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

Deliverable D2.3

Technical requirements of the use cases, economic and deployment implications

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List of Abbreviations

Term	Description
3D	three-dimensional
3GPP	3rd Generation Partnership Project
4G	4th Generation mobile wireless communication system
5G	5th Generation mobile wireless communication system
5GPPP	5G Infrastructure Public Private Partnership
5QI	5G QoS Identifiers
AI	Artificial Intelligence
AIA	Athens International Airport
AMIS	Airside Monitoring Inspection Specialist
ANAV	Italian National Association of Bus Passenger Transport
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
B2B2C	Business to Business to Consumer
BBU	Base Band Units
BSS	Business Support Systems
CCS	Cultural and Creative Sector
CDN	Content Delivery Network
CH	Cultural Heritage
CHT	Cultural Heritage Tourism
CN	Core Network
CPE	Customer Premises Equipment
CPM	Cost per thousand (also called Cost Per Mille)
DICOM	Digital Imaging Communications in Medicine
DL	Down Link
DTT	Digital terrestrial television
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
ENI	Experiential Networked Intelligence
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplex
GAM	Modern Art Gallery
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHz	Gigahertz
gNB	5G NodeB
GPS	Global Positioning System
GSMA	Global System for Mobile Communications Association
GST	Generic Network Slice Template
GUI	Graphical User Interface
HCAA	Hellenic Civil Aviation Administration
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
ICT	Information and Communication Technologies
IIT	Istituto Italiano di Tecnologia
IoT	Internet of Things
IMS	IP Multimedia Subsystem
IP	Internet Protocol

IPR	Intellectual Property Rights
ISG	Industry Specification Group
IT	Information Technology
KPI	Key Performance Indicator
LBS	Location Base Service
LTE	Long Term Evolution
MANO	Management and Network Orchestration
MCH	Multicast Channel
MEC	Multi-access Edge Computing
MIMO	Multiple-Input Multiple-Output
mMTC	Massive Machine Type Communication
MMTel	multimedia telephony service
mmWave	millimeter wave
MNO	Mobile Network Operator
MR	Mixed Reality
MTC	Machine Type Communication
NA	Non-Applicable
NB-IoT	Narrow Band IoT
NEST	NEtwork Slice Type
NFV	Network Function Virtualization
NR	New Radio
NSA	Non-StandAlone
NSC	Network Slice Customer
NSSAA	Network Slice Specific Authentication and Authorization
ONAP	Open Network Automation Platform
OPEX	OPerational EXpenditure
OR	Operating Room
OSS	Operations Support Systems
OSM	ETSI Open Source MANO
PDB	Packet Delay Budget
PER	Packet Error Rate
PMCH	Physical Multicast Channel
PoC	Proof of Concept
PSB	Public Service Broadcasting
PTM	Point-to-Multipoint
PTP	Precision Time Protocol
RTV	Real Time Video

QALY	Quality Adjusted Life Years
QAM	Quadrature amplitude modulation
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RTT	Round Trip Time
RTV	Real Time Video
RoI	Return on Investment
SA	Stand Alone
SBA	Service Based Architecture
SDI	Serial Digital Interface
SDS	Security Duty Supervisor
SLA	Service Level Agreement
SOP	Standard Operating Procedures
SSC	Session and Service Continuity Support
SSNIP	Small but Significant Non-transitory Increase in Prices
STARLIT	SmarT living plAtform powered by aRtificiaL Intelligence & robusT IoTconnectivity
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TST	Testing Scenario Template
UDP	User Datagram Protocol
UE	User Equipment
UHD	Ultra-High Definition
UI	User Interface
UL	Up Link
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communication
UWB	UltraWideBand
V2X	Vehicle-to-everything
vEPC	virtual Evolved Packet Core
VNF	Virtual Network Function
VPN	Virtual Private Network
VR	Virtual Reality
WOR	Wireless Operating Room
WP	Work Package
XR	eXtended Reality

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Executive Summary

5G-TOURS responds to the *5G PPP ICT-19-2019 Advanced 5G validation trials across multiple vertical industries call*, whose main goal is to achieve the European 5G Vision of 5G empowering vertical industries closer to deployment.

The project is implementing a set of use cases with the objective of improving the quality of life in a city, as well as the experience of the tourists visiting that city. Grouped in 3 different themes, 5G-TOURS has deployed end-to-end trials in real environments, each theme in a different trial site: 1) Turin, the touristic city; 2) Rennes, the safe city; and 3) Athens; the mobility-efficient city.

In concrete, thirteen different use cases are being addressed, each of them with a specific purpose, different stakeholders and users, a variety of technologies, etc. This document provides a standard framework for presenting the various aspects of these diverse use cases, including a complete description of each of the use cases, not only from a functional point of view, but also from technical, deployment and economical perspectives. For each of the use cases, it provides:

- **A final description of the functionality of the use case**. This description is the result of the refinement and continuous analysis of the use cases during the project lifetime.
- **Updated sequence diagrams** that enrich such descriptions by defining the flow of events and interactions of the key actors with the 5G-TOURS infrastructure.
- **Final use case specific user and network requirements**. This deliverable includes a reviewed version of the initial requirements provided by the verticals and that were presented in deliverable D2.2 as well as their analysis. The same methodology has been used, but with a better knowledge and understanding from the teams, acquired as the developments and the first implementations of the use cases evolved.
- **GSMA Network slice Types (NEST)**, a novelty introduced by the GSMA and used in this deliverable that provides a standard technical formulation of how verticals should explain their requirements to network operators.

Although the definition of the user and network requirements, the methodology and templates used in the project for their collection, normalization and analysis were explained in the previous deliverable D2.2, the approach followed is summarized again in this deliverable for the benefit of the reader. The relationship of these requirements with the KPIs being used in the project to evaluate the use cases and the 5G PPP KPIs is also explained.

5G-TOURS uses and extends the 5G-EVE platform in order to support its use cases. Therefore, additionally to the user and network requirements, the use cases also introduced some system requirements that helped to identify how the 5G-EVE infrastructure has to be enhanced for the successful deployment of these use cases. The enhanced functionality developed by the project is also briefly introduced in this deliverable, as well as an analysis of the dependences, deployment implications and interactions.

Before presenting the different use cases, we describe the specific site into which the use cases are being deployed, describing its main functionalities and peculiarities with respect to the other two, and analysing the particular deployment implications.

Finally, the economic drivers for the commercial deployment of 5G-TOURS use cases are analysed. For that, we first introduce the framework for understanding economic and commercial potential of the 5G-TOURS use cases and then the evaluation cases used for assessing benefits and commercial exploitation. Finally, the approach and results for our assessment of the economic benefits of different specific settings are presented, including the key findings from benefits analysis across evaluation cases.

1 Introduction

1.1 Purpose

This deliverable is the final of a series of three WP2 reports delivered by the project consortium during its 36-month work plan.

The first report, "*D2.1Use cases, deployment and techno-economic requirements - high level description"* [1], was delivered in M4. It provided an initial description of the use cases design and of the requirements specification and technologies for the three cities. It also analysed the preliminary deployment and economic implications. It provided a solid basis upon which other WPs could initiate their activities.

The purpose of the second one, "*D2.2 Touristic city, safe city, and mobility-efficient city use cases – final version"* [2], delivered in M15, described the system design and the requirements specification for each of the platforms where the use cases were going to be deployed.

This third one, "*D2.3 Technical requirements of the use cases, economic and deployment implications – final version",* includes the final description of the use cases, their requirements as well as deployment and economic implications. Its outcome is based on the conclusions and work conducted during the whole life of the project.

1.2 Document Structure

The deliverable is organized in the following manner:

- **Section 1** (this section) is an introduction to the deliverable.
- **Section 2** provides an overview of the methodology used to provide technical requirements, both user and network requirements as well as system requirements. The main general results are highlighted as well as the relationship of these requirements with the KPIs being used in the project to evaluate the use cases and the 5G PPP KPIs.
- **Section 3** presents the 5G-TOURS deployment considerations and dependencies with the 5G-EVE project.
- **Sections 4, 5** and **6** are dedicated to each of the cities. They describe the platform and their specific deployment considerations as well as the final description of the different use cases, their requirements, sequence diagrams, GSMA Network Slice Types (NEST), etc.
- **Section 7** presents the economic drivers for the 5G-TOURS use cases in commercial deployments.
- Finally, **Section 8** provides conclusions.

2 Technical requirements

The purpose of this section is to present the final outputs of the work done in task *T2.2 Derivation of technical requirements*. The main goal of this task was to analyze the technical requirements considering the functionalities specified in task *T2.1 Definition of use cases functionality*, providing the system design and the requirements specification for each of the platforms where the use cases are being deployed.

2.1 User and network requirements

D2.2 included the definition of the user and network requirements, the methodology and templates used in the project for their collection, as well as their values and analysis. This initial analysis concluded that the management of requirements in 5G-TOURS should be a concurrent or iterative research and development process. The Use Cases (UC) analysis in D2.2 identified a need for review and validation of requirements, since, in some cases, it was detected that some of the requirements had been potentially over specified. Thus, WP2 identified a need to maintain user requirement dialogues through to project completion.

This deliverable D2.3 includes a revised version of those requirements, gathered using the same methodology, but with a better knowledge and understanding from the verticals, which has facilitated them being more precise when providing their requirements.

Although the methodology for the compilation, normalization and analysis of the user and network requirements was deeply explained in D2.2, for the sake of the reader, we summarized the approach followed bellow.

2.1.1 Methodology for user and network requirements collection and analysis

As the end-user needs are a primary driver of the value creation process, we first identified those requirements that could be explicitly linked to the needs of the end user. When consuming a service over a mobile network, the customer values the quality of their experience rather than being concerned about technical communications terms like Mbps or milliseconds latency. Table 1 lists this type of requirements that has to do with the experience of the end user.

Sixteen user requirements were identified as sufficient to define the vertical requirements in 5G-TOURS. These are divided into five logical groups: Content, Functional, Composite, Structural and Service Specific. To gather the user requirements from the thirteen UCs, the template illustrated in Table 1 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. This template came along with the definition / explanation of each of the user requirements (see Appendix A – User requirements definition), as well as examples to aid understanding of what is expected to be provided to capture the end user needs.

Having established the user requirements, we progressed to the network requirement derivation. After surveying a lot of generic best practice methods to efficiently derive requirements from the initial user requirements, we decided to develop a customised approach which took into account the diversity of UCs implemented in 5G-TOURS. First, 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. They are shown in Table 2, that shows the template that was facilitated to the with the analyst teams guided by the corresponding definitions (see Appendix B – Network requirements definition).

For the visualisation of the technical requirements, we decide to make use of radar charts. Although we had identified twelve different network requirements, we chose to enhance this representation to a 10-axis radar chart (security and availability were excluded). On the other hand, as we wanted to illustrate the general capabilities of 4G and 5G and the differences between them as well as their correlation with each of UC-specific gathered requirements, a radar chart based on 4G/5G capabilities of Table 3 like the one illustrated in Figure 1 was used.

This radar chart will be subsequently used as a reference since all the use case requirements will be mapped onto this one to assess their existing and future needs. 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.

Table 1. 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 2. 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						

Table 3. 4G/5G capabilities for mapping the vertical's use cases requirements.

	General 4G/5G Capabilities	Units	4G	5G
1	Latency (in milliseconds) - round trip - Min/Max	msec	25	10
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	300	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

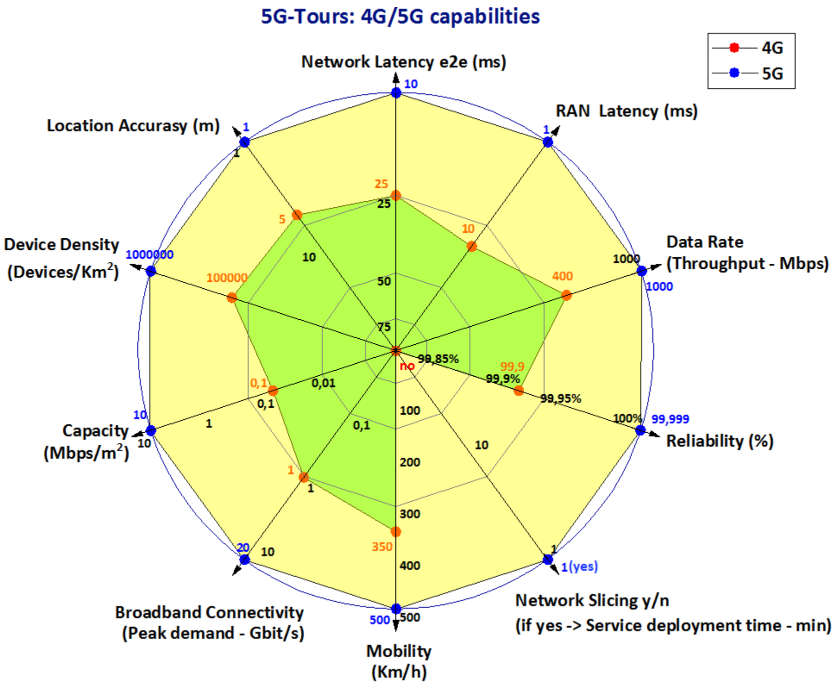


Figure 1.An illustrative radar chart for visualisation of network requirements.

2.1.2 Relation with WP7 and 5GPPP KPIs

The network requirements, defined by WP2 during the requirement collection phase, were then translated into KPIs in WP7 whose definition is presented in detail in D7.2 [3].

Table 4 illustrates the mapping between these network requirements, the KPIs considered in D7.2, as well as their relation to the 5G PPP KPIs (see Table 5).

Table 4. Requirements to KPI to 5G PPP KPI mapping.

