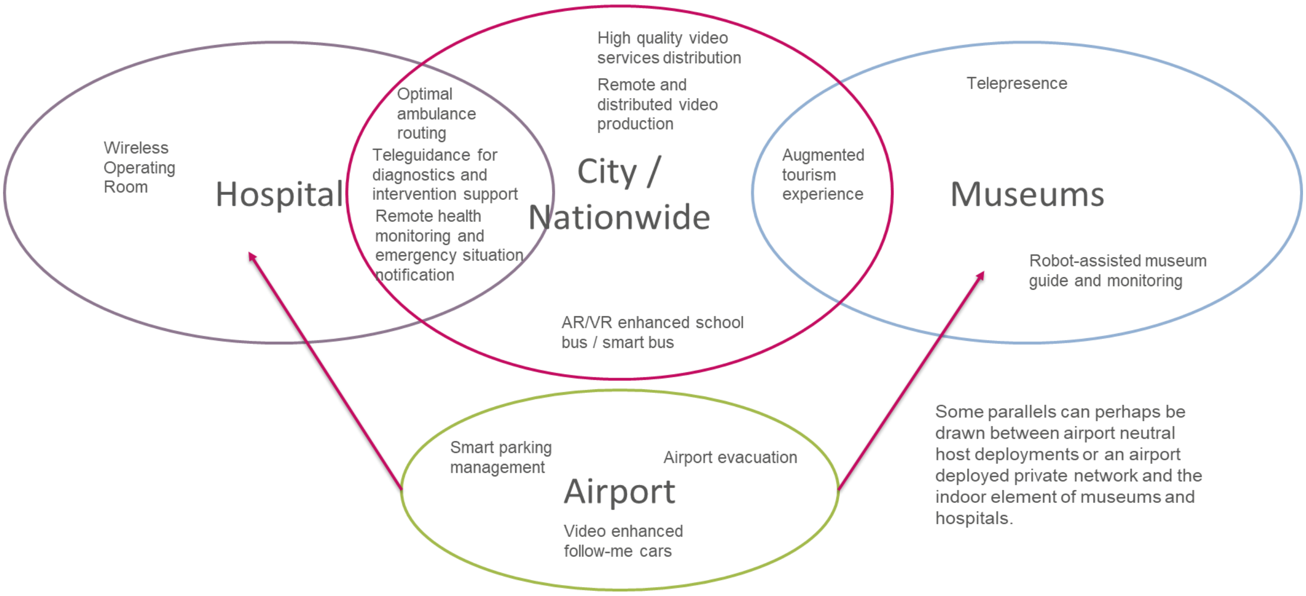


Figure 50: Overlaps in service coverage areas of the 5G-TOURS UCs

From Figure 50 we can see two distinct categories of network deployment solutions emerging:

1. **Wide area, outdoor focused networks**. These may provide services on a citywide or even nationwide basis. This has implications for the frequency bands and power levels required for these network deployments and hence for? the stakeholders who might be in a position to deploy such networks. These include existing MNOs with nationwide mobile spectrum licences. However, other less traditional models are emerging for these types of networks such as third-party infrastructure providers reusing (with prior agreement) MNO spectrum or localised spectrum to deploy shared infrastructure which then provides wholesale services to MNOs and other Communication Service Providers (CSPs).
2. **More localised, indoor and outdoor campus focused networks**. Whilst national level exclusive spectrum owner enabled deployments are still potentially the most likely approach such deployments are increasingly being facilitated by the assignment of mobile spectrum for use on a localised basis in some countries such as Germany, the Netherlands, US and UK. This allows verticals or more niche network providers to install and run their own localised private network independent of MNOs should they choose. Equally, MNOs may opt to acquire localised spectrum licences to provide more localised, private networks separate from their existing public network for particular vertical clients or even to use their existing wide area public network if existing coverage and service level is adequate.

In the case of both network deployment solution categories above, Figure 50 shows that there is the opportunity still to combine UCs on shared multi-service infrastructure sets. For example, a localized network deployed at an airport will require network slicing to provide a combination of mMTC focused smart parking, eMBB and URLLC focused video for enhanced follow-me cars and URLLC for airport evacuation. We can see that the most potential for sharing infrastructure comes from the UCs requiring wider area coverage. The wider the coverage area, the wider the range of UCs however implying that network slicing will be crucial to these multi-service wider area shared infrastructure sets.

There is also the option for deployment of **hybrid network style solutions** that combine localised private small cell networks with wider area coverage on a public network. This would be attractive for UCs that have some overlap in coverage area between requiring wider area coverage and transition onto localised private networks. Smart ambulances would be an example of this.

The network deployment types suggested here will be considered further in the business model analysis in WP8. This will include investigations on different network ownership and value flow models for the scenarios considered.

7 Commercial and economic drivers for the 5G-TOURS UCs

The previous chapters presented the technical requirements of the 5G-TOURS UCs. But to be deployed and operational in a commercial or public service setting, these UCs must deliver commercial and/or socio-economic benefits. This chapter presents an initial assessment of the benefits motivating the 5G-TOURS UCs. This will be expanded upon in the remainder of the 5G-TOURS project, with the final benefits assessment reported in Deliverable D2.3.

Potential infrastructure deployment models for the 5G-TOURS UCs have been described in Section 6. These will be expanded upon in WP8 in the remainder of the project to understand network dimensioning and related costs. However, network costs, driven by the technical requirements set in the previous chapters, only make up one part of a wireless service provider's business case. Revenue forecasts for new wireless services need to be compared against these network costs to understand return on investment and whether there are commercial drivers for a given use case. Revenues are in turn driven by the "value" (both commercial and socio-economic) that a wireless service can bring to a user, as this impacts their willingness to pay. It is this "value" or benefits assessment for each of the 5G-TOURS use cases that work package 2 will undertake throughout the project lifetime. This will then feed into the revenues and business model assessment in WP8.

In this chapter we:

- Introduce our framework for assessing the benefits and techno-economic value of UCs (section 7.1).
- Present the motivation for the 5G-TOURS UCs. UCs are grouped by vertical as follows:
    - UCs enhancing visitor experience (section 7.2);
    - UCs advancing media and entertainment (section 7.3);
    - UCs improving healthcare (section 7.4);
    - UCs enhancing airport operations (section 7.5);
    - UCs enhancing road and rail passenger experience (section 7.6);
- Conclude on the relative levels of value generated by each UC group and those most likely to attract willingness to pay amongst end users (section 7.7).

In this initial assessment, we make qualitative assertions on the economic value of the UCs and provide initial views on quantitative indicators. This sets the direction for a maturing quantitative analysis as the project proceeds. We also identify areas of uncertainty in our economic value assessment of the UCs and suggest approaches that could be taken to validate claims (such as user feedback from the 5G-TOURS testbeds). This will feed into Work Package 7, System integration and evaluation. Also, where relevant, we briefly discuss the impact of COVID-19 on the commercial and economic benefits of 5G-TOURS UCs and how these UCs are even more relevant in the current and post COVID-19 era.

7.1 5G-TOURS techno-economic assessment framework

Figure 51 shows our techno-economic assessment framework. This indicates the steps to assess the viability of deploying and operating the UCs in a commercial or public service setting. These include:

- Working with end user stakeholders to understand their **service requirements and usage profiles** that network costs and benefits can be dimensioned against.
- Assessing the **commercial business case** for a UC or group of UCs including:
    - Forecasting potential **revenues** based on willingness to pay for the envisaged UCs. This is driven by the operational benefits or private value which a UC delivers to the end user or tenant procuring the service. Willingness to pay for a service will consider any end user device or other service management platform costs that will be borne by the user.
    - Assessing **incremental costs** to repurpose the existing consumer focused network to support the more challenging technical requirements needed per UC. This includes initial capital expenditure (CAPEX) on network equipment and infrastructure installation as well as the ongoing operational expenditure (OPEX) of running that network and related supporting services.
    - Calculating Return on Investment (ROI) based on revenues vs. cost to determine if there is a commercial motivation for deploying the UCs.
- Quantifying the **social and wider economic benefits** of the UCs. The UCs may generate public value via:

  - Indirect economic benefits to other sectors in the economy.
  - Social benefits such as: environmental benefits (e.g. reductions in pollution), greater social inclusion of disadvantaged people, and better integration of remote and rural areas.

  If some UCs are not commercially viable, this step is particularly important.
- Forming a list of **candidate deployment options and commercial models** for the UCs, based on reviewing the business case and socio-economic value results. UCs with a low commercial ROI but high socio-economic value might still be viable to be deployed under a public service partnership model or other form of government intervention.
- Validating the candidate deployment options and commercial models with related stakeholders.
- Initial assessment of the economic changes and opportunities in the COVID and post COVID era for each UC. Due to the practicalities of the deliverable schedule, this will mainly be assessed in later deliverables.

We focus on the benefits elements of this framework in this work package and report. These form an input to work package 8, which covers the commercial exploitation of the 5G-TOURS UCs and the remaining elements of the framework.