Network requirement	KPI	5G PPP KPI	5G PPP KPI value
Latency (ms)	Latency (ms)	P1	10 ms
RAN latency (ms)	RAN latency (ms)	P1	1 ms
Throughput (Mbps)	Throughput (Mbps)	P1	50 Mbps
Reliability (%)	Reliability (%)	P4	99.999%
Availability (%)	Availability (%)	P4	99.999%
Mobility (Km/h)	Mobility (Km/h)	P1	500 Km/h
Broadband connectivity (Gbps)	Broadband connectivity (Gbps)	P1	20 Gbps
Network slicing (Y/N)	Slice deployment time (min)	P3	90 min
Security (Y/N)	Per use case (e.g., grade, secrecy, resilience)	P4	"Carrier grade"
Capacity (Mbps/m^2)	Capacity (Mbps/m^2)	P1	10 Mbps/m^2
Device density (dev/km^2)	Device density (dev/km^2)	P5	1M terminals/km2
Location accuracy (m)	Location accuracy (m)	P1	1m

The last column of Table 4 presents the relative target values of the KPIs based on the 5G PPP phase II KPIs document [4].

Table 5. 5G PPP KPIs.

	5G PPP KPI
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
P2	Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
P3	Reducing the average service creation time cycle from 90 hours to 90 minutes
P4	Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
P5	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
P6	Ensuring for everyone and everywhere the access to a wider panel of services and applications at lower cost

2.1.3 Main results and conclusions

In order to make this document easy to read, we provide a general overall view and analysis of the requirements, together with the main conclusions in this section. The detailed UC-individual user and network requirements, the radar charts, as well as the corresponding analysis are presented later in Sections 4, 5 and 6, in which we provide all the information describing each of the thirteen use cases: final description, user and network requirements, sequence diagrams and GSMA NESTs.

2.1.3.1 User requirements

Table 6 presents the overall user requirements for the 13 5G-TOURS UC, from which we can produce Table 7, where the number of UCs per requirement metric is illustrated. Especially in those UCs where there are sub use cases, it is possible to have more than one value to some user requirements.

Table 6. User requirements.

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
Touristic city	Augmented Tourism Experiense	Yes	No	No	High	Low	Walking-Running Speed	High	Very fast	low	Medium	Sporadic / low (IoT)	Medium Dencity /low (IoT)	No	Yes	n/a (IoT)
	Telepresense	Yes	Yes	Yes	low	Low	Walking-Running Speed	Medium	Fast	medium	baseline	St.medium, (media) Sp.high, (controls) St. low (IoT)	Medium Dencity /medium	No	No	n/a
	Robot-Assisted Museum Guide	Yes	Yes	Yes	medium	medium	Walking	Low	Very fast	medium	High	sustained medium	sparse high	No	No	n/a
	High-Quality Video Services Distribution	Yes	Yes	No	High	No	Medium+ walking/running speed +stationary	Low	slow-medium	medium	baseline	sustained high	Medium Dencity low	Yes	No	medium
	Distributed Video Production	No	Yes	Yes	No	High	Walking Running speed/ stationary	low	1. Very fast 2. Low	high	baseline	sustained high	dense high	No	Not important	n/a
Safe city	Remote health Monitoring	Yes	Yes	Yes	medium	medium	Stationary to Walking speed	low	Very fast	high	high	sustained medium	Medium density low	Yes	No	low
	Teleguidance for Diagnostics and Intervention sup.	Yes	Yes	Yes	High/Medium/Low	medium	Stationary and High speed	low	fast/medium	high	ultra-high	st. high, Br. Low, Sp. High	Medium density low	No	No	medium
	Wireless Operating Room	Yes	Yes	Yes	none	none	Stationary	none	slow	low	high	st. high	Medium density low	No	No	low
	Optimal Ambulance Routing	Yes	Yes	Yes	medium	medium	Stationary to High speed	medium	Very fast	high	medium	sustained medium	Medium density low	Yes	No	low
Mobility-efficient city	Smart Parking Management	No	No	No	High	Low	Medium speed	high	fast	high	medium	sporadic medium	medium density medium	No	No	medium
	Video Enhanced Ground Based Mov. Vehicle	Yes	No	No	high	none	High speed	high	fast	high	high	Bursty high	sparse medium	No	Yes	high
	Emergency Airport Evacuation	No	No	No	high	No	medium speed	high	fast	high	high	Bursty high	Dense medium	No	No	medium
	AR/VR Enhanced Educational Bus Excersion	Yes	No	No	high	medium	VR high speed/AR walking-running-stationary	No	fast	low	medium	Bursty high	dense high	Yes	Yes	medium

Table 7. Number of UCs per requirement metrics.

	Metrics					
User Requirements	**n/a**	**Yes**	**No**	**High**	**Medium**	**Low**
Video Reception		10	3			
Video Transmission		8	5			
Voice Communication		7	6			
Data Reception (DL)	2			7	4	2
Data Transmission (UL)	4			1	3	5
Mobility				4	3	10
Location Information	2			4	2	5
Fast Response (Low Latency)				10	2	3
Reliability/Availability				7	3	3
Security / Privacy				6	4	3
Service / Traffic type - Sustained				4	5	1
Service / Traffic type - Bursty				3	0	1
Service / Traffic type - Sporadic)				2	1	1
Interactivity & Space Dependency - Dense				2	1	0
Interactivity & Space Dependency - Medium				0	2	6
Interactivity & Space Dependency - Sparse				1	1	0
Edge Computing		4	9			
Edge Storage	1	3	9			
Battery Life	4			1	5	3
other	13					

Then a histogram of the numbers of UCs for each one of the user requirements is illustrated in Figure 2 below:

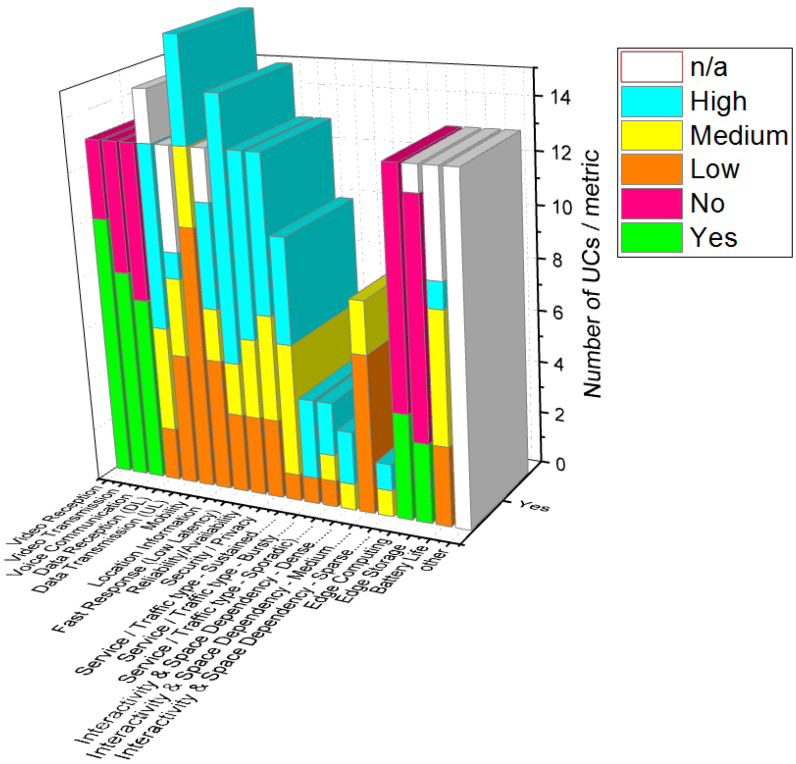


Figure 2. Number of UCs per Metric.

2.1.3.2 Network requirements

The first main conclusion we can make from the analysis of the network requirements is that most of the UCs require a 5G network in order to deliver the prescribed service in a satisfactory way.

From the total of 22 radar charts created for the analysis of the network requirements, the percentage of the overall requirements that are being covered by existing technologies (4G/LTE) and those that need the 5G capabilities is shown in Table 8 below.

Table 8. Percentage of network requirements covered by 4G or 5G.

Network Requirements	Covered by 4G	Need 5G
Network Latency (e2e)	59,1%	40,9%
RAN Latency (one way)	70,0%	30,0%
Throughput	84,2%	15,8%
Reliability	4,8%	95,2%
Network Slicing	23,8%	76,2%
Mobility	100,0%	0,0%
Broadband Connectivity	87,5%	12,5%
Capacity	66,7%	33,3%
Device Density	84,6%	15,4%
Location Accuracy	35,7%	64,8%

In brief, as shown in Figure 3 below, the most requested network capability is reliability, while the second one is the support of network slicing. Note that the 5G capability for slicing is “1 sec” for establishing a slice.

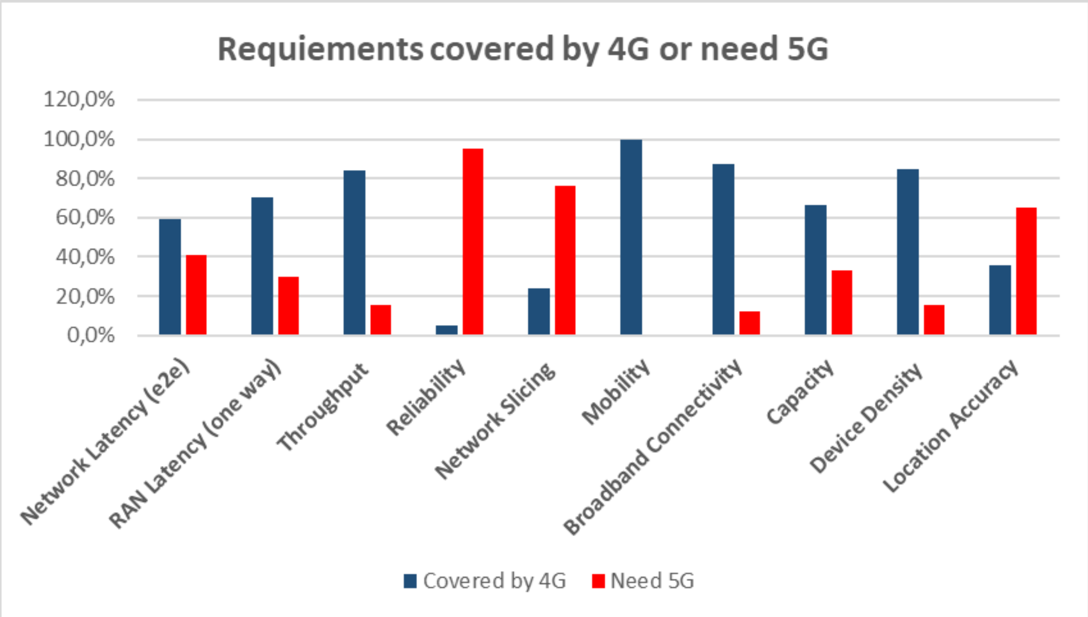


Figure 3: UC’s request for 4G or 5G

For these UCs, careful network planning and dimensioning as well as other information and novel approaches should be adopted in order to deliver the required values. This evaluation will be performed at a later stage in the project in WP7.

In some cases, as it is shown in Figure 4 below and it will be also mentioned in the section corresponding to each specific UC, we see that some requirements reach the limits of the foreseen capabilities of the 5G network. These demanding requirements are mainly in term of:

- Reliability: 23,8% reach the limits of 5G.
- Capacity: 20% reach the limits of 5G.

- Location Accuracy: 7,7% reach the limits of 5G.

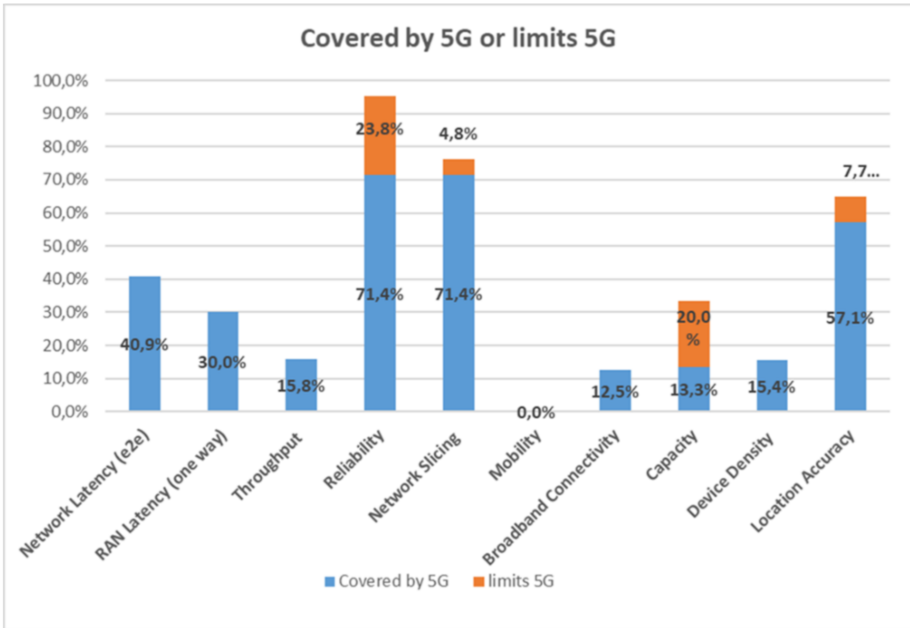


Figure 4. Percentages of UC's requirements that need 5G or reach the limits of 5G.

The solution for satisfying the required Capacity is usually to carefully plan the Radio Access Network and expanding the Network throughput Resources.

The answer to provide the ultra-high Location Accuracy is described in the analysis and is to consider (if the requirement cannot be relaxed) other positioning modalities. The solution is complicated when mobility is also required.

Finally, the ultra-Reliability can be addressed by planning, redundancy in resources, and higher quality equipment / components at the expense of price.

The analysis performed in this report is a valuable insight into what 5G Network technologies should focus on to better serve the needs of the end-users.

Table 9. Percentage of network requirements covered by 4G or 5G per UC.

UCs	Req. covered by 4G	Req. need 5G
UC1	65,8%	34,2%
UC2	82,4%	17,6%
UC3	77,8%	22,2%
UC4	42,9%	57,1%
UC5	58,8%	41,2%
UC6	57,9%	42,1%
UC7	60,0%	40,0%
UC8	16,7%	83,3%
UC9	60,0%	40,0%
UC10	68,8%	31,3%
UC11	70,0%	30,0%
UC12	20,0%	80,0%
UC13	50,0%	50,0%

Finally, in Table 9 and the two charts below (bar chart Figure 5 and histogram Figure 6), the need for 4G and 5G is depicted per UC.

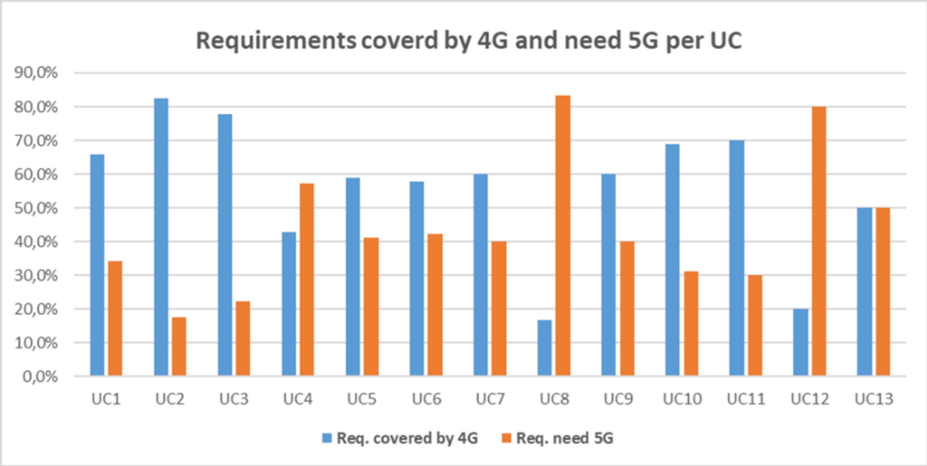


Figure 5. Bar chart for the need of 4G and 5G per UC.

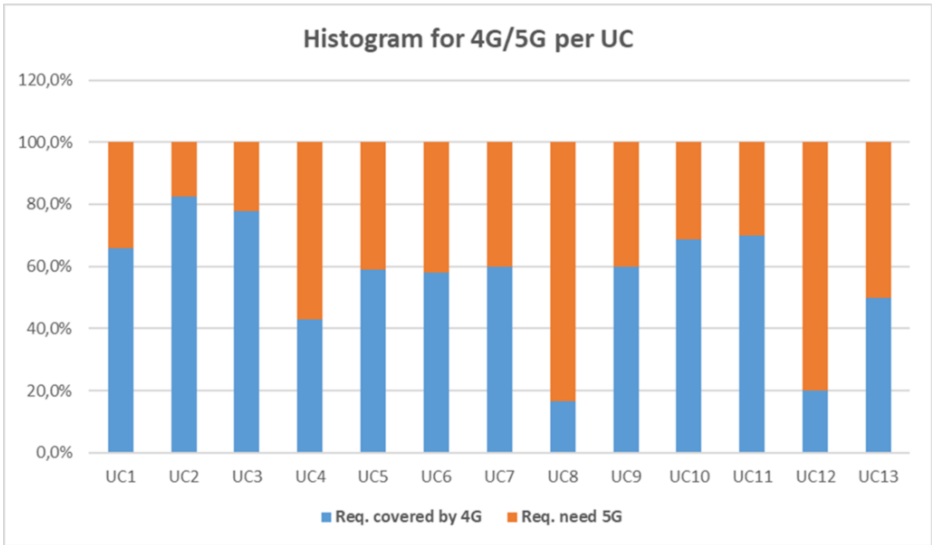


Figure 6. Histogram for the need of 4G and 5G per UC.

As we can see for the above charts, UC8 is the one with the more need for 5G to satisfy its requirements and less need for 4G (16%), while the second one is UC12 with 4G need of 20%.

2.1.3.3 Service types / Slices

Table 10 categorises the use case analysts' views on the network service / slice types required per UC in terms of the three core slice categories, namely: URLLC, mMTC, and eMBB. This is also presented graphically in Figure 7 and Figure 8. Both figures 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.

Data show that the highest demand is for URLLC (9 UCs), followed by eMBB (8 UCs) and followed by mMTC with the lowest demand (from 4 UCs).

Table 10. 5G-TOURS UCs 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	4	8
		69,23%	30,77%	61,54%

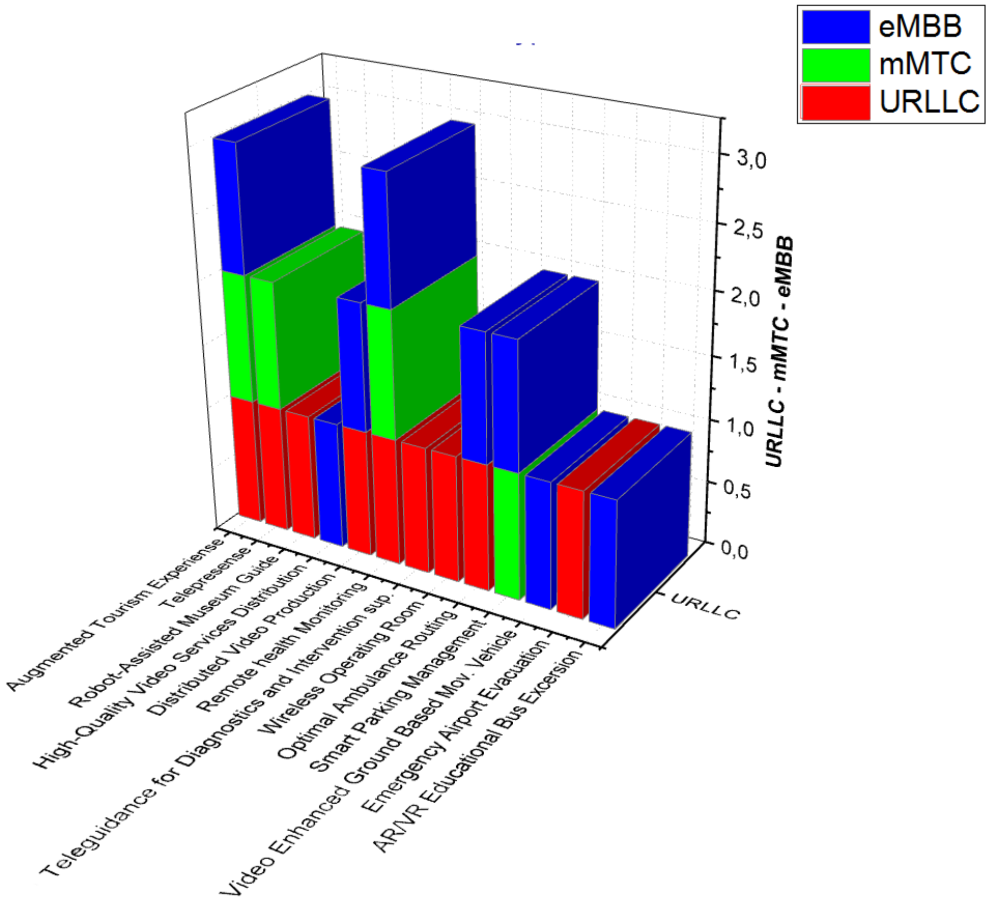


Figure 7. Service types/slices requirements per use case scenario.

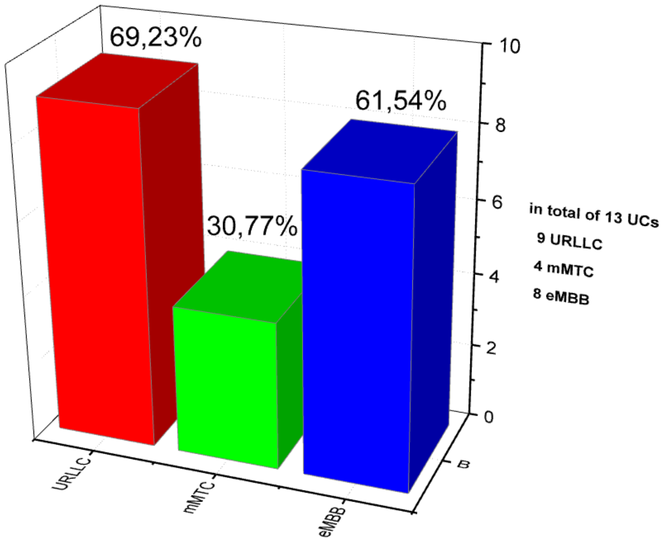


Figure 8. Service types/slices requirements demand.

2.2 System requirements

Many of the 5G-TOURS envisioned use cases will benefit from the enhanced additional functionality that the project consortium developed on top of the existing 5G-EVE platform. These activities in some cases will introduce additional side functionalities, such as monitoring features, or include some fundamental network function, such as the broadcast support, which is mandatory for the correct realization of some of the UCs. That is, UCs introduced requirement (also through the NEST templates definition) which were then fulfilled by WP3. They are categorized in the section below.

2.2.1 Service Layer and vertical interaction

In order to provide the enhanced services envisioned by the project on top of a 5G infrastructure, vertical service providers need to have a more direct interaction with the network. This imposes a more open network exposure functionality from the operator who has to share significant network metrics to allow the service provider to tailor the operation of the service according to the changing environmental conditions. This operation is fulfilled in 5G-TOURS by the service layer, which, in addition to the open SDK, will provide ways to foster the interaction between verticals and operators, in the following ways:

- Continuous KPI monitoring though network exposure functionality. While the definition of the relevant KPIs changes according to the different UCs, the service layer monitoring functionality focuses on the most common one such as the end-to-end latency and the per user throughput. The selected KPI and the monitoring granularity are defined and required from WP2 through the NESTs.
- Programmatic onboarding of network slices though the 5G-EVE portal.

These aspects are specified in each UC NEST templated.

2.2.2 AI Enhanced Orchestration

In 5G-TOURS, Artificial Intelligence (AI) will be prominently used by network operators to optimize the resource provisioning within the network. Operational functionality such as intelligent resource assignments and network resource assignment will be provided through AI. While this is not directly influencing the operation of the UCs from the service provider point of view, this will indirectly benefit the verticals by enabling cheaper OPEX costs. Additionally, the operation of the network could bridge the intelligences developed in the network infrastructure and the ones developed by service provider. This functionality is implemented in the Athens site, and it has been showcased in the 5G-TOURS supported PoC in the ETSI ENI ISG [5].

2.2.3 Broadcast Support

Broadcast is a fundamental enabler of UC4. The requirement coming from this UC has been fulfilled by the operation of a 3GPP Rel. 16 High Power High Tower solution and the Broadcast-enabled 5G Core deployed in the Universitat Politécnica de Valencia (UPV) premises and connected to the 5G-EVE Italian site as an additional branch. All these requirements have been duly specified by the UC owner and implemented by the network developers.

2.2.4 Other innovations

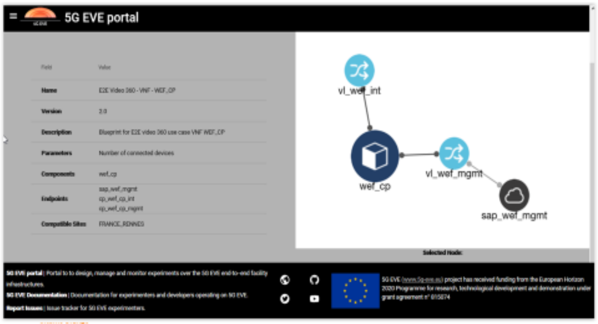
Sometimes UCs have very stringent requirements in terms of bandwidth and latency which challenge even the most innovative hardware deployment available in 5G-EVE. Therefore, for some UCs, 5G-TOURS partners deployed new hardware that either provides superior performance, such as the 26 GHz network deployed in France, or include 5G functionality in challenging environments such as the museum in Turin or the Hospital in Rennes. As also captured by the reports produced by the respective WPs, the deployment in the museum, which is protected by cultural heritage regulations forbids that antennas or other network elements break the historic environment, while the deployment in the hospital, that has to be fully integrated with the existing medical infrastructure deployment, had to pass very strict tests about the electromagnetic footprint in such a challenging environment.

3 Deployment considerations

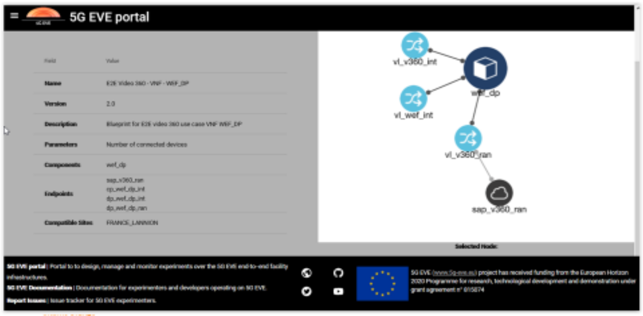
3.1 Dependencies with 5G-EVE

The 5G-EVE end-to-end (E2E) facility is composed of four interconnected sites facilities located in Greece, Italy, Spain, and France that support several use cases for verticals and experimenters [6]. The objective is to build a European 5G end-to-end facility that will host a selection of use cases to be deployed by verticals. 5G-TOURS, as a verticals-oriented project, uses three out of the four 5G-EVE locations (Greece, France, and Italy) and extends on the platform to support their use cases.

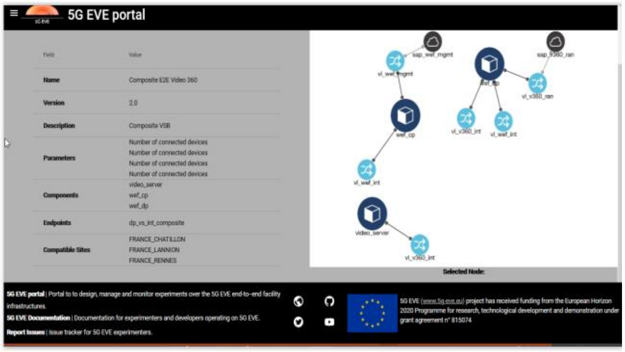
a: Video service VSB at Orange Châtillon



b: Wef_cp VSB at BCOM Rennes



c: Wef_dp VSB at BCOM Lannion



d: Composite French multi-site VSB

Figure 9. Example for Vertical Service Blueprint for multi-site.