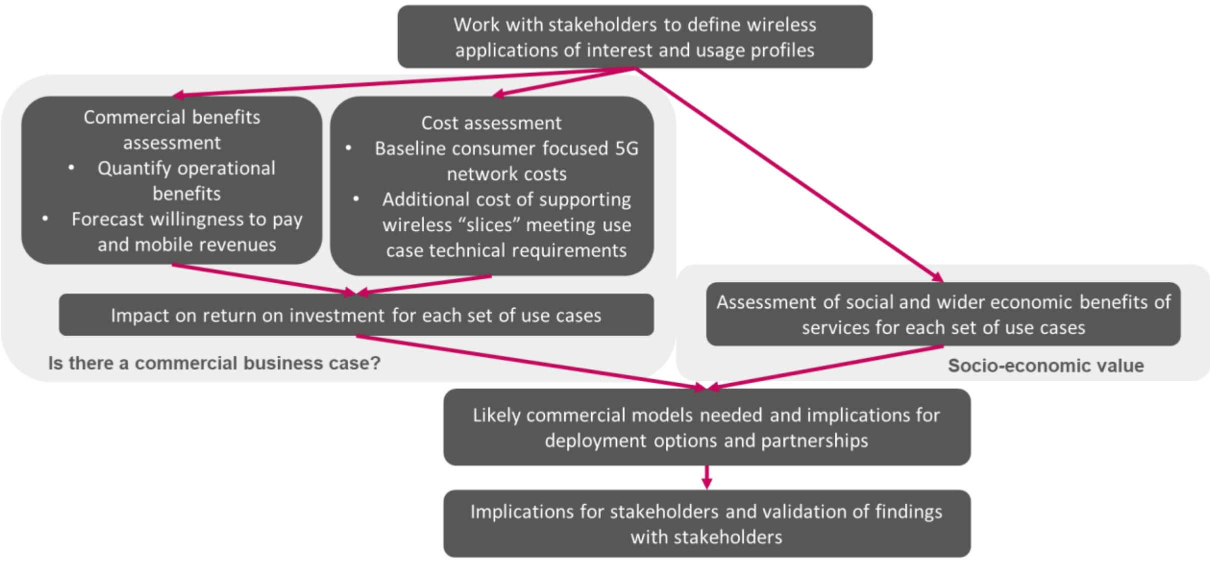


Figure 51: 5G-TOURS techno-economic assessment framework

7.1.1 Standard economic transactions and the concept of willingness to pay as a measure of value

We begin with the simplest type of economic transaction, that between an individual seller and buyer (i.e. the consumer of a product or service which can be a business or individual), to illustrate the underpinning of our value assessment framework. In basic economic theory, value relates to the concept of utility, the enjoyment or usefulness from consuming a product or service. However, utility is abstract and difficult to measure directly. Instead, economics looks at the consumer's choices between products which are determined by *relative* utility of different products, their prices and the consumer's income (J & Milgrom, 2004).

Therefore, our approach is to formulate a choice framework and this approach has been implicitly followed in previous analyses of the socioeconomic benefits of 5G UCs in projects such as 5G NORMA and 5G MoNArch. The choice framework says that consumers will purchase a product if their willingness to pay (WTP) – which represents the product's value to them in money terms – is greater than the price.

WTP is the key concept in our analysis of value generation and drives our approach to estimating value. It implicitly takes into account how much money the consumer has to spend overall and the other products it may want to spend its income on. Broadly speaking, the product (or group of products provided over a common platform) will be profitable if the price is greater than the relevant costs, though we are not examining profitability in this analysis.

7.1.2 Economic transactions in the 5G Platform context and more complex commercial relationships

In contrast to the simple economic transaction described above, the range of commercial relationships between the seller and buyer is more complex in the type of 5G UCs we are considering. If the buyer is another business, we define the commercial relationship as business to business (B2B) – the seller is the MNO/CSP and the business buying the service is a vertical, in the terminology of this project. If the buyer is an individual, we would define the commercial relationship as business to consumer (B2C), although none of the UCs in this project falls into this category.

The commercial relationship can be one step more complicated still. This is because many of the UCs involve services provided over a 5G enabled platform (by the MNO/CSP) to both individuals (here we introduce the term end-consumer[10]) and businesses (verticals), while the end-consumer and vertical also have a relationship with each other. We use the term business to business to consumer (B2B2C) to describe this commercial relationship.

Figure 52 below represents the B2B, B2C and B2B2C relationships diagrammatically.

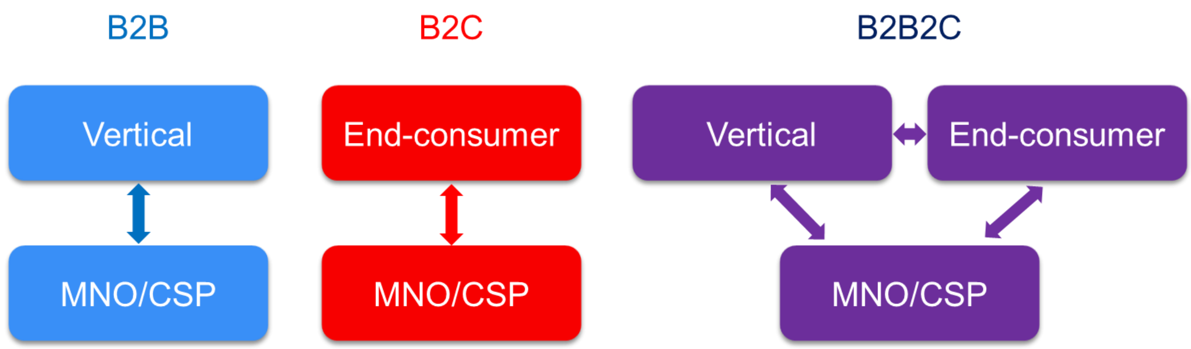


Figure 52: B2B and B2B2C relationships

The B2B2C relationship can be broken down into two further categories.

- The vertical's and the end-consumer's use of the service are directly aligned, for example a healthcare provider gets diagnostic information from a wearable health monitoring device. In these examples, the vertical is likely to be the main client of the 5G service provider and end-user devices may be provided through the vertical, particularly if specialist devices are needed. The end-consumer may be charged for use of the service and revenue generation may be an objective in its own right for the vertical.
- The vertical gets an indirect benefit from the use of the service, i.e. there is an externality[11] involved that is unrelated to the service the consumer uses. For example, most social media is used by end-consumers for social interaction, whereas businesses use data collected by the platform on the end-consumers to target advertising at sub-groups of the end-consumer user base. Sometimes, these situations are called two-sided markets to emphasise the fact that, where service platforms are concerned, there may be two sets of clients – other businesses and end-consumers – whose use of the platform is linked through externalities. It may be possible for end-consumers to use their own devices, depending on the services. The vertical will have an incentive to pay for the costs of the service to get the externality e.g. stimulating tourism visits by offering the 5G enriched experience at a reduced cost or free.

[10] We use the term "end-consumer" to identify individual customers that may use a platform and a vertical's services. However the term consumer can be used more widely to denote any purchaser including a business (e.g. a vertical) buying from another business (e.g. a platform provider).

[11] An externality or spin-off effect occurs when a transaction between a buyer and seller has a positive or negative impact on a third-party which was not involved in that transaction.

Table 33 below categorises the UCs in terms of these commercial relationships. This categorisation is useful because it tells us which areas to focus on in assessing the value generated by the UCs. A fuller description is provided in the following sections that discuss the UCs in detail.

Table 33: Classification of UCs by commercial relationship

UC	Commercial Relationship	
Augmented tourism experience	B2B2C	Vertical (museum, tour operator) and end-consumer (visitor) both use the 5G platform
Telepresence	B2B2C	Vertical (museum, tour operator) and end-consumer (visitor) both use the 5G platform
Robot-assisted museum guide and monitoring	B2B2C	Vertical (museum, tour operator) and end-consumer (visitor) both use the 5G platform
High quality video services distribution	B2B2C	Vertical (media provider) and end-consumer (viewer) both use the 5G platform
Remote and distributed video production	B2B	The vertical (media producer) is sole customer for the 5G platform
Remote health monitoring and emergency situation notification	B2B2C	Vertical (health and social care provider) and end-consumer (patient) both use the 5G platform
Teleguidance for diagnostics and intervention support	B2B	The vertical (remote healthcare specialist) is sole customer for the 5G platform
Wireless Operating Room	B2B	The vertical (healthcare provider) is sole customer for the 5G platform
Optimal ambulance routing	B2B	The vertical (healthcare: ambulance service) is sole customer for the 5G platform
Smart parking management	B2B2C	Vertical (airport) and end-consumer (traveller) both use the 5G platform
Airport evacuation	B2B	The vertical (airport) is sole customer for the 5G platform
Video enhanced follow-me cars	B2B	The vertical (airport) is sole customer for the 5G platform
AR/VR enhanced smart bus	B2B2C	Vertical (airport) and end-consumer (traveller) both use the 5G platform

7.1.3 Sources of value in the context of the 5G platform environment and its commercial relationships

WTP is still the key means of estimating value in these more varied commercial relationships. One way of estimating WTP is to estimate a demand curve which measures how consumers respond to changes in price. In some cases, historical information on how consumers have reacted to price changes is available to do this. However, this approach cannot be used for new services since historical information is not available. Statistical surveys can be used to ask consumers about their potential demand for new services and how it varies with price. Alternatively, if any existing services are substitutes for the new service, WTP for those existing services can be used to inform WTP for the new service.