The E2E operation process defined in 5G-EVE, described in [6], is used to deploy a use case. The use case needs blueprint files with a specific syntax, to be available in the common Gitlab repository of the project before integrating them in the platform. The deployment follows a multi-site approach that is able to place the VNF in a specific location or site. Figure 9 illustrates how and where the VNF components are deployed (a: Video server in Orange Châtillon, b: Wef_cp at BCOM Rennes, c: Wef_dp at BCOM Lannion and d: Composite multi-site VSB) in a typical case.

5G-TOURS use cases leverage the capabilities of 5G-EVE to support their requirements. These requirements are expressed in the form of 5G-EVE compatible blueprints.

This benefits the use cases by using the monitoring functionalities (providing the collection and visualization functionalities of data) and supporting the visualization of monitoring data through the 5G-EVE portal GUI, in addition to other internal functionalities for performance validation and evaluation based on KPIs. Figure 10 illustrates the E2E view of the 5G-EVE platform for an experimenter.

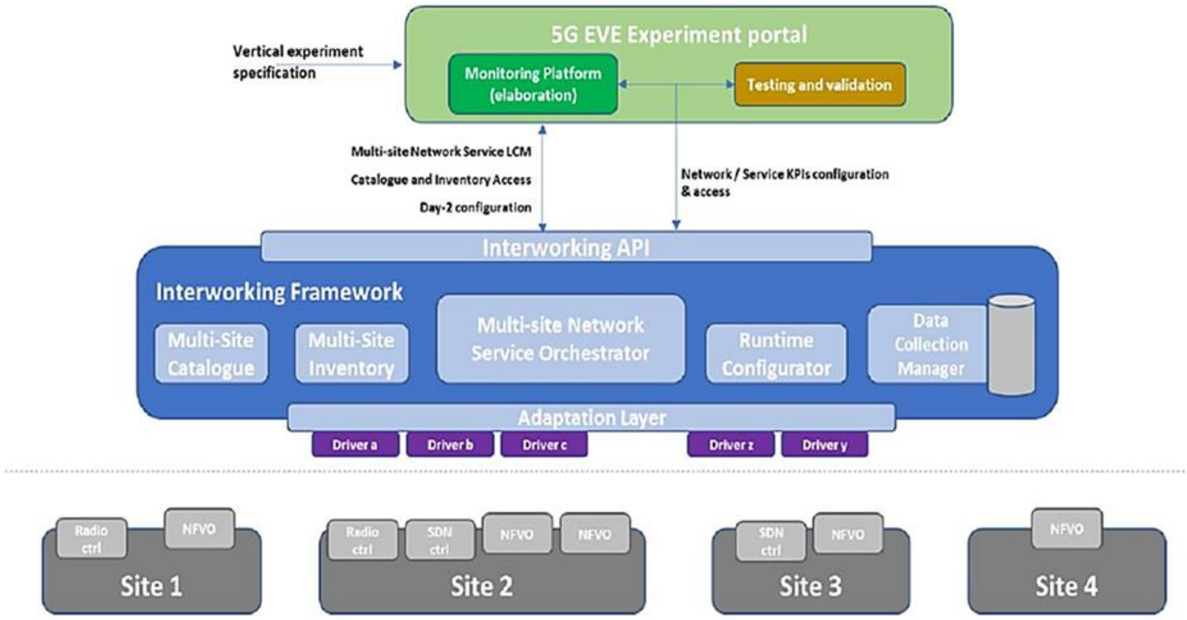


Figure 10. Interworking Framework architecture as defined in 5G EVE D3.1 [7].

The interaction between 5G-TOURS and 5G-EVE is based on roles with the framework as a guide. In the following, we explain the roles in 5G-EVE and their equivalent in 5G-TOURS:

- **Vertical**: actor with the knowledge of the service to be tested, including SLAs and service components.
  - The UC owners in 5G-TOURS are the Verticals.
- **Verticals' VNF Provider**: actor who provides the VNF packages for the vertical applications.
  - A partner from 5G-TOURS or 5G-EVE that knows the compatibility of the VNF with the destination infrastructure. An integrator in between is also possible.
- **Experiment developer**: actor responsible for specifying the blueprints associated to an experiment, as well as the associated NFV network services descriptors. This user has the knowledge about the 5G-EVE infrastructure and expertise about NFV network service modelling.
  - In general, not the UC owner. An integrator or a partner with sufficient knowledge of 5G-EVE framework in collaboration with the UC owner.
- **Experimenter**: actor responsible for the request of an experiment and the assessment of its results; defines the characteristics of an experiment starting from its blueprint, requests the deployment of related virtual environment and experiment execution and analyses results and KPIs.
  - The UC owners or trusted integrators to test the UC and guarantee the respect of SLAs.
- **Site manager:** system and infrastructure administrator for a 5G-EVE site.
  - 5G-EVE are the site managers in our context, and we rely on the partners to achieve successful experiments.

Another way to express technical constraints from the telco operator are the GSMA NEST Templates. This is a more standardized way, outside of the scope of 5G-EVE, that describes how a vertical should explain its technical requirements to a network operator. More information about this is provided in the section below.

3.2 GSMA Network Slice Type (NEST)

The Generic Network Slice Template (GST) is a set of attributes that can characterise a type of network slice/service. GST is generic and is not tied to any specific network deployment. The NEtwork Slice

Type (NEST) is a GST filled with values assigned to express a given set of requirements to support a network slice customer use case (see Figure 11).

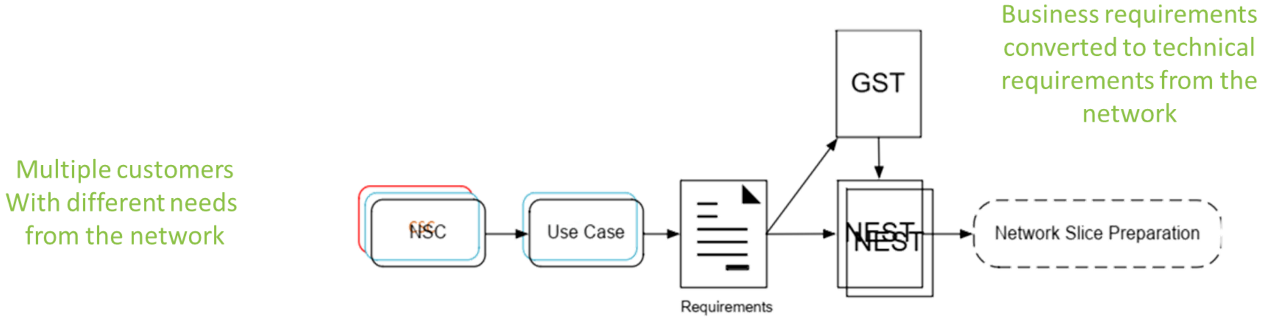


Figure 11. GSMA NEST Template

The slicing requirements of the Use cases of 5G-TOURS are expressed in a standardized manner with regards to the underlying infrastructure; the GSMA Network Slice Type (NEST) Templates [8]. A slice is a logical network that provides specific network capabilities and network characteristics to its owner. The slice can have specific requirements agreed between a vertical and network operator. This relationship of infrastructure provider and vertical/experimenter is very well represented for all 5G-TOURS use cases.

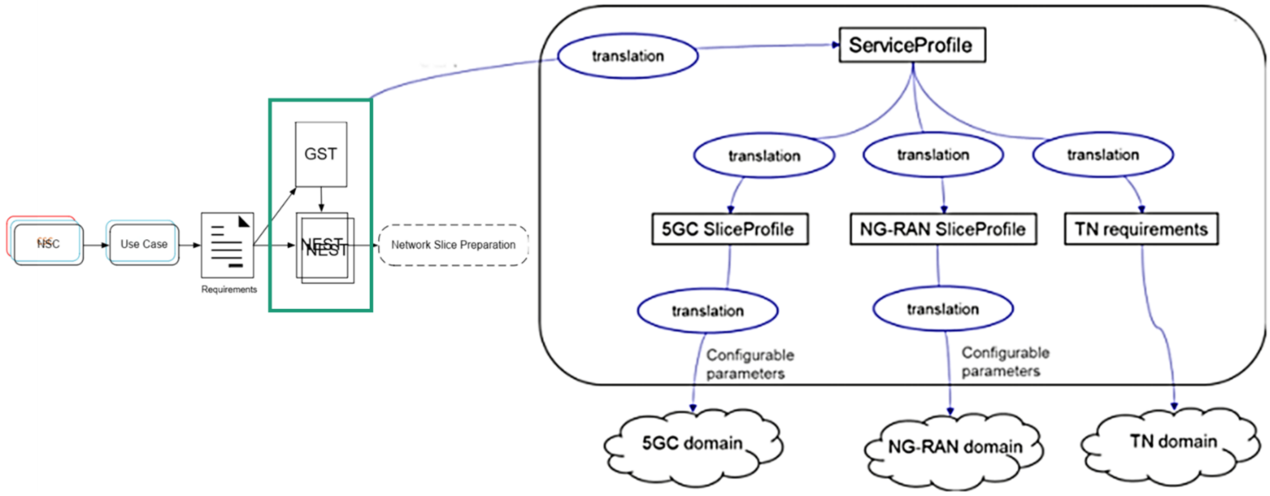


Figure 12. From requirements to slice description

A network slice could span across multiple network domains in theory. In the context of 5G-TOURS, only one domain at a time, under the responsibility of the same infrastructure provider is used. The resources of the network slice are also dedicated to the experimenter in our case.

In order to create a GSMA Template, the verticals follow a simple methodology that consists of analysing its use of the network and translating that into a GST file by answering a set of standard questions present in the standard GSMA Template as illustrated in Figure 12.

In 5G-TOURS, in order to ease the translation between the NEST templates and the actual site deployment and configuration, the Testing Scenario Templates (TST) are used in line with the 5G-TOURS evaluation methodology presented in WP7. The TSTs (realised per network slice) enhances and extends the NEST templates with additional information related to:

a) the network configuration (both in RAN and Core);
b) the UE capabilities;
c) the service characteristics;
d) the environmental details in which the tests are executed;
e) the metrics and KPIs to be collected and validated.

In this way, the TSTs guides the technical people responsible for the actual deployment of the UCs to realise the translation steps described in Figure 12. The creation of TST is based on the work done and the testing templates used in 5G PPP Test, Measurement and KPIs Validation (TMV) Working Group [9]. The TST together with some indicative values is presented in Table 11.

Table 11. Testing Scenario Template.

Parameter group	Test scenarios parameter	Example value
3GPP standard	3GPP Release	Rel.15
	3GPP Architecture option	NSA
RAN	Band	3.5 Ghz
	Bandwidth	50 MHz
	Carrier aggregation	16
	UL/DL pattern	FDD
	Modulation	64QAM
	MIMO	2 layers
Core	Deployment	Edge/Central
UE	Category	CAT 7
	MIMO	2 layers
Service	Deployment	Edge/Central
	Service type	eMBB/URLLC/mMTC
Environment	Indoor/Outdoor	Indoor
	Number of UEs	10
	Number of cells	3
	Device density	#devices/km^2
	Mobility	60Km/h
	Background traffic	UE emulation
Metrics (list)	Metric name	RTT latency
	Unit	ms
	Probe position (network)	UE
	Probe position (layer)	APP layer
	Sampling rate	1min
KPIs (list)	KPI name	E2E latency
	Unit	ms
	Criteria	<10ms
	Analysis equation	AVG (RTT latency (metric)/2)

4 The Touristic City

4.1 The Platform

At the time of writing this document, the network solution of the Turin site is under its second implementation phase (i.e., phase 2). As reported, in D4.2 [10], the two phases approach was introduced due to the impossibility to deploy a network solution that would support all the aspects in terms of use case technical requirements, outdoor and indoor coverages, trials time plan, and the integration with the 5G-EVE infrastructure, at its first implementation. The network implementation of phase 2 is constituted by two parallel, independent, and complementary activities:

- **In-field**: this branch can be considered as a prosecution of the phase 1, in which the network solution will provide the 5G indoor coverage of Palazzo Madama and Modern Art Gallery (GAM) based on an NSA (Non-Standalone) architecture deployment and connected to the TIM's commercial Core Network (CN). The on-field branch will also address the use case integration with 5G-EVE infrastructure in terms of NFV infrastructure and 5G-EVE portal usage.
- **Experimental**: this branch is going to be based on the E2E NSA 5G network solution developed by 5G-EVE at the TIM laboratory, providing almost full integration with the 5G-EVE infrastructure. The objective of this branch is to experiment innovative slicing management functionalities using the EVER orchestrator [6].

Based on this phased approach, the Turin site network solution will be essentially based on the 5G-EVE platform as described in D3.3 [11] and reported in Figure 13, in which the integration aspects between the 5G-TOURS network solution and the 5G-EVE infrastructure are depicted. The deployment implications related to the two on-filed and experimental branches described above are reported in the following section.