The closer a substitute of an existing service is to a new service the better an indicator it will be. In our analysis, we firstly assess whether there are any existing substitutes and then we assess how close they are to the new service. We distinguish between two main cases:

- Where the UC is an enhancement to an existing service, substitutes for that service exist and past choices in terms of prices paid and take-up can give an indication of value (and indeed the potential demand for that service). The greater the enhancement, the poorer existing services will be as substitutes;
- Other UCs tend towards totally new services. The more innovative the UC are, the less likely the substitutes are to represent the full value. For example, telepresence at a museum is a substitute for visiting

in person, however an extended reality service may also enrich the virtual visit so much that it would be impossible to replicate in a real-life context.

Where there are no close substitutes and the UC is providing new functionality to businesses or new services to end-users, we can simulate the user choice by looking at:

- The costs that could be saved due to the new service;
- Increases in productivity due to greater efficiency that an innovation allows; and
- The ability for the vertical to generate revenue (directly or indirectly) from end-consumers in the B2B2C UCs.

As an illustration, teleworking generates direct economic benefits by saving commuting costs for employees and office space costs for employers. It also generates social benefits by reducing the environmental costs of greenhouse gas emissions and traffic congestion. ımproved productivity also creates direct economic benefits allowing firms to produce the same volume of goods with fewer resources. It may also generate social benefits. For example, smart buses may enable higher quality (and hence higher productivity) educational experiences and better-quality education will also bring a benefit to society.

In the following sections, we use the above framework to review the motivation for each UC and the most appropriate approach for assessing the value and willingness to pay for the services proposed under the UC groups. This will be expanded upon as the project progresses and, where relevant, re-enforced by validation via end user surveys linked to the testbed events in work package 7.

The individual UCs have been grouped under five headings which relate to a specific vertical and/or a 5G application platform under which they could be provided:

- Enhancing visitor experience;
- Media and entertainment;
- Improving healthcare;
- Enhanced airport operations;
- Enhanced road and rail passenger experience.

7.2 UCs enhancing visitor experience

We group the following three UCs under our 5G platform[12] for enhancing visitor experience for cultural institutions such as museums and in tourism more generally in indoor and outdoor situations. The UCs are:

- Augmented tourism experience;
- Remote tourism;
- Telepresence;
- Robot-assisted museum guide and monitoring.

The logic behind grouping the UCs is that a tourism business or cultural institution might use any one of the three UCs, or a combination thereof for enhancing visitor experiences. The organisation will conceive of the combination of services it wants to provide as a whole and buy the 5G applications that support it (ideally as a package). Moreover, it may develop a common set of inputs to serve the combination of UCs, e.g. video content used to support a remote telepresence user may be re-purposed for an on-site augmented tourism experience provided over augmented reality. The mix of UCs will vary by organisation and depend upon its objectives and the nature of end-consumer demand.

[12] This is a term we use to functionally represent the provision of 5G connectivity provided by MNOs and CSPs. It is not intended to be a technical description of the network architecture. The term also ties into another meaning of the word platform as a facility that is used to provide multiple services that have some costs in common, and which generates economies of scope across the services.

7.2.1 Benefits to the vertical

The UCs in this category are all B2B2C services since the main customers for the 5G platform will be museums, tourist sites, city tourism agencies and private businesses such as tour guiding and they provide services to end-consumers – tourists or visitors – which enrich or enhance the visitor's experience. An example of such a service is the Domus Aurea in Rome which enables visitors to experience the structure as it originally was through Virtual Reality (VR) and video narration (coopculture, n.d.). The VR experience is included within the standard entry price of €20. Services can be delivered in a range of ways, video content, extended reality etc. to a range of devices including mobile handsets, VR headsets, tablets and so on.

Innovative services are also being developed using Augmented Reality (AR) both in cultural tourism and other forms of tourism e.g. those connected to sport and the natural world. However, many of these current services are adapted to work offline or to fixed terminals and do not rely significantly on mobile data connectivity. Nevertheless, they illustrate potential interest in AR tourism apps.

For example, a travel app on the iTunes platform provides an offline, AR enriched visitor experience by over-laying information about points of interest on a camera image captured on a tablet screen in Florence (Garcia, n.d.). Several skiing apps, e.g. the Skadi app, use AR to provide information about: ski itineraries adapted to user skill levels; amenities; levels of crowding and can even introduce gaming elements similar to the way Pokemon Go operates (Telegraph, 2019). Only the real-time updates require connectivity, however. The rest of the functions work offline. Zoos and other outdoor centres are also likely to be good candidates for the success-ful use of AR services. For example, Phillip Island penguin reserve in Australia has integrated AR technology into what it calls an immersive experience, separate from general site admission (Phillip Island, n.d.) and charges AUS$18 for a standard entry. We note, however, that the AR service is projected onto fixed facilities within the centre, rather than to visitors' devices. Currently there appears to be more momentum behind AR services be-cause visitors can roam with their devices over the entire cultural site whereas VR requires a dedicated space for safety reasons.

We assume that it is necessary that the vertical buys a customised service from the 5G platform provider in order to obtain the necessary functionality for a fully mobile, connected service to end-consumers. As a corol-lary, we assume that proprietary networks, e.g. those using unlicensed spectrum, are unlikely to provide the necessary quality of service for these enhanced tourism UCs; the limited nature of the XR cultural and tourism apps currently being provided suggests this is the case, though it is possible this could change in the future. This assumption is important in judging the availability of substitutes and the vertical's WTP for a customised ser-vice.

The scope for generating value arises from the two main models for the interaction between the tourism or cultural service and the visitor and depends on the nature of the service and the business/institution's goals.

- For cultural venues, 5G applications could be provided free or at low cost so that the enriched experi-ence attracts more people and leads to increased revenue. It may also help to meet wider goals (which may be particularly important for cultural institutions) such as;
  - Accessibility and reach - tourist sites may become more accessible to hitherto under-repre-sented groups. For example, extended Reality (XR) applications may make cultural and histor-ical tourism more relevant to young people used to digital leisure activities such as gaming and may even borrow some techniques from video games. Robot-guides may facilitate and enrich access for people with some types of disability.
  - Education – several museums have been exploring the potential of XR in this respect including the British Museum and Océanopolis, Brest offering an immersive VR experience that is both leisure and educational (b-com, n.d.). In 2019, the typical price for a 15-minute immersive VR session was €8 on top of the admission price (OceanOpolis, n.d.). This is the classic two-sided market situation with an externality between the business and the end-user;
- As some of the examples in the bulleted list above show, museums and other tourism businesses may also have scope to sell the augmented tourism experience as a premium or additional service to a stand-ard visit, as a way of generating extra revenue.
- A third option would be an advertising funded service that is free to the end-consumer. For example, a AR app that highlights local points of interest and provides itineraries might offer discounts from local

businesses, though this may have to be done sensitively, and with a clear demarcation between advertorial and non-advertorial content, so as not to detract significantly from the overall experience.

The most obvious substitutes for the augmented tourism experience and robot-assisted museum guide UCs are: audio-guides; human guides or non-interactive tourism apps that are not sensitive to location or context. None of these provides the level of enriched or immersive experience that well-designed implementations of the 5G UCs could provide.

For example, human guides can tailor information closely to visitors' knowledge and understanding, particularly the smaller the group being guided. However, it would be costly to replicate the level of control that an automated guided tour could offer because it would require a large number of skilled human guides to serve the same number of visitors as an XR guide. Moreover, a human guided tour clearly cannot deliver the type of immersive A/V experience that these tourism UCs can provide.

Telepresence may be the application most suited to direct end-consumer charges, because the substitutes are quite limited, e.g. viewing cultural treasures through recorded video or photos is a poor substitute for the level of remote interaction and user control of the visit that telepresence allows. Telepresence may also increase the number of potential visitors because it may facilitate cheaper access for those on low incomes or who live far away and may not be able to afford the cost of travel to the cultural / tourist site. Telepresence also increases capacity in terms of the number simultaneous visitors.

So, in conclusion the 5G-TOURS UCs related to tourism could provide a significantly better end-consumer experience which could generate direct revenues from sales of premium visits or through increasing the number of standard visitors and tourists. Although the use of XR in cultural and tourism settings is in its early stages, and service may not have the full functionality that 5G can deliver, evidence suggests that they are attractive to end-consumers that some may be willing to pay for a premium experience.

For example, over 70,000 visitors paid for the Phillip Island AR experience mentioned above in 2018/19, roughly 7% of total visitors (Penguins, n.d.). This evidence should be enriched during the 5G-TOURS stakeholder activities. Some tourism app providers follow a dual strategy of offering both a free version and a paid for services with additional features. It is also possible that end-consumers could come to expect augmented tourism experiences in the future as standard and they become an essential part of the tourist offering rather than a premium service. However, the market is still in the early stages of testing technologies and visitor appetites for immersive experiences, hence it is difficult to draw firm conclusions at this stage.

7.2.2 Benefits to wider society, the economy and the environment

The local economy and especially the hospitality sector – hotels, restaurants, bars – will benefit as a result of a successful rollout of the 5G-TOURS UCs related to tourism. Enhancing tourism and visits to cultural institutions makes a city or town more attractive. Notwithstanding the current COVID-19 crisis (discussed later in this section), the overall amount of cultural and touristic activity should increase as a result, as should the overall number of visitors to places where these applications are available. This should translate into an increase in the proportion of income spent on tourism, both directly and indirectly on the wider local economy.

There is little information on which to estimate how much overall city tourism might increase as a result of the UCs, though we believe it could be significant given that increasing visitor numbers is one of the key objectives for the verticals in using these services. However, data on the average spend per tourist per night could be used to estimate the impact of say a 5% or 10% increase in tourism on wider revenues in the local economy. We could also look at current number of employees and revenue in the local hospitality sector to derive high level estimates of the potential impact of the UCs on employment.

As discussed in the previous section, institutions dealing with cultural heritage can have monetary and non-monetary objectives for using 5G applications to enrich the visitor's experience such as maximising access and education. Fulfilling these objectives creates wider benefits for society in terms of fostering an appreciation of cultural heritage. These benefits can include a more informed and engaged civil society, greater inclusion, better mental health and societal cohesion, although all these benefits are intangible and may be challenging to measure.

Education per se has a wider benefit to society in addition to the direct benefit to students. Better education arguably makes a society more stable and successful. Hence, augmenting educational experiences in relation to cultural heritage should bring wider benefits to society.

There are clear parallels between the social benefits of expanding access to cultural heritage and that of Public Service Broadcasting (PSB) (i.e. using television and radio as media to inform and educate, as well as to entertain). Detailed assessments of the social value of public service broadcasting and viewing willingness to pay extra for PSB services compared to fully commercial broadcasting have been made in the past: e.g. Ofcom's assessment of the value of public service broadcasting, (Ofcom, 2005). This type of study could be used as a proxy to estimate the potential social benefits in the absence of specific studies in the culture/tourism sectors.

In the longer term, COVID-19 could lead to changes in local and national governments' approach to tourism and amplify concerns that heavy touristic environments are negatively impacted by the volume of tourists, though tourism is economically essential. At a practical level, COVID-19 could in the short term severely restrict the number of visitors to many touristic cities, making immersive experiences, such as those suggested in 5G-TOURS, a viable alternative for visitors.

COVID-19 has stimulated discussion in Italy regarding "Intelligent Tourism". The augmented tourism UC may help mitigate the negative impact of rapidly increasing tourist volumes while retaining some of the economic benefit. For example, telepresence eliminates the need to travel to experience sites of cultural and touristic interest. Reduced travel, and in particular a reduction in the degree of heavy tourism, would have environmental benefits through lower greenhouse gas emission and congestion. It would also reduce the distortion of local economies that cities from Barcelona to Amsterdam have experienced, e.g. in the housing market.

However, this will depend on how much telepresence expands the addressable market, i.e. whether it is used by those who would have visited anyway or by those who would be unlikely ever to visit in person. We believe that telepresence may appeal most to those who would otherwise find it difficult to visit cultural sites for reasons such as cost, disability and distance, in which case the number of real-life visits and associated environmental and other impacts may not fall significantly.

On the other hand, if the augmented tourism UCs lead to increased real-life tourism, greenhouse gas emissions and congestion could actually rise. This effect can be taken into account alongside the wider economic benefits of tourism to local business discussed above.

7.2.3 Related verticals

Of all three UCs in this category, the use of telepresence to allow remote participation and enriched experiences appears to have the greatest potential application to other verticals.

Telepresence could be used in training and education to allow remote participation. Context sensitive A/V material could be developed to allow the remote attendee to access additional, rich information specific to a course. Attendees could remotely control cameras and even robotic elements to participate actively in learning, do laboratory work or engage in training simulations.

Telepresence and XR could also be used to provide an enriched sport experience. AR and VR could be used to bring the atmosphere or a big event to a remote spectator. Information on players and match statistics could be available on request, in a range of formats by the spectator.

7.3 UCs advancing media and entertainment

We have grouped the following two UCs together under our 5G platform for supporting media and entertainment:

- High quality video services distribution,
- Remote and distributed video production.

Both UCs are linked to the UCs enriching the visitor experience in tourism through facilitating the production and distribution of video, AR and VR content. However, they could equally be used as a means of producing and distributing more general content to end-consumers. The businesses that may want to use these services could be separate organisations or they may be vertically integrated over content production and distribution.

7.3.1 Benefits to the vertical

The high-quality video services distribution UC follows a B2B2C commercial relationship, whereas the remote and distributed video production UC follows a B2B business model. The video distribution UC seeks to provide high quality reception of content for end-consumers including in areas or at times of high demand, implying that content can be distributed more effectively using this 5G application than with legacy technologies. Hence, the value should flow from the higher quality of experience that end-consumers enjoy.

Assessing the willingness to pay of end-consumers is difficult because they are likely only to respond to significant changes in quality of experience. For example, if 5G is essential for an XR tourism application to be usable, significant value could be created for end users in this case. However, if 5G only increases reception quality but does not take it to the “next level”, i.e. no discrete jump in performance, the value to end-consumers will be limited. 5G may also impact quality of experience in other ways such as making content more dynamic and relevant to the user’s situation via distributed content.

The video production UC enables more dynamic and real time production of content. It derives its value from enabling the coordination of a high quality, reliable, mobile, multi-camera team on a video production shoot by a remote director. This may give directors more flexibility to film where it is difficult to maintain direct physical contact with the whole production team, for example at a large outdoor site or a live sporting event, replace costly cables and cable-work/time in all situations, enable a single studio to handle more events because the production/directors do not have to travel, ensure production consistency and simplicity (including in work force) by having only the camera and cameramen travel on site whereas the rest of the team uses the same equipment in the studio etc . It may also enable directors remotely to use production equipment that is not easily transportable. Further, it will reduce production costs for high quality events that up to now had to use expensive, cumbersome, complex and stationary satellite or fibre communications, replacing them with 5G.

The main source of cost savings in the video production UC is likely to be savings in overall production time and production equipment cost and travel as well as transmission costs (SATCOM, fibre), because 5G allows for instant synchronisation of video and sound across a number of individual camera operators and because more efficient collaboration reduces the need to reshoot scenes. It is difficult to predict these potential cost savings before the application is actually used. However, 5G-TOURS may be able to provide some initial indications of time savings during its lifetime. WTP will also be driven by the value to the producers of being able to operate more efficiently and flexibly. This could facilitate higher quality outcomes in creative terms. However, it is not clear how this might translate into revenues from museum/tourism companies or indirectly from end-consumers.

7.3.2 Benefits to wider society, the economy and the environment

Taking the narrow perspective of providing content for augmented tourism experiences, the wider socio-economic benefits will be driven by the same forces as the tourism UCs described earlier, i.e. the knock-on benefits of increased tourism and cultural visits on the local economy. These benefits would already be included in the assessment for the augmented tourism UCs themselves. Hence, to consider them as benefits additional to those from enriching visitor experiences would be double counting.

However, it may be possible to estimate what proportion of the overall wider economic and social benefits from enriched tourism and cultural experiences could be allocated to these UCs. We could use the share of the cost represented by media production and distribution in providing the enhanced tourism/cultural service as a rough indication of the share of value added of media production and distribution.

The media and content distribution UC might also generate additional societal benefits if it enables PSB content to reach new viewers. Traditional television channels (through which PSB TV is typically provided) have declined since the advent of social media. So, if new content distribution platforms could engage new viewers with PSB services, particularly younger people who are less like to watch traditional TV channels, the reach of PSB would increase. We could use existing studies on the value of PSB to estimate this potential social benefit.

7.4 UCs improving healthcare

We have grouped the following four UCs together under our 5G platform for improving healthcare:

- Remote health monitoring and emergency situation notification;
- Teleguidance for diagnostics and intervention support;
- Wireless Operating Room;
- Optimal ambulance routing.

Grouping them together recognises the connected nature of different elements of the sector from preventative care, primary care, ambulance services, hospitals and social care.

7.4.1 Benefits to the vertical

The UCs applying to the health care vertical all represent B2B applications (hence the healthcare provider is the 5G platform provider's customer) apart from the remote health monitoring UC. This latter UC could be considered either B2B or B2B2C depending on whether the wearable monitoring devices are bundled as part of the overall healthcare service or can be purchased independently by patients and are interoperable with multiple healthcare provider systems.

The UCs, with the exception of smart ambulance routeing, bring similar innovations to bear on healthcare – leveraging expertise through connecting specialists remotely and using communications and information sharing to facilitate collaborative working. While sharing these common themes, the UCs apply at different physical locations within the health system: in the home; for a person on the move; at the site of an emergency / at the ambulance; and in a local facility at the edges of the healthcare system (as opposed to a centralised facility). The concept of virtualising a room in the hospital and bringing it to the patient starts to emerge. This can also be thought of as virtually increasing the capacity of key hospital facilities and increasing the utilisation of medical expertise.

The value to the healthcare vertical across all the UCs is driven by their impact on healthcare providers' operations and can lead to booth increases in productivity and reductions in cost from organising production processes and procedures more efficiently.

Remote health monitoring, teleguidance for diagnostics, and the wireless operating room are all innovations which provide better quality treatment to patients which should lead to better health outcomes.

- Specialists can apply their skills and experience more quickly and more widely by being able to diagnose or even intervene in patient care remotely. Moreover, some clinicians are trialling the remote guidance of several procedures in parallel, enabling even more patients to be attended to by specialists (Karolinska, n.d.).
- Routine activities such as monitoring the taking of medicines and consultations for patients with chronic problems can be carried out at the home over a video link, without the need for visits to medical facilities. The Liverpool 5G Health and Social Care Testbed reported benefits for healthcare services in terms of reduced visits to general practitioners (13-30%) and hospitals (Liverpool5G, 2019).
- In situations in which senior specialists are unlikely to be present, e.g. at the scene of an accident, more junior personnel can provide better care with the assistance of a remote specialist.
- Medical issues may be identified earlier because doctors have better and more timely information on pathology; and
- Collaborative working techniques lead to better decision making within the healthcare team.