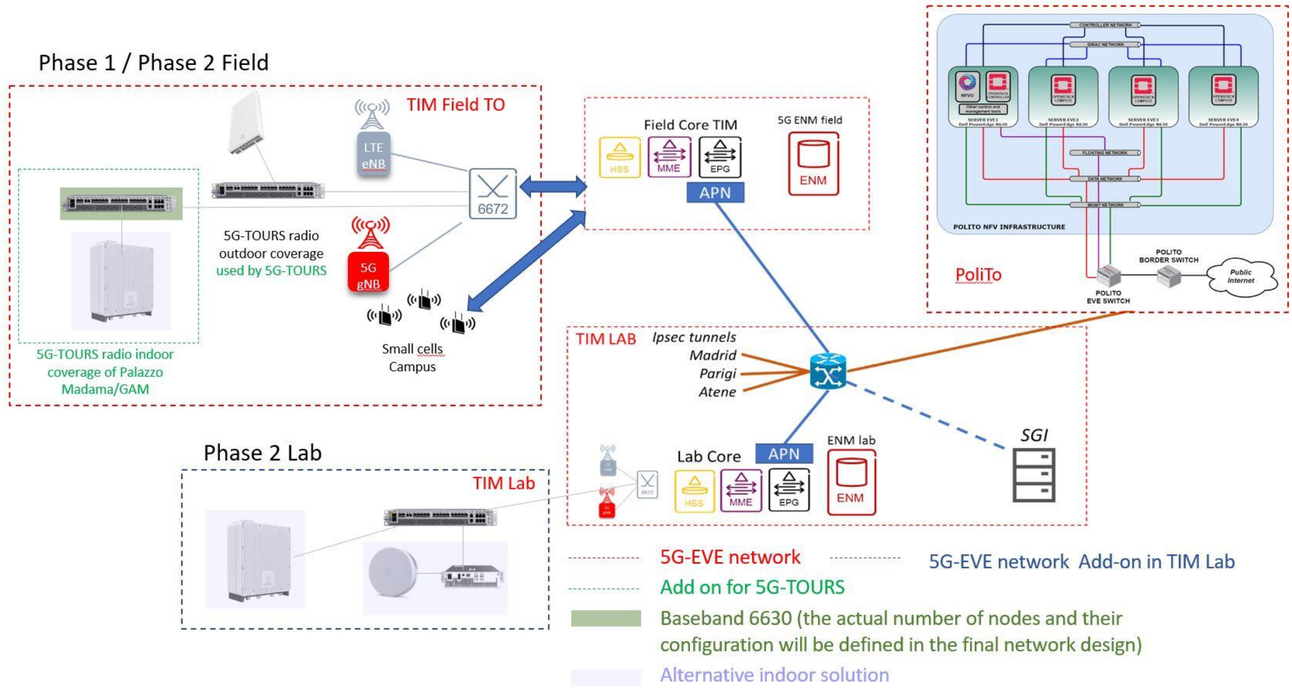


Figure 13. Turin site overall platform based in 5G EVE infrastructure.

4.2 Deployment implications

As anticipated in the previous section, the in-field branch will be based on TIM's 5G commercial network that has been deployed according to the Rel-15 NSA option 3 architecture. From this perspective, the 5G indoor coverage of the two museums can be considered as a fully-fledged extension of the 4G/5G outdoor coverage provided by TIM. On this basis, all the UCs experimentation that will run over the in-field network will not implement any slicing features (e.g., slices onboarding, slices management, etc.) at the CN and/or radio access levels since these are not supported by the Rel-15 network devices. Nevertheless, the in-field branch will provide a real pre-commercial implementation of the UCs, demonstrating how 5G is able to meet their technical and performance requirements that 4G would not be able to provide.

On the other side, the experimentation branch will use the 5G-EVE network solution deployed at TIM's laboratory. Even if this deployment is still based on an NSA architecture, the Evolved Packet Core (EPC) node is supported by the so called EVER orchestrator (please refer to [6] for a detailed description of the infrastructure and functionalities). In this context, slicing management functionalities based on 5G-TOURS innovation will be experimented through UC1, that is encompassing all the three slice types such as eMBB (for the AR part), URLLC (for the VR part) and mMTC (for the IoT layer based on the sensor that will be installed at Palazzo Madama). Based on this, Figure 14 depicts the end-to-end architecture instantiation for UC1 (see [11]).

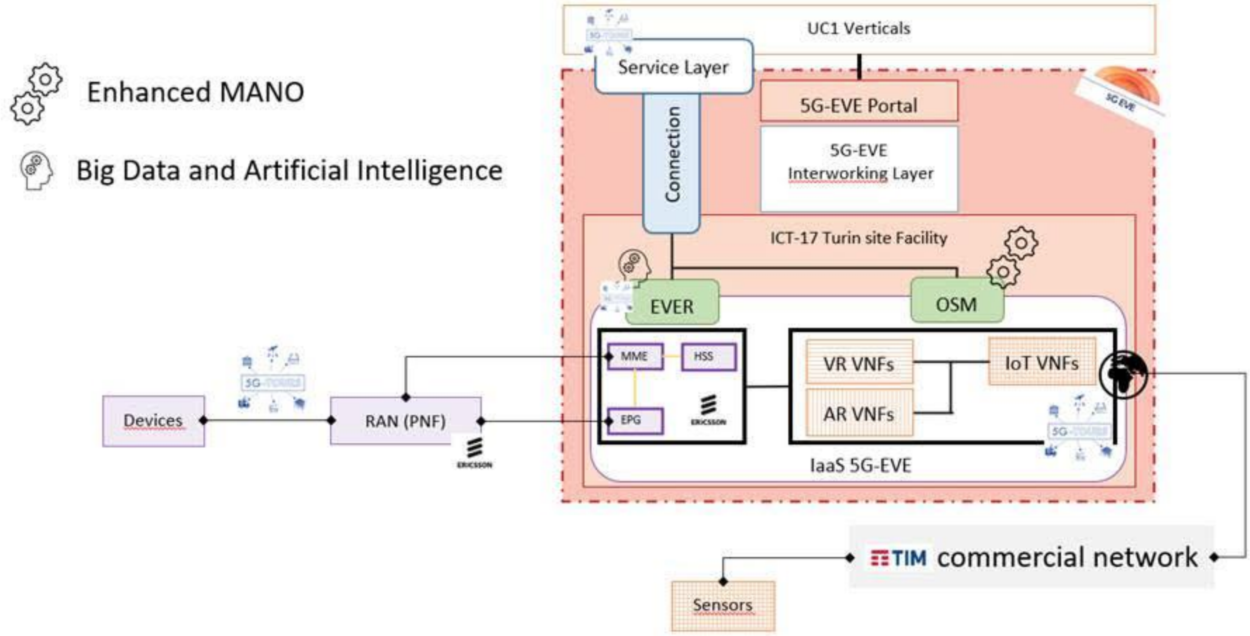


Figure 14. UC1 architecture instantiation.

The next section reports the user and network requirements, sequence diagrams and NEST description for the different UCs of the Turin site. With respect to the slice definition, it has to be highlighted that the requirements and the sequence diagram consider a target implementation solution in which slicing management will be supported by all the network elements (i.e., CN and RAN) as well as the application layer of the UCs. In such a case, for example, UC5 will require the instantiation of two different slices (i.e., eMBB and URLLC), but, in its experimentation on the 5G commercial network, the slicing cannot not be implemented. As mentioned before, studies are currently ongoing to experiment slicing functionalities for UC1 in the laboratory context.

4.3 UCs

4.3.1 UC1 - Augmented tourism experience

4.3.1.1 High level description

This use case aims to provide the visitors of targeted museums with an improved and more engaging experience based on the use of eXtended Reality (XR) technologies. The UC1 is divided into two sub use cases: UC1a, that will take place in Palazzo Madama enclosing two scenarios, Augmented Reality (AR) and Virtual Reality (VR), and UC1b that will be based in GAM. Each scenario is described in the sections below.

4.3.1.1.1 UC1a AR and VR: In the very heart of Turin

This sub-UC aims to create and test an integrated, immersive visit in the Museum and surrounding areas using a mobile application (App) that uses different technologies. Through the App, the visitor will have access to additional information such as level of crowding in a museum room, map of the museum, and related points of interest as well as access to more content related to specific rooms and artworks. It will be possible to interact with 3D objects or participate in a virtual scenario to improve the visitor knowledge by taking actions. Furthermore, at the end of the visit, the App will help visitors suggesting further places of interest using interaction with "smart city services". Finally, once at home, the city tourists can retrieve artworks previously stored during the tour. The application also integrates an emergency notification system that will notify the user in case of fire or earthquake directly into their smartphones.

4.3.1.1.2 UC1b: GAM and Edulab – Gamification, let's play artist

The objective of this sub-UC is to allow users to enter the life of De Maria contemporary artist and to directly test the 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 with gamification and will allow children to work on an interactive wall reproducing the artist's canvas by choosing shape and colours contents.

4.3.1.2 UC specific User and Network Requirements

For the implementation of the three scenarios, the following requirements from the user perspective are needed:

Table 12. 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	**Sporatic / low (IoT) (reviewd)**
	12	**Interactivity & Space Dependency:**	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	**Medium Density /Low (IoT) (reviewd)**
Structural User Requirements	13	***Edge Computing :***	Yes/No	**No**
	14	***Edge Storage :***	Yes/No	**Yes**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**N/A (IoT) (reviewd)**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated in the following Table 13, Table 14, and Table 15, where the vertical use case requirements for the 3 sub-use cases of use case 1 are shown.

Table 13. UC1a – Augmented Tourism Experience AR (mMTC & eMBB)- network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) UC1a : AR - Augmented tourism experience (in Palazzo Madama)			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec		100	100		20	100
2	**RAN** Latency (in milliseconds) - one way	msec		25	50		25	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		30Kbps - 130Kbps	400Mbps - 600 Bbps		30Kbps	600Mbps
4	Reliability (%) - Min/Max	%		99,99%	99,9999%		99.99%	99,9999%
5	Availability (%) - Min/Max	%		99,999%	99,99%		99,99%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		N/A	10		0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps		No	0.08		0.08	0.08
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N		No	50		50	90
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y (Baseline)	Y			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2		1*	12**		1	12
11	Device Density	Dev/Km^2		20+	400		20	400
12	Location Accuracy	m		N/A	1		1	1

(*) 1 Mbps/Km^2 = 0,000001 Mbps/m^2

(**) 12 Mbps/Km^2 = 0,000012 Mbps/m^2

Table 14. UC1a – Augmented Tourism Experience VR (URLLC) - network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) UC1a : VR - Augmented tourism experience (in Palazzo Madama)			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	20				20	100
2	**RAN** Latency (in milliseconds) - one way	msec	10				10	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	100				80	100
4	Reliability (%) - Min/Max	%	99,9999%				99.99%	99,9999%
5	Availability (%) - Min/Max	%	99,99%				99,99%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10				0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0.08				0.08	0.08
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	50				50	90
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12				1	12
11	Device Density	Dev/Km^2	400				20	400
12	Location Accuracy	m	<1				1	1

Table 15. UC1b – Augmented Tourism Experience (URLLC) - network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) UC1b : Augmented tourism experience (in in GAM)			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	20				20	100
2	**RAN** Latency (in milliseconds) - one way	msec	10				10	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	80				30	80
4	Reliability (%) - Min/Max	%	99,9999%				99.99%	99,9999%
5	Availability (%) - Min/Max	%	99,99%				99,99%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10				0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0.08				0.08	0.08
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	50				50	90
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12				1	12
11	Device Density	Dev/Km^2	400				20	400
12	Location Accuracy	m	<1				1	1

The corresponding radar charts comparing the three scenario-specific requirements against the 4G/5G networks capabilities are shown in Figure 15, Figure 16, Figure 17, and Figure 18.

The relation between sub-use cases and slices is the following:

- UC1a AR, running in Palazzo madama, is eMMB and mMTC.
- UC1a VR, also running in Palazzo madama, is URLLC.
- UC1b is URLLC and running in GAM.

The Augmented Tourism Experience use case utilized all three traffic types (namely URLLC, mMTC and eMBB communications).

All three traffic types need the 5G network capabilities for providing the extra Location Accuracy, Throughput and High reliability that the current 4G/LTE networks cannot deliver.

Furthermore, for UC1a VR and UC1b, the URLLC traffic requires also an end-to-end Network Latency in the order of 20 msec that will better be delivered using the 5G network capabilities. This low latency is due to the need of some interactivity.

Moreover, for the URLLC, mMTC and eMBB traffic, the Location Accuracy Requirement of 1 meter challenges the 5G capabilities to the limit, which may need an LBS (Location-Based Service) to be provided by the network provider or by using antennas information to locate the UE device, in order to acquire the accurate position of the end user.

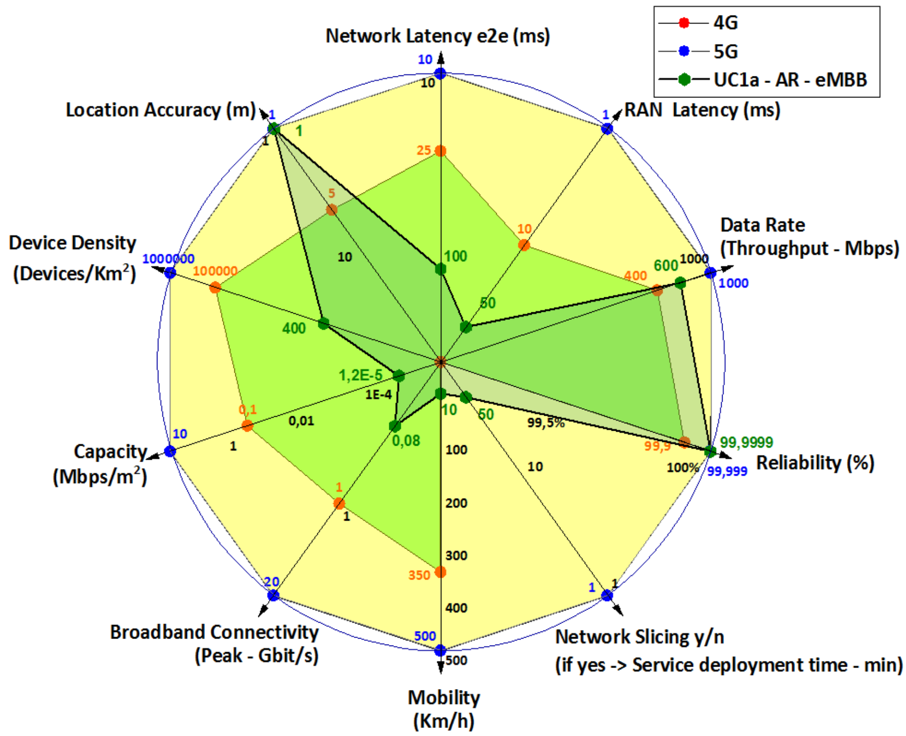


Figure 15. Radar chart for UC1a AR scenario – eMBB network requirements.