The obverse of these productivity increases is, in many cases, cost savings. For example, leveraging specialist skills enables patients to be diagnosed or treated with a less costly mix of resources without jeopardising quality of care. Scarce and costly resources in major hospitals can be freed up and less costly, lower utilised facilities can be used instead e.g. outpatient facilities in the wireless operating room UC. Faster recovery due to better patient outcomes will also free up patient beds, reducing the overall cost of treatment per patient.

Smart ambulance routeing also increases efficiency and can lead to cost savings (faster journey times imply the cost per ambulance callout declines) and increased productivity (each ambulance can do more trips on average per unit of time and the patient outcomes should improve as they can be treated more quickly). It also routes the ambulance to the most appropriate specialist venue which should also increase efficiency and deliver better patient outcomes.

These UCs all embody significant innovations in patient care, therefore the range of substitutes is limited in terms of practical alternative approaches that would achieve similar outcomes. For example, the wider coverage that specialists can deliver using teleguidance and telepresence could be replicated by employing significantly more specialists, but this would have a much greater cost that would not be practical. Similarly, replicating the benefits of the wireless operating room could involve expanding operating or intensive care facilities at major hospitals, but this would again be challenging on the grounds of cost and practicality. Remote monitoring, as used in the Liverpool 5G trial, is a substitute for GP and hospital visits. However, remote monitoring delivered additional benefits that GP/hospital visits do not replicate – patients reported feeling less lonely, appreciated the greater independence, and the ability to arrange consultations at times that were convenient to them.

In theory, legacy technologies could deliver some of the functionality needed for these UCs, and indeed there are already existing remote health monitoring services. However, 5G may have an advantage in delivering the levels of latency and the capacity required for high definition video and xR content especially where security and reliability concerns rule out WiFi or for services to ambulances and in outdoor locations where WiFi is not present. WiFi could be technically suitable for connecting individuals to healthcare services in the home or the office for services where reliability and security are not seen as critical. The potential to use WiFi as a substitute for 5G, security concerns notwithstanding, could therefore affect WTP to pay for the remote monitoring and diagnosis UC over 5G. LTE could also deliver some of the functionality of these 5G healthcare UCs, particularly remote monitoring. However, we believe that it is unlikely to provide the latency required for tele-guidance or the capacity to support the high-quality video required for the wireless operating room. This will be reviewed as the project progresses.

In general, however, WTP for these UCs will be driven mainly by productivity gains and cost savings. Healthcare services are often cost constrained, either by governments and/or the health insurance market, hence it may be best to frame the issue as the impact of productivity gains on healthcare costs. This fits in well with one of the 4 pillars of healthcare which encapsulate a set of organising principles that are being implemented in many healthcare systems around the world. (Sikka, et al., 2015).

Evidence is currently limited on the potential productivity gains available in healthcare. However, some 5G trials have looked at the impact of 5G on productivity in other settings, e.g. the use of remote specialist and AR services in maintenance of manufacturing equipment – e.g. in 2019 Worcester Bosch reported a 2% increase in productivity from a 5G trial which allowed senior engineers remotely to guide on-site maintenance of factory equipment (UK5G, 2019).

Another example of significant potential efficiency savings comes from the use of a web-based telehealth system developed by Moorfields hospital in London. Their remote referral system connected eye care specialists at several hospitals to community optometry via digital health platforms. It allows eye care provided in the community to receive input from specialists at eye hospitals, thus preventing unnecessary hospital visits. In their research, 54% of community optometrist referrals to main eye hospitals could be avoided. In addition, urgent referrals could be seen more quickly at hospitals, which is essential for the prevention of sight loss (Kern, et al., 2019).

Finally, smart ambulance trials such as that underway in the West Midlands 5G testbed in the UK, could be a useful source of data on productivity gains and clinical benefits if results emerge during the course of our analysis in 5G-TOURS. The trial is looking at teleguidance, haptic response equipment and the use of remote diagnostics in the ambulance (WMCA, 2019).

7.4.2 Benefits to wider society, the economy and the environment

These healthcare UCs will generate wider benefits in terms of: spin-off to the healthcare industry; benefits to patients (and indirectly to society through improved population health); and benefits to the environment.

The better patient outcomes resulting from all four UCs will lead to spin-offs or externalities in the wider healthcare sector, since they improve overall population health. If healthcare provision integrates its various components, these benefits will be internalised by the system and they will add to healthcare providers’ WTP for the UCs. However, if there are multiple separate healthcare providers, the spin-off effects will have to be counted separately and will not contribute to WTP for the 5G applications without government intervention.

The spin-off benefits include the following:

- Better diagnosis of medical problems reduces the overall cost of treatment per patient because earlier diagnosis often leads to less intensive, less complex treatment;
- Reduced probability of complications, resurgence of diseases and reduced susceptibility to other illnesses because patients recover better and more quickly;
- Reduced spending on recovery and rehabilitative care, allowing more effective use of these resources; and
- Reduced need for social care expenditure because patients with chronic conditions are healthier and can live longer independently.

Studies of improvements in detection and treatment for major diseases, such as cancer or cardio-vascular issues, and their longer-term impact on healthcare costs may offer an indication of the wider financial impact that better patient outcomes could provide.

Patients will benefit for many of the same reasons above. Faster treatment and better outcomes will lead to a better quality of life for patients. Remote health monitoring should also give suffers of chronic illnesses greater independence and security. These conditions account for a substantial proportion of healthcare spending, for example, the UK spent 10% of its total health budget on Type 2 diabetes in 2014 (NHS, 2015). A market exists already for remote monitoring devices and mobile health applications. Data on spending by individuals should give an insight into individual willingness to pay (as distinct from healthcare providers' WTP) for the remote health monitoring UC. However, it will be important to try to identify the additional benefits that the 5G UC brings over and above today's services. For example, if in the course of the project we can translate technical differences in functionality into differences in performance that end-consumers will understand, a survey method could be used to explore how much end-consumer value higher functionality.

The patient experience will also improve since care can be provided more conveniently in the home or outpatient clinic, saving time and, where relevant, giving patients more flexibility to manage their illnesses and fit their healthcare into their daily lives.

Finally, the environment will benefit from smart ambulance routeing, at least in theory. There should be a moderate but non-negligible impact on congestion and greenhouse gases from the optimisation of ambulance routes. However, we anticipate that the increase in productivity from smart ambulance routeing will manifest itself in more cases being dealt with per ambulance rather than a reduction in their travel time, thus limiting the final impact on the environment.

Reduced travel for patients should, however, have a modest environmental impact by way of a reduction in traffic congestion and greenhouse gases from personal transport.

7.4.3 Related verticals

There is scope for using these UCs in other sectors or situations. Although the UCs are very tailored to healthcare, the applications, especially the remote leveraging of specialist skills by telepresence and teleguidance, could be used more generally in a number of different settings.

AR and telepresence could be used in the maintenance of complex plant and equipment in manufacturing and in utilities such as energy and telecommunications, and there are already some trials in manufacturing settings such as the Worcester Bosch trial mentioned above. Similar applications could be developed for construction and architecture, e.g. for verifying progress against plans and addressing problems in real-time. For example, 5G-MoNArch investigated the use of AR in facilities construction work at the port of Hamburg. In addition, the UCs may apply to other emergency service contexts such as the fire service, policing and disaster response.

Finally, smart routeing technology could be used in other emergency service situations as above. It could also be used in a number of different environments from bin collection to logistics. However, these settings do not have the same requirement for emergency operation as ambulances.

7.5 UCs for enhanced airport operations

We have grouped the following three UCs together under our 5G platform for enhanced airport operations:

- Smart parking management;
- Airport evacuation;
- Video-enhanced ground-based moving vehicles.

Although the services are not necessarily linked to the same degree as in the healthcare platform, the airport operator would commission services under each of them, thus we consider them together.

7.5.1 Benefits to the vertical

The UCs in this setting fall into two distinct categories. The smart parking UC follows a B2B2C business model and illustrates a classic case of a two-sided market: the passenger uses the application to park more quickly and the airport benefits from the passenger spending more time in the airport.

The value to the airport in the smart parking UC comes from the extra expenditure of the passenger who spends more time in the airport because parking is faster. Hence, the airport will take a share of this extra spending through its charges to the shops and restaurants on its premises. Revenue growth from commercial activities such as retail is seen as increasingly important by airport operators given that other revenues, i.e. charges to airlines, are heavily regulated.

There is no direct substitute for smart parking since it is an enhancement to standard parking facilities, therefore the airport's WTP will depend on the potential additional revenues it can generate. Assumptions on the feasible savings in parking times could allow an estimation of the extra time passengers would have inside the airport terminal. This could enable high level estimates of the potential impact on retail spending though the relationship between spending and time spent in the terminal is unlikely to be one to one.

In contrast to smart parking, the airport evacuation and video enhanced follow-me car UCs both follow B2B business models and their main rationale is to increase safety and reduce costs through reducing the need for drivers (though new jobs may be created and redeployment may be possible in monitoring the follow-me cars). Within our framework of analysis, the value of these UCs can be thought of as deriving from greater operational efficiency in airport evacuation and airside / runway management. These efficiency gains should lead to cost savings and better outcomes in the follow-me car UC. However, the airport evacuation UC is focused more on enabling better outcomes in case of emergency, hence its value will derive from productivity gains in airport safety.

We can characterise this value and the associated willingness to pay as the cost of avoiding part of the potential loss in business resulting from landside (i.e. in the terminal) and airside incidents. Augmented airport evacuation does not prevent incidents but reduces the time taken for evacuation and should allow them to be dealt with more quickly, reducing damage and the time needed to re-open facilities. If the average annual number of incidents is small, the marginal value of this UC might be limited.

However, even if the value to the airport were limited, it is possible that deploying such systems could become a regulatory requirement if the potential costs to society in terms of the impact on human life (as discussed in the next sub-section) were significant.

The video enhanced follow-me cars can reduce the probability of airside incidents as well as assist in resolving them more quickly. Both effects would reduce runway down-time and the impact this has on the airport. If information were available on the number and cost of such incidents, estimates could be made of the potential benefits to the airport that could be delivered. However, we note that the potential impact may be difficult to predict in advance of putting UCs like these into practice, therefore any assessment will contain an element of speculation.

A final source of value to the airport is that these services also make it more attractive to passengers and airlines. Use of these services may come to be seen as a necessity to remain competitive or a source of competitive advantage where there are multiple airports serving the same domestic population or competing internationally as airline hubs. Hence, we could look at the potential impact of a marginal loss in market share, say 1%-5%, on the airport business.

7.5.2 Benefits to wider society, the economy and the environment

In the smart parking UC, the airport is unlikely to charge passengers to use the application because the value clearly lies in getting passengers into the airport more quickly and charging for smart parking would be a disincentive.

The value of smart parking to passengers is the time saved parking. This could be estimated by applying data typically produced by national statistical authorities on the value of leisure time to assumptions on average parking times and potential savings at the airport. Passengers will also value the convenience of smart parking and the greater certainty over their arrival time at the airport terminal. However, convenience is a more difficult benefit to assess using third party data. It would likely require the use of survey based statistical analysis, such as stated preference analyses, which could be carried out at the trial site.

There will also be some environmental benefit to faster parking since vehicles will spend less time searching for a parking space and hence emit fewer greenhouse gases. However, given that parking will probably represent a small proportion of the total travel time, on average, we do not expect this effect to be large.

The two safety related UCs have a clear wider benefit to society in terms of reducing potential loss of life and injury from landside and airside incidents. Data on the annual average number of such incidents and their typical impact on passenger and crew would help to establish estimates of the value that could be gained by introducing these UCs. As noted above, there will be an element of subjectivity in any assumptions on the potential effectiveness of these applications in advance of their use in real-life situations.

7.5.3 Related verticals

The smart parking and airport evacuation UCs can be extended to a number of other settings that have in common large venues attracting a large footfall and where many visitors arrive by car. This includes shopping centres, major railway stations, large hospitals, sports stadia, entertainment venues and museums. Educational establishments, particularly universities, may also be a target for the enhanced evacuation UC.

Venues such as sports stadia would benefit from offering smart parking in a similar fashion to airports through increased spend on food, drink and souvenirs on top of their revenues from admissions. Shopping centres could benefit even more since retail is their main business. Hospitals would benefit differently; the risk of patients being late for appointments and the associated disruptions would fall. However, these benefits are only likely to be significant at the largest hospitals, where there was significant congestion in parking.

There are fewer areas to which the video enhanced follow-me car UC can be extended because it relates to a more specific need than the other airport UCs considered. However, there may be applications in other dangerous environments where vehicles interact and the cost of an accident is high, for example, military operations and use in extractive industries such as mining.

7.6 UCs for enhanced road and rail passenger experience

The following UC falls under our value categorisation for enhanced road and rail passenger experience:

- AR/VR enhanced smart bus.

The model for this UC is bus or coach passenger transport, however we also consider other forms of passenger transport such as rail in our analysis.

7.6.1 Benefits to the vertical

This UC follows a B2B2C model where the "smart" bus (or another passenger transport) is equipped with AR and VR capability. The economic actors would be the provider of 5G connectivity, the bus operator, the purchaser of the enhanced educational / tourist information application and content creators of educational material and entertainment. There are several possibilities for how the value chain is organised and the relationships between these players. Figure 53 below illustrates some of the potential relationships. The arrows between the economic actors illustrate the possible flow of revenues between them.

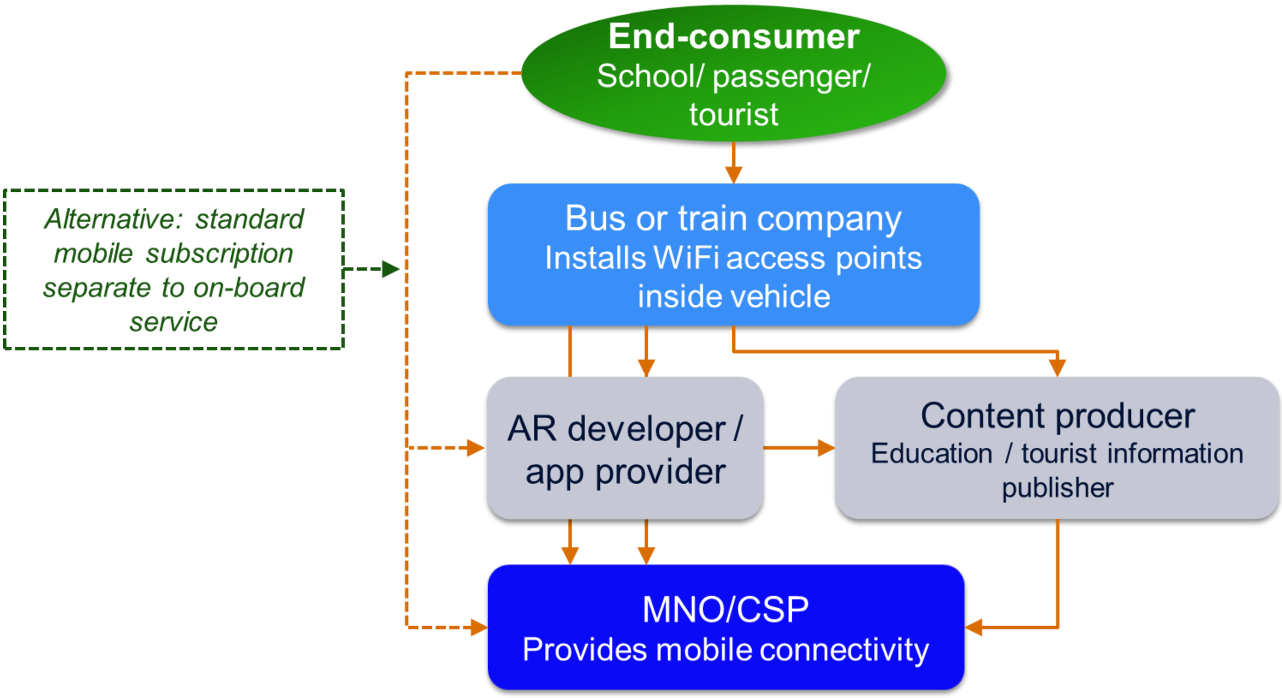


Figure 53: Example relationships in the enhanced road and rail passenger experience platform

We expect that schools (or universities), rather than students, would purchase the educational application. Schools may deal separately with bus operators and content creators or may want to purchase the services bundled together. Educational content is likely to be ready made and could be available from companies currently producing educational materials in other formats.

By contrast, in tourism, the cost of the service may be passed directly onto the tour operator's clients or absorbed by the tour operator as in the educational application. In addition, it may be cost effective for some tour operators to commission their own specific content if such material were to be used regularly. 5G connectivity may be bundled with the hire of the xR equipped bus, though large tourism operators may also decide to purchase 5G connectivity themselves in order to have more control of the service. Finally, it is possible that some tourism companies will operate their own xR equipped buses, and equally that bus operators could expand up the value chain into tourism services.

More generally, buses or trains could provide connectivity to the passenger to support in-vehicle entertainment to the passengers' own devices. This would be similar in approach to today's WiFi services (with an LTE or other link to the vehicle and WiFi to distribute the service inside) which are provided by certain bus operators in Europe – e.g. SNCF OuiBus in France, Alsa in Spain – and rail operators across Europe, particularly on high speed trains – e.g. Eurostar, ICE, Thalys, etc. Many of these services are currently provided free to passengers, though quality varies in terms of service availability, speed and download limits. Passengers have the alternative of using their own 4G services for mobile data, but quality is often limited.

The enhanced passenger experiences in education and tourism should enrich the passengers' journey. The quality of the experience increases, and this is the main driver of value. Willingness to pay for the enhanced experience by schools, tour companies or tourists will be difficult to calculate for several reasons:

- The driver of value is increased quality, therefore there are unlikely to be any cost savings in the wider educational system or the tour operation that could inform WTP;
- It appears difficult to deliver the XR augmented experience by other means hence there are unlikely to be any close substitutes from which WTP could be estimated;
- As a result, WTP will depend on the preferences of schools and tourists for the enhanced service. Schools could value this kind of service highly if it led to better results for pupils. This is clearly difficult to assess in advance or measure by analytical survey techniques. The impact of smart bus. on the overall attractiveness of tourism may be more amenable to survey analysis. The trial sites for this UC provide an opportunity for the project to collect this type of information.