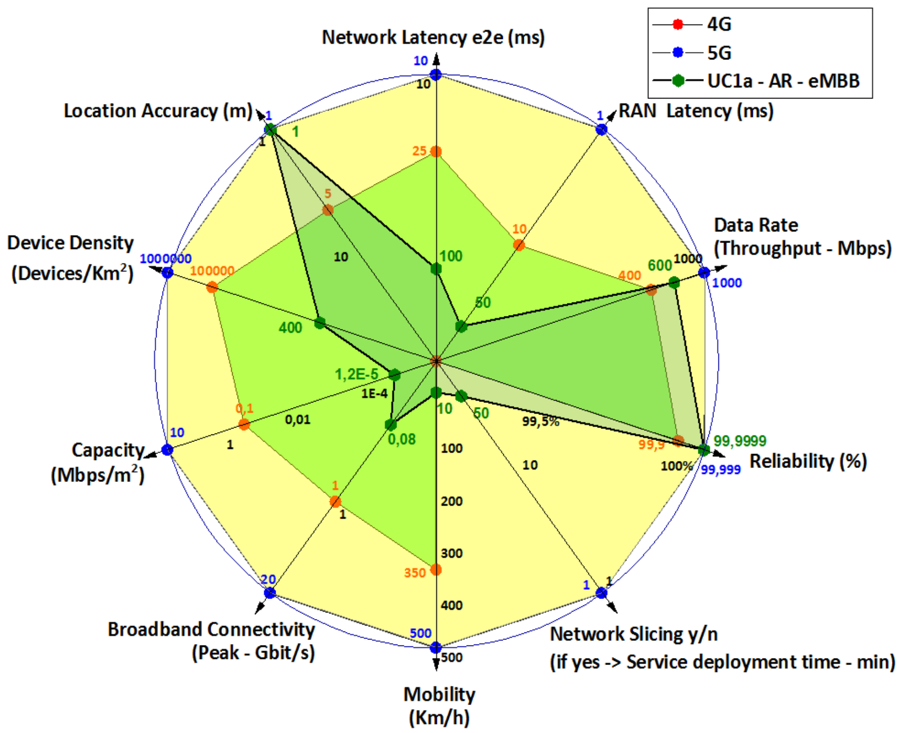


Figure 16. Radar chart for UC1a AR scenario – mMTC network requirements.

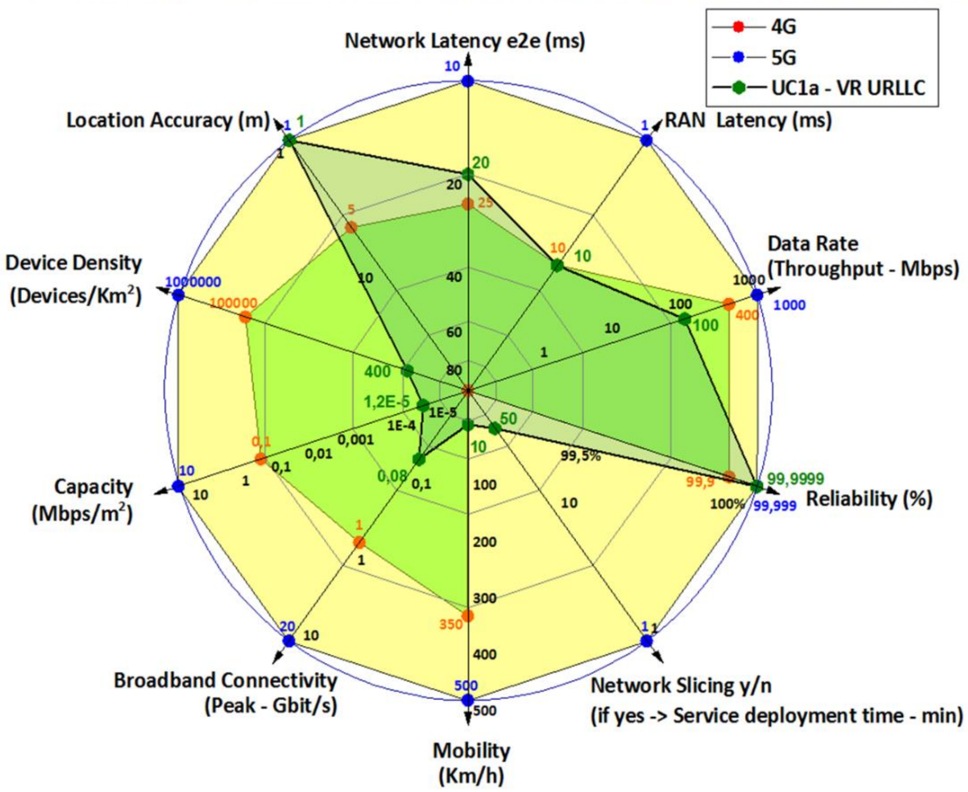


Figure 17. Radar chart for UC1a VR scenario URLLC network requirements.

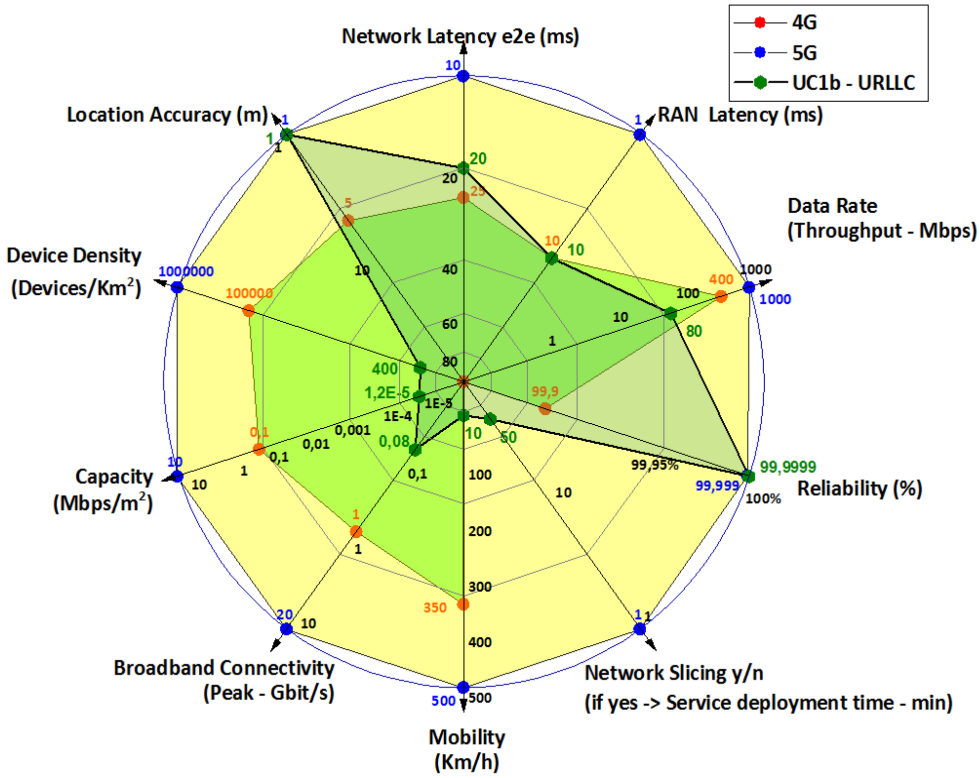
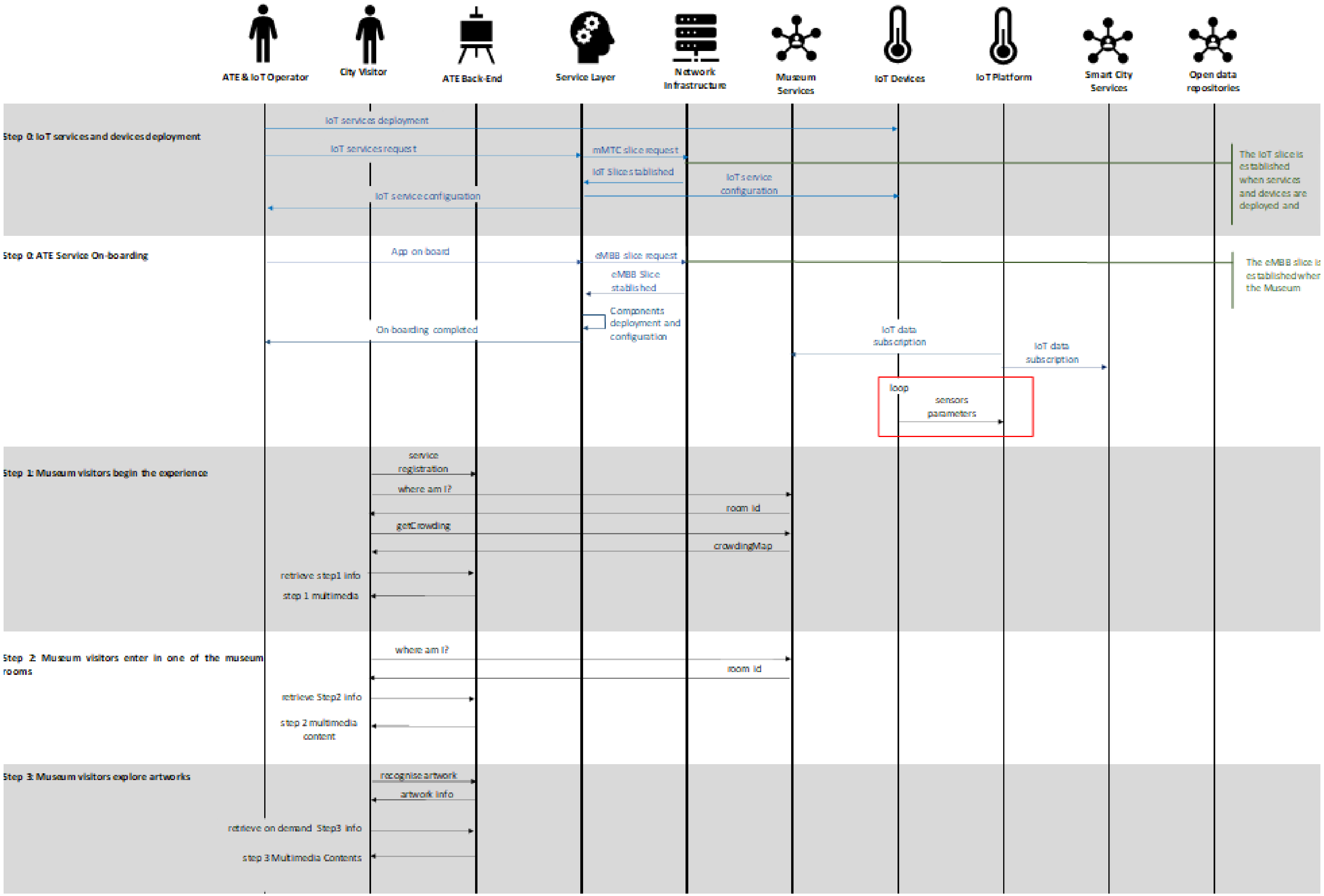


Figure 18. Radar chart for UC1b scenario URLLC network requirements.