The value of the more general in-vehicle entertainment service depends on the quality of the standard 5G service to the bus or train. If the standard service is not consistent enough to support services such as streaming video in the bus or train, like 4G today, there will be value to the passenger in having 5G connectivity distributed via on-board WiFi. However, the current tendency to provide free WiFi suggests that the end-consumer will continue to expect these services as a right and will not expect to pay for them at the point of use. It may be possible that fares could be increased to cover the cost of the service. However, passenger fares are often highly regulated and it may be difficult for operators to generate profit from the service. Indeed, operators may have to absorb some or all of the cost in order to remain competitive.

7.6.2 Benefits to wider society, the economy and the environment

We expect the benefits to wider society from this UC to be relatively limited. The local tourism-based economy could benefit, similar to the augmented tourism UCs. Making the journey more attractive to tourists could increase the overall number of tourist visits. However, an enhanced journey is at one remove from the tourist attraction itself, hence we believe that any spin-off effect would be lower than for the augmented tourism UCs discussed above. The need for educational and tourism-based content would also create added value and employment in the content creation sector.

Making public transport more attractive in relation to private vehicles could also benefit wide society through the environmental benefits of public transport use compared to cars. Of course, connectivity is only one factor of many that influence choice of the mode of transport, so that would limit the potential impact. A statistical analysis on the choice of transport mode taking into account 5G connectivity across various modes of public transport and private transport would help to illustrate the potential wider benefits through a potential increase in public transport use.

Currently, there are a limited number of studies in this area, but the evidence they provide is encouraging. (Hong, et al., 2019) finds a significant and positive association between the frequency of Internet use while travelling and the use of public transport for commuting. It also found that even for those who prefer cars to public transport, frequent Internet users were more likely to choose public transport if connectivity were available.

7.7 Conclusions on potential of the UCs

We can produce an indicative prioritisation of the potential socioeconomic impact of the UCs based on our analysis of the drivers of value above, together with information on the share of national income for the industrial sectors into which the UCs fall (which we present just below). This prioritisation is necessarily high level since the technical and commercial propositions for the UCs need to be further developed. During the course of this project, we envisage an iterative process between refining the UC prioritisation and developing the underlying technical and commercial analysis.

We use three criteria to assess the socioeconomic potential of the UCs:

- Contribution of the sector to national income, as measured by share of EU Gross Domestic Product (GDP);
- Potential wider socioeconomic impact; and
- Level of innovation – we measure this by how difficult it is to replicate the service using existing substitutes.

Ideally, we would also consider a fourth criterion, the potential need for the UC. The information to assess this is not yet available, though we intend to investigate this during the course of the project.

7.7.1 Economic importance of the verticals

Healthcare is by far the leading sector in terms of its contribution to GDP, accounting for 9.9% of EU GDP (eurostat, 2020), followed by tourism at 3.9% (European Parliament, 2020) and aviation at 2.1%. (Commission, 2020). Road and rail passenger transport accounts for 1.5% of GDP (eurostat, 2017), (European Commission, 2019). The audio-visual sector (excluding cinema) accounts for 0.7% of EU GDP (Council of Europe, 2020) (eurostat, 2020).

7.7.2 Ranking of the UCs potential

Table 34 below presents our high-level assessment of the socio economic potential of the UCs. We reiterate that this first stage analysis should be taken as indicative only.

Table 34: Indicative ranking of UCs against potential socioeconomic impact

UC	Relative economic size of sector	Wider socioeconomic benefit	Innovation/ difficulty to replicate	Total Score (out of 5)*
Augmented tourism experience	Medium	Medium	High	3.7
Telepresence	Medium	Medium	High	3.7
Robot-assisted museum guide and monitoring	Medium	Medium	High	3.7
High quality video services distribution	Low/ medium	Low / medium	Medium	2.3
Remote and distributed video production	Medium/High	Medium	Medium	3.3
Remote health monitoring and emergency situation notification	High	Medium / high	Medium	4
Teleguidance for diagnostics and intervention support	High	Medium	High	4.3
Wireless Operating Room	High	Medium	High	4.3
Optimal ambulance routing	High	Medium	Medium	3.7
Smart parking management	Medium	Low / medium	Low / medium	2.3
Airport evacuation	Medium	Low / medium	Low / medium	2.3
Video enhanced follow-me cars	Medium	Low / medium	High	3.3
Enhanced road and rail passenger experience	Medium	Medium	Medium	3

** We take the average score over the three criteria: low = 1, low / medium = 2, medium = 3, medium / high = 4 and high = 5.*

We conclude that the platform with the greatest potential to generate value is that for improving healthcare, followed by enhanced visitor experience. The enhanced airport operation (particularly video enhanced follow-me cars), media and entertainment and enhanced road and rail passenger experience platforms are next, followed closely by the media and entertainment platform.

8 Conclusions and next steps

This document provides the UC user, network and sequence diagrams to articulate the functional and performance requirements of the three 5G-TOURS City platforms at the level of abstraction typical of a System Design Requirements analysis. These requirements are agreed with architecture and system design experts in WP3 and, for each City location, derived in partnership with WP4, WP5 and WP6. These UC requirements have also been established in partnership with WP7, and will be taken forward in WP7 to determine the most appropriate way to measure performance against the required KPIs and develop verification and validation implementations.

User Requirements have been identified and defined and then translated into network and 5G-TOURS system requirements. This analysis was made per UC, where requirements have been framed in quantitative KPIs representations with spider diagrams. These diagrams help to visualise the needs of the vertical and illustrate a stretching of performance requirements above standard 4G offerings today. By mapping of both the 4G and 5G capability we can determine features in the transition from 4G to 5G and where particular features of 5G may increase value by enhancing the user or vertical experience.

At least one sequence diagram per UC has been included to better illustrate the context and the logic behind the UC, bringing entities together through functional interactions. The objective was to apply an approach that went beyond a less formal textual description as captured in D2.1 and that encouraged specificity where necessary. However, we are careful not to over specify, allowing developers the freedom in their implementation choices whilst removing ambiguity in an accessible way for project stakeholders in the vertical who are generally not experts in networking systems.

Requirements management in 5G-TOURS has not finished for WP2. It is not a one-way or waterfall process, but rather a concurrent or iterative research and development process. UC analysts have identified a need for validation of requirements, and in particular the User requirements. User expectations of 5G capabilities based on their desires as a vertical are in some cases exceeding expected standard 5G deployments, and in some instances even though 5G can meet the requirements, requirements are potentially over specified. Thus, WP2 has identified a need to, and shall, maintain user requirement dialogues through to project completion.

Preliminary socioeconomic considerations have also been provided with the intention of setting the direction of analysis for the next period of the project. The economic considerations in combination with the technical KPIs of the user and network and the associated economic actors will enable the formulation of a targeted analysis and engagement with stakeholders for validation activities but also provides a basis for the business model and business case analysis of WP8.

Initial evaluations of potential COVID-19 impact on the 5G-TOURS UCs, and of the post-COVID economic recovery opportunities, have commenced and are touched upon in this document. This aspect of the project is still under evaluation. Whilst a market communications positioning of the UCs from a dissemination and industrial liaison perspective is a fine goal in itself; there is in fact a genuine intent in the consortium to determine how 5G-TOURS can refine UC implementations to even more effectively demonstrate potential for supporting economic recovery from COVID-19. Therefore, whilst this document does capture the final UC System Design Requirements at this time, we do not rule out potentially significant enhancements to requirements during the next stages of 5G-TOURS as the implications of COVID-19 on verticals of interest to 5G-TOURS become apparent.

The phased delivery of the platforms will result in a continual evolution of deployed and available capabilities at each of the UC trial sites. This presents challenges for WP2, WP7 and WP8. UC and platform verification and validation relies on correlating technical performance measurements from the systems along with data gathered from users based on their Quality of Experience and willingness to pay responses. The general approach to phasing of deployment tied to the requirements captured in this document allows for the next stage of verification and validation planning to proceed so optimal timing can be determined.

During the analysis stimulated by the development of this document, 5G-TOURS has established requirements templates that have been populated with content that in essence provides an internal asset removing ambiguity around the specification of the 5G-TOURS UCs. These internal analysis assets consist of User and Network Performance Requirements, Radar Charts, UC Sequence Diagrams and Platform Context Diagrams. In essence, this document provides a snapshot at a point in the project where the UCs are finalised from a System Design

Requirement perspective. Nevertheless, as technical and business validation progress along with deployment and UC trials, material changes are inevitable. Some changes could have significant cost and timing implications for the project and may require authorisation by the 5G-TOURS Project Management Committee, whilst minor changes can be actioned at a WP2 level and flow through to other WPs. Dealing with such issues may well require a formalisation of change management, using changes against D2.2 as the reference for co-ordination of change. Because of the long time before the next deliverable (D2.3), these changes will be captured in internal documents of WP2 and used as a basis for UC development. The final version of the technical requirements of the UCs, economic and deployment implications will be included in the last deliverable of WP2, D2.3, to be delivered at the end of the project.

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Appendix A – Requirement Survey Templates

User Requirements Survey Template and supporting explanations

Table 35: User Requirements and metrics requirements gathering template

	5G-Tours Use case name: [UC XX] - [NAME]			
	a/a	**User Requirements Description**	**Metrics**	**values and Units**
Content User Requirements	1	**Video Reception:**	Yes/No no of UEs	
	2	**Video Transmission:**	Yes/No no of Channels	
	3	**Voice Communication:**	Yes/No	
	4	**Data Reception (DL):**	High/Medium/Low	
	5	***Data Transmission (UL) :***	High/Medium/Low	
Functional User Requirements	6	**Mobility:**	High Speed / Medium Speed / Walking-Running Speed / Stationary	
	7	**Location Information:**	High / Medium / Low Accuracy	
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	
	9	**Reliability/Availability:**	high / medium / low	
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	
Composite User Requirements	11	**Service / Traffic Type:**	Sustained High/medium/Low data rate Bursty High/medium/Low, burst-size Sporadic High/medium/Low msg/s	
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	
Structural User Requirements	13	***Edge Computing :***	Yes/No	
	14	***Edge Storage :***	Yes/No	
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	
	16	***other***	User specified	

Table 36: Content based user requirements

	a/a	User Requirements Description	Metrics and Units
Content User Requirements	1	**Video Reception:** Indicates the need to receive high definition Video (4K,8K) on his/her device, TV/monitor or VR/AR end device. This need can be interpreted into a network requirement for download bandwidth needs depending on the video format (HD, 4K etc.) and also the number of channels that must be simultaneously be received (i.e. 2 in the case of a stereoscopic/3D end device).	It is a Boolean value. The expected response is Yes or No. If the answer is yes, then some explanation(s) can be expected in terms of the nature of the video stream (i.e. format) and the number of simultaneous streams/channels that are being received. In case more details can be provided the indicative bitrates for different video formats are:
	2	**Video Transmission:** Indicates the user need to transmit video information of different formats and definitions/resolutions and frame rates (i.e. 4K or 8K or even 360o). This user requirement influences he upload bitrates to be provided in the Mobile Access Network. The indicative bitrates for different video formats are similar to the ones of the previous requirement (Video	Similarly, to the previous user requirement, the expected answer is Yes or No. In the case of a positive answer more can details should be given regarding the format of video stream and/or the number of streams.
	3	**Voice Communication:** Indicates the need to have voice interactive communication - real time full duplex between end-users of the network or between end user a Voice Service Platform. This communication can be one-to-one, one-to-many or many-to-many (call-conference).	This is another Boolean requirement whose expected answer is Yes or No. From the Network point of view this means the delivery of Voice Switching Capabilities and the demand for 128 Kbps bidirectional traffic on demand with reasonably short Latency of 50-200 msec. In addition, this value can be used in order to evaluate if the 5G infrastructure providers would need additional components in the Mobile Core, such as IMS VNFs.
	4	**Data Reception (DL):** Indicates the need to receive any kind of data (Download - DL) from the network at various speeds/bitrates. This requirement together with the nature of the data traffic (mentioned as Service/ Traffic Type requirement) directly influences the dimensioning of the	The value of this requirement is provided in a qualitative manner by selecting High/Medium/Low representing values of 1 Gbps / 100 Mbps / 10 Mbps (or less) respectively. If these values are not adequate, the vertical can also indicate Ultra High which represents a data stream of 10 Gbps.
	5	***Data Transmission (UL)*:** Indicated the need to transmit different types of data (Upload - UL) from the user end device to the network and/or other users. Together with the Service/Traffic Type requirement (explained further below), this requirement guides the network planners to correctly size not only the uplink bandwidth but also the backhauling capacity of the network.	The metrics for this requirement are the same as the one above (High/Medium/Low) with the only difference being the direction of the traffic from the User towards the Network.

Table 37: Functional based user requirements

Functional User Requirements	6	**Mobility:** Indicates the user need to receive and transmit information (any of the previous types, Video, Data and Voice) while moving (at low-walking and/or high speeds-train/car/airplane). Indicate speeds are 5 Km/h for walking, 50-150 km/h for automobile and 300-500 Km/h i.e for Fast Trains. If the end-user or device are stationary there is no mobility requirement and the moving speed is set to 0 km/h. All speeds and speed ranges should be supported by the network, but when planning how to best support a use case it is very useful to know the expected speed of motion of the end-device so as to i.e. define the hand-over specifications accordingly.	The metric of this requirement is the moving speed of the user and/or end-device. Since this can be varying the range is given as High Speed (300-500 km/h), Medium Speed (50-200 Km/h), Walking/Running Speed (5-10 Km/h) and Stationary (0 Km/h).
	7	**Location Information:** Indicates the need to make available and provide location (within certain accuracy) information of the end-device/user. For certain services (i.e. navigation of moving vehicle, autonomous driving, localization of a patient, etc.) it is very important to know the location of the end-device (and therefore the end-user) possibly in 3 dimensions. The accuracy needed it will also depend on the application and can be a few tens	Boolean (Yes/No) response is expected. In the case of Yes then approximate accuracy should be given rated as High / Medium / Low representing accuracies of +/- 0.5 / 4 & 50 meters respectively.
	8	**Fast Response (Low Latency):** The time between issuing a request (i.e. change direction) or transmitting of a piece of information (i.e. an alarm happened), and receiving a response is received should be as short as possible. Technology wise this is the end-to-end Latency of a Telecommunication Network also referred to as round-trip-delay. A simple measurement of this is done via the ICMP protocol with the “ping” command.	The requirement can be defined as Slow/Fast and Very Fast representing network latencies around 100, 25 and 5 ms respectively.
	9	**Reliability/Availability:** Indicates whether the Service is to be provided 24/7 (24 hours/day 7days/week continuously) without interruption or small interruptions can be acceptable (i.e. if a communication attempt fails, it can be repeated without consequences after xx amount of seconds). Reliability and Availability are different but from the user point of view is the perception of having service everywhere and all the time and how sensitive is the service to communications’ brief disruption. It is usually measured as	This requirement can be valued as High/Medium or Low representing reliability of 99.99999% / 99.999% / 99.99% (7 nines, 5 nines and 4 nines).
	10	**Security / Privacy:** Last but not least this requirement indicates the need to protect the usability and integrity of user data, equipment and network. Furthermore, it indicates that the Privacy of User Identity and Information should be protected. Access also to the User Data & information should be controlled to the degree of security desirable (i.e. public, restricted, confidential, or military/top-secret).	The metrics for this requirement are None-public / Baseline /Medium /High / Ultra-High grade for no security all the way to military type security/encryption levels.

Table 38: Composite user requirements

Composite User Requirements	11	**Service / Traffic Type:** This user requirement describes the traffic characteristics that the end-users (as a whole) receive and/or generate. It indicates whether there is a need for large volume of traffic to be sustained over long periods of time, or large pieces of information/data to be received or transmitted within a brief period of time (impulses/bursts), or maybe small amount of information must be exchanged at certain (regular or irregular) time intervals (i.e. like in the case of IoT or control signals).	According to the description of this requirement, the possible metrics are Sustained (continues data traffic) / Bursty (traffic in bursts) and Sporadic (at regular or irregular intervals). Each data flow type can then be defined as High/Medium or Low and indicative values are i.e for sustained 1 Gbps / 100 Mbps and 10 Mbps (for high/medium and low) respectively. Similarly, representative values for the other traffic values can be found in Table 2 bellow.
	12	**Interactivity & Space Dependency:** This user requirement, is a measure of the spatial distribution of the end-users/devices. It indicates the ability to issue commands (or even send data/video) and requests and receive acknowledgement of execution and/or reaction (that can be in the form of data/video) within a very short period of time (in the msec order of magnitude) from a large number of "collocated" end user/devices etc. (example is gaming and or guidance for emergency evacuation, transaction stock/financial markets or the more common request for a Web Page).	The metric of this requirement is Dense (High Density), Medium Density, Sparse (Low Density) representing >1 UE per m2 / 1 UE per 25 m2 / <1 UE per 100 m2 respectively. For each density, the interaction with the network/service can be characterized as High/Medium and Low representing 1.000 / 100 / 1 transaction per second.

Table 39: Structural user requirements

Structural User Requirements	13	***Edge Computing* :** For certain applications and/or Services there is a need to have computing power / CPU at close proximity with the end device. For example, collision avoidance for a fast moving industrial robot might require complex analysis and calculations to be performed (using the robot sensors and camera input) within a very short time, and then a command to i.e. change course should be given at the shortest possible latency. The simultaneous demand of High CPU power and very low latency can only be achieved by placing Computing Power at close proximity to the end-device (next to the gNB).	It is a Boolean value (Yes or No)
	14	***Edge Storage* :** Similarly, to the previous user requirement, the simultaneous need to store and retrieve large amount of information with the least possible delay for storage and retrieval actions indicate that Edge Storage Capabilities to be provided. Examples of such situations are surveillance using swarms of drones that need to upload real-time HD-Video, which will quickly dictate emergency actions, or an autonomous vehicle that downloads detailed maps in real time while moving.	It is a Boolean value (Yes or No)

Table 40: Service specific user requirements

Service Specific (examples)	15	***Battery Life:*** Service provisioning depends on battery power (i.e. remote sensors) and battery life (energy efficient operation) is very important due to the high OPEX associated with battery monitoring and replacement	High /Medium/ Low
	16	***other***	user specified

Network Requirements Survey Template

Table 41: Template for collecting general 5G network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	Use case name			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec						
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps						
4	Reliability (%) - Min/Max	%						
5	Availability (%) - Min/Max	%						
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h						
7	Broadband Connectivity (peak demand)	Y/N or Gbps						
8	Network Slicing (Y/N) - if Y sercice deployment time (min	Y/N						
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N						
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2						
11	Device Density	Dev/Km^2						
12	Location Accuracy	m						