4.3.1.3 Updated sequence diagrams

4.3.1.3.1 UC1a AR Augmented tourism experience. In the very heart of Turin



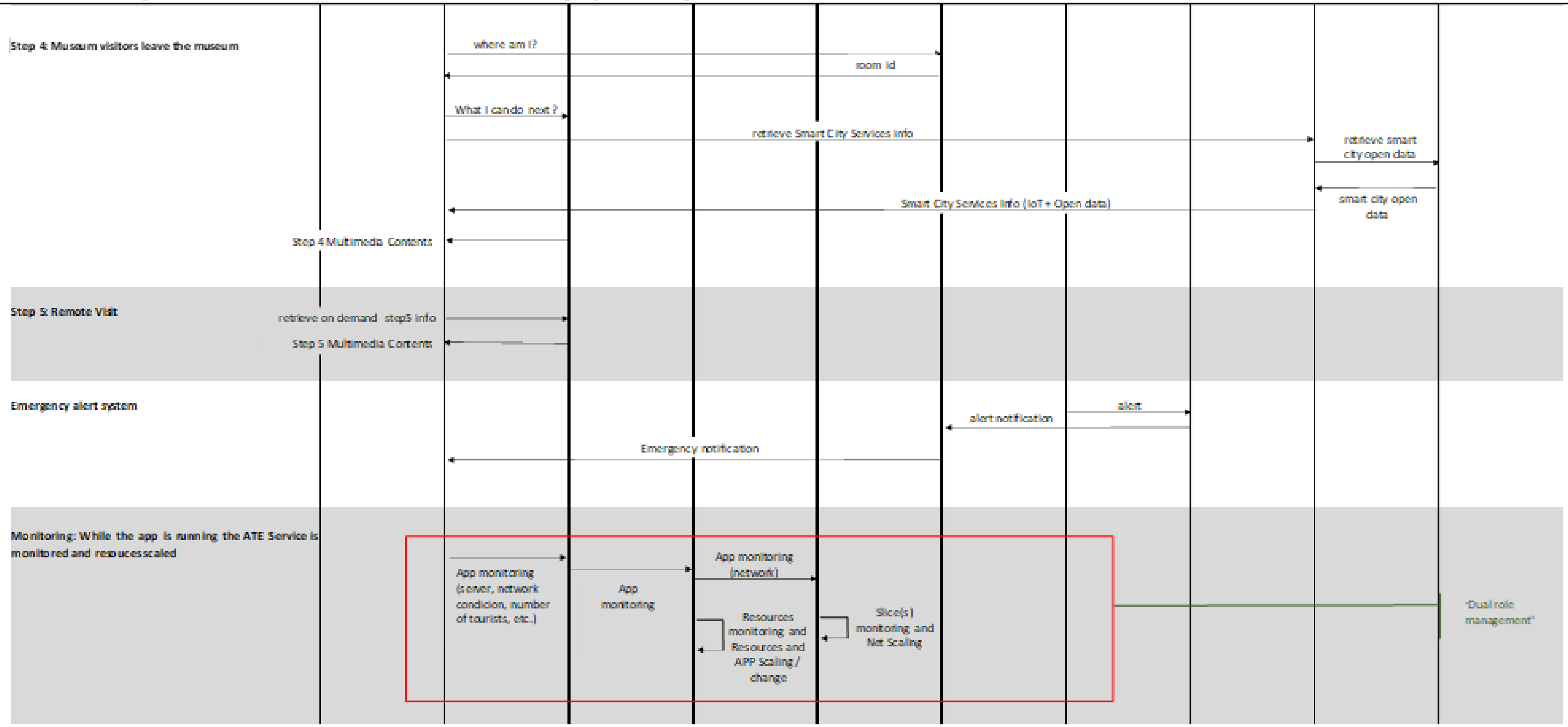
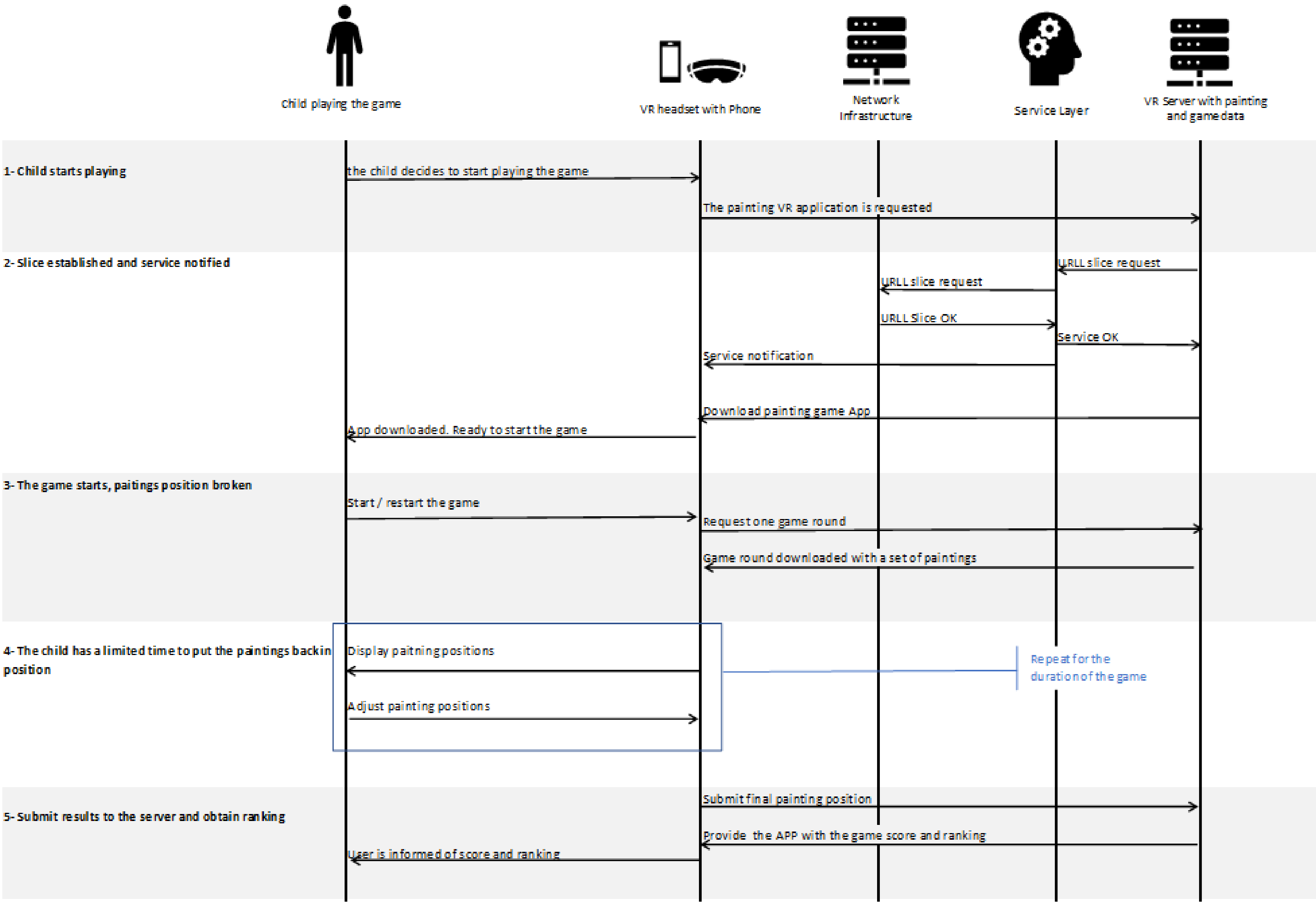


Figure 19. UC1a AR sequence diagram.

4.3.1.3.2 UC1a VR Augmented tourism experience. In the very heart of Turin



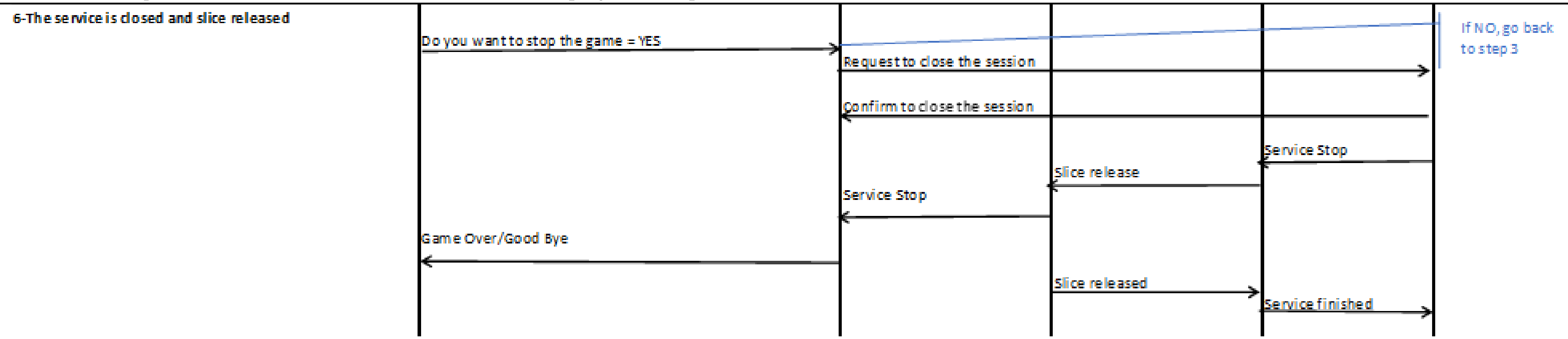
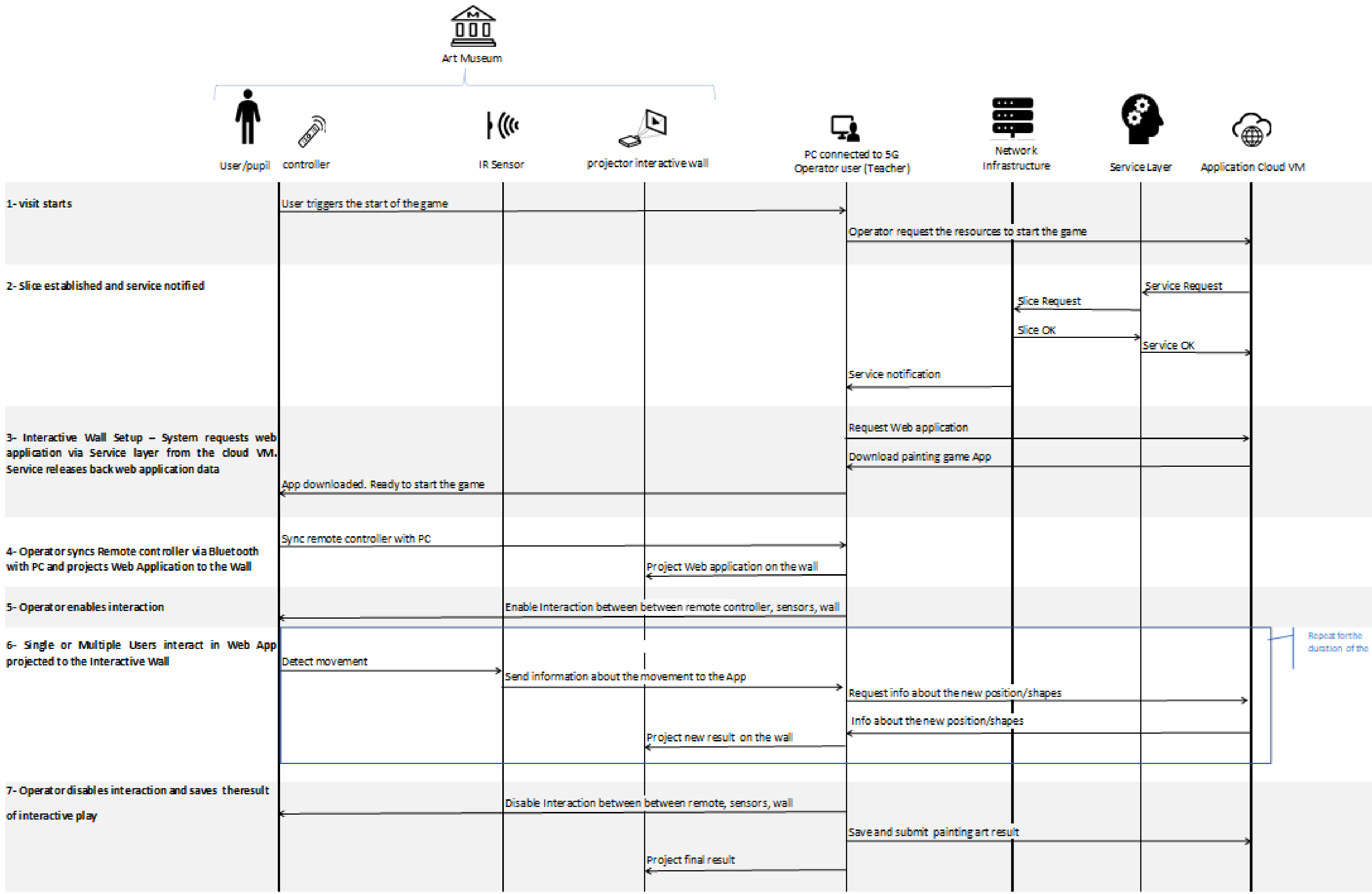


Figure 20. UC1a VR sequence diagram.

4.3.1.3.3 UC1b Augmented tourism experience. GAM and Edulab – Gamification, let´s play artist



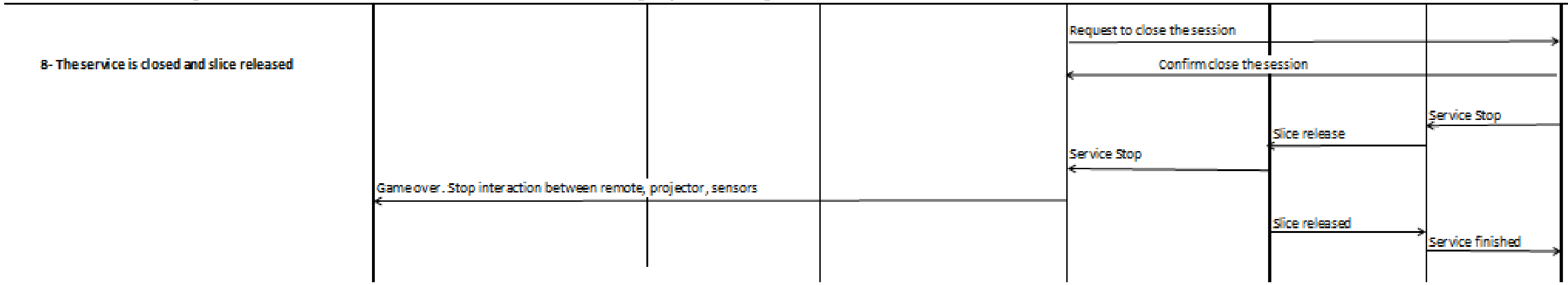


Figure 21. UC1b sequence diagram.

4.3.1.4 NEST

4.3.1.4.1 UC1a AR

Attribute	Subparameter	eMBB	mMTC	Additional info
Availability		99.99%	99.999%	
Area of Service		IT		
	Region specification	TO, Piedmont		
Delay Tolerance		Not supported		
Deterministic Communication	Availability	Not supported		
	Periodicity	NA		
Downlink throughput per network slice instance	Guaranteed	~ 6Gbps	600 Kbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage # Terminals for UC1.a AR (eMBB) = 15 #Terminals for UC1.a AR (mMTC) = 20NB-IoT boards
	Maximum	~ 9Gbps	2.6Mbps	
Downlink Throughput Per User	Guaranteed	400Mbps (For a download of 100MB in 2s)	30 Kbps	
	Maximum	600Mbps (For a download of 150MB in 2s)	130Kbps	
Energy Efficiency	Network slice energy efficiency	NA		
	Time frame of the measurement	NA		
Group Communication Support		Not supported		
Isolation level	Isolation	Logical Isolation		
	Physical Isolation	NA		
	Logical Isolation	Virtual resource isolation		
Location Based Message Delivery		NA		
Maximum Supported Packet Size		1500 Bytes		
Mission critical support	Mission critical support	Non-mission-critical		
	Mission critical capability support	NA		
	Mission critical service support	NA		
MMTel Support		Not supported		
NB-IoT Support		Supported		This is not needed for the beaconing system, but UC1.a AR will support anyway NB-IoT in order to provide information about pollution and/or about emergency situations (i.e. fire/earthquake) through appropriate IoT sensors that will be installed at Palazzo

Attribute	Subparameter	eMBB	mMTC	Additional info
				Madama and in the surroundings. Such IoT service will use the 4G network since 5G enabled sensors are not yet available and the service itself has not been activated on the 5G network yet
NSC Network Functions		Multimedia Backend	NA	
Number of connections		15	20	Number of connections = Number of terminals
Number of terminals		15	20	For mMTC, as terminal, we refer to boards used to sense temperature, humidity, fire and earthquake inside the museum. Beacons are not connected to the network; they only transmit an id using BLE (Bluetooth Low Energy) that is captured by the mobile app.
Performance Monitoring	Availability	User Data Rate (DL and UL), RTT latency, Reliability		KPIs provided by 5G-EVE exposed through the service layer
	Monitoring	Per second		
Performance Prediction	Availability	Not supported		
	Prediction	Not supported		
Positioning Support	Availability	NA		
	Prediction	NA		
	Accuracy	NA		
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR		
Root Cause Investigation		Not supported		
Session and Service Continuity Support		SSC mode 1		Confirmed with 5G-EVE Turin
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice		
Slice Quality of Service	3GPP 5QI	80		eMBB: Low latency, eMBB applications, AR mMTC: Scalar associated to latency < 10ms
	Resource Type	Non-GBR		Value defined by 5QI = 80
	Priority Level	68		Value defined by 5QI = 80
	Packet Delay Budget (PDB)	0.01		Value defined by 5QI = 80
	Packet Error Rate (PER)	10^{-6}		Value defined by 5QI = 80
	Jitter	NA		Value defined by 5QI = 80
	Maximum Packet Loss Rate	NA		Value defined by 5QI = 80
Support for Non-IP traffic		Not supported		
Supported Device Velocity		10 km/h Pedestrian	0 km/h Stationary	
Synchronicity	Availability	Not supported		

Attribute	Subparameter	eMBB	mMTC	Additional info
	Accuracy	NA		Being a TDD system, 5G supports synchronicity as per radio interface specifications; this is not anyway related to the UC but to the 5G system behaviour itself.
Terminal Density		15 devices/Km^2	20 devices/km^2	
Uplink Throughput Per network slice instance	Guaranteed	300Mbps	600 Kbps	Downlink Throughput Per User * maximum number of users
	Maximum	450Mbps	3.2 Mbps	
Uplink Throughput Per User	Guaranteed	20Mbps	30 Kbps	
	Maximum	30Mbps	160 Kbps	
User Management Openness		Not supported		
User Data Access	Data access	Direct internet access		
	Tunnelling Mechanism	NA		
V2X communication mode		Not supported		
Latency from UPF to App Server		NA		
Network Slice Specific Authentication and Authorization (NSSAA)		Supported		

4.3.1.4.2 UC1a VR

Attribute	Subparameter	URLLC	Additional info
Availability		99.99%	
Area of Service		IT	
	Region specification	TO, Piedmont	
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	>160 Mbps	Calculated like: Downlink Throughput Per User*number of users Users = 2 devices for UC1.a VR
	Maximum	200 Mbps	
Downlink Throughput Per User	Guaranteed	>80 Mbps	
	Maximum	100 Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		Not supported	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Non-mission-critical	
	Mission critical capability support	NA	

Attribute	Subparameter	URLLC	Additional info
	Mission critical service support	NA	
MMTel Support		Not supported	
NB-IoT Support		Not supported	
NSC Network Functions		User- environment interactions backend	
Number of connections		2	Assumption: Number of connections = Number of terminals. In practice, from the infrastructure point of view, the number of terminals is only limited by the maximum cell throughput divided by the minimum throughput per terminal. At the moment, we are considering: 2 devices for UC1.a VR
Number of terminals		2	
Performance Monitoring	Availability	User Data Rate (DL and UL), RTT latency, Reliability, Availability	
	Monitoring	Per second	
Performance Prediction	Availability	Not supported	
	Prediction	Not supported	
Positioning Support	Availability	NA	
	Prediction	NA	
	Accuracy	NA	
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice	
Slice Quality of Service	3GPP 5QI	80	Low latency, eMBB applications, AR
	Resource Type	Non-GBR	Value defined by 5QI= 80 (non mission critical traffic)
	Priority Level	68	Value defined by 5QI= 80
	Packet Delay Budget (PDB)	0.01	Value defined by 5QI= 80
	Packet Error Rate (PER)	10^{-6}	Value defined by 5QI= 80
	Jitter	NA	Value defined by 5QI= 80
	Maximum Packet Loss Rate	NA	Value defined by 5QI= 80
Support for Non-IP traffic		Not supported	
Supported Device Velocity		10 km/h - Pedestrian	
Synchronicity	Availability	Not supported	Being a TDD system, 5G supports synchronicity as per radio inter-
	Accuracy	NA	

Attribute	Subparameter	URLLC	Additional info
			face specifications; this is not anyway related to the UC but to the 5G system behaviour itself
Terminal Density		2 device/km^2	2 users
Uplink Throughput Per network slice instance	Guaranteed	40 Mbps	Uplink Throughput Per User * maximum number of users
	Maximum	60 Mbps	
Uplink Throughput Per User	Guaranteed	20 Mbps	
	Maximum	30 Mbps	
User Management Openness		Not supported	
User Data Access	Data access	Direct internet access	
	Tunnelling Mechanism	NA	
V2X communication mode		Not supported	
Latency from UPF to App Server		NA	
Network Slice Specific Authentication and Authorization (NSSAA)		Supported	

4.3.1.4.3 UC1b

Attribute	Subparameter	URLLC	Additional info
Availability		99.99%	
Area of Service		IT	
	Region specification	TO, Piedmont	
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	>30 Mbps	Calculated like: Downlink Throughput Per User * number of users Users= 1 for UC1.b
	Maximum	80 Mbps	
Downlink Throughput Per User	Guaranteed	>30 Mbps	
	Maximum	80 Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		Not supported	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Non-mission-critical	
	Mission critical capability support	NA	
	Mission critical service support	NA	

Attribute	Subparameter	URLLC	Additional info
MMTel Support		Not supported	
NB-IoT Support		Not supported	
NSC Network Functions		NA	
Number of connections		1	Assumption: Number of connections = Number of terminals
Number of terminals		1	
Performance Monitoring	Availability	User Data Rate (DL and UL), RTT latency, Reliability, Availability	
	Monitoring	Per second	
Performance Prediction	Availability	Not supported	
	Prediction	Not supported	
Positioning Support	Availability	NA	
	Prediction	NA	
	Accuracy	NA	
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice	
Slice Quality of Service	3GPP 5QI	7	Voice, video (live streaming), interactive video
	Resource Type	Non-GBR	Value defined by 5QI = 7
	Priority Level	70	Value defined by 5QI = 7
	Packet Delay Budget (PDB)	0.1	Value defined by 5QI = 7
	Packet Error Rate (PER)	10^{-3}	Value defined by 5QI = 7
	Jitter	NA	Value defined by 5QI = 7
	Maximum Packet Loss Rate	NA	Value defined by 5QI = 7
Support for Non-IP traffic		Not supported	
Supported Device Velocity		10 km/h - Pedestrian	
Synchronicity	Availability	Not supported	Being a TDD system, 5G supports synchronicity as per radio interface specifications; this is not anyway related to the UC but to the 5G system behaviour itself
	Accuracy	NA	
Terminal Density		1/2 device/km2	This is generic information provided in D2.2 = 400 devices/km2. For this specific trial the number will be much less:1 or 2 devices/km2
Uplink Throughput Per network slice instance	Guaranteed	<40 Mbps	Uplink Throughput Per User * maximum number of users
	Maximum	<40 Mbps	
Uplink Throughput Per User	Guaranteed	<40 Mbps	

Attribute	Subparameter	URLLC	Additional info
	Maximum	<40 Mbps	
User Management Openness		Not supported	
User Data Access	Data access	Direct internet access	
	Tunnelling Mechanism	NA	
V2X communication mode		Not supported	
Latency from UPF to App Server		NA	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

4.3.2 UC2 – Telepresence

4.3.2.1 High level description

UC2 refers to technologies that allow users to appear to be present in a space the person is not physically. Through a telepresence robot assisted experience, the users of UC2 shall 1) have the opportunity to enjoy a remote visit of the museum inaccessible 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).

Each of these three sub use cases are explained in more detail in the sections below.

4.3.2.1.1 UC2a Telepresence. Palazzo Madama exclusive exhibitions for all

This specific sub-use case will be set in Palazzo Madama and will be characterized by a remote visit to the museum basement and underground, an area normally closed to the public and difficult to be reached. At the present time, it is only visible through the glass floating floor of the main hall at ground floor.

4.3.2.1.2 UC2b Telepresence. Play and visit modern art from museum to school

The objective of this sub-use case is to offer enhanced educational activities to students at school. The target audience for this application are children from 6 to 13 years old. Because of the UC’s target, gamification throughout the creation of a virtual “Treasure Hunt” in the GAM museum will be used.

4.3.2.1.3 UC2c Surveillance of the museum

Robots will be used for tele-surveillance of the Palazzo Madama museum both during day and night hours. The use case shares IoT data collected in UC1.a regarding the crowding level of rooms, safety conditions (fire and earthquakes alerts) and other information like temperature and humidity inside each room (to preserve artworks).

4.3.2.2 UC specific User and Network Requirements

For the implementation of this UC, the requirements shown in Table 16 are needed from the user perspective.

The mapping of the above user requirements into network requirements are illustrated into the Table 17, where the vertical use case requirements for the use case 2 are shown.

Table 16. 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 / Medium (reviewed)**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Fast (reviewed)**
	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 (media) (reviewed)** **Sporadic / high (controls)** **Sporatic / low (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 (reviewed)**
	14	***Edge Storage :***	Yes/No	**No**
Service Specific (Examples)	15	***Battery Life:***	High /Medium/ Low	**N.A.**
	16	***other***	User specified	**N.A.**

Table 17. UC2 – Telepresence network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - UC2 – Telepresence			Priority	Range	
			URLLC	mMTC*	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	50	100		High	50	200
2	**RAN** Latency (in milliseconds) - one way	msec	10	25		High		25
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	30	1<		High	~10	~30
4	Reliability (%) - Min/Max	%	99,99%	99,99%			99%	99,99%
5	Availability (%) - Min/Max	%	99,99%	99,999%			99%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	1	N/A			0,1	1
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,1	No				0,1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	N	No				
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y (Baseline)	Y (Baseline)				
10	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	30**	1 ***				
11	Device Density	Dev/Km^2	2	20+			10	100
12	Location Accuracy	m	2	N/A			1	5

(*) mMTC: mMTC requirements are needed for IoT sensors

(**) 30 Mbps/Km^2 = 0,00003 Mbps/m^2

(***) 1 Mbps/Km^2 = 0,000001 Mbps/m^2

The corresponding radar charts of the use case general requirements against the 4G/5G networks capabilities are shown in Figure 22 and Figure 23.

The Telepresence use case needs a 5G network order to achieve the required Location Accuracy, Reliability, and Slicing (Service deployment time).

With respect to the previous deliverable D2.2, the values of E2E Network Latency and the RAN Latency for URLLC and mMTC have been revised to (50 ms, 10 ms) and (100 ms, 25 ms) respectively thanks to the improvements in the application development. Especially for URLLC, the new values are positioned at the limits of the 4G capabilities; therefore, 5G is requested to meet such requirements in a real network deployment. Furthermore, the Location Accuracy requirement of 2 m in URLLC, can easily be covered by 5G LBS service.

Moreover, the mMTC requirements are needed for the IoT sensors. This is the only case where the reliability can't be achieved by 4G and need 5G network.

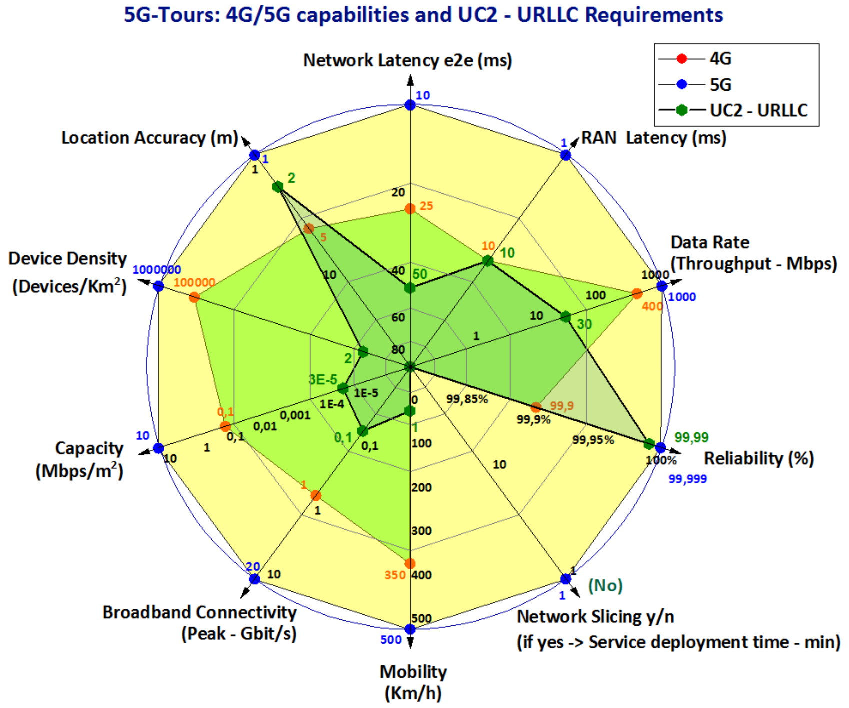


Figure 22. Radar chart for UC2 Telepresence URLLC network requirements.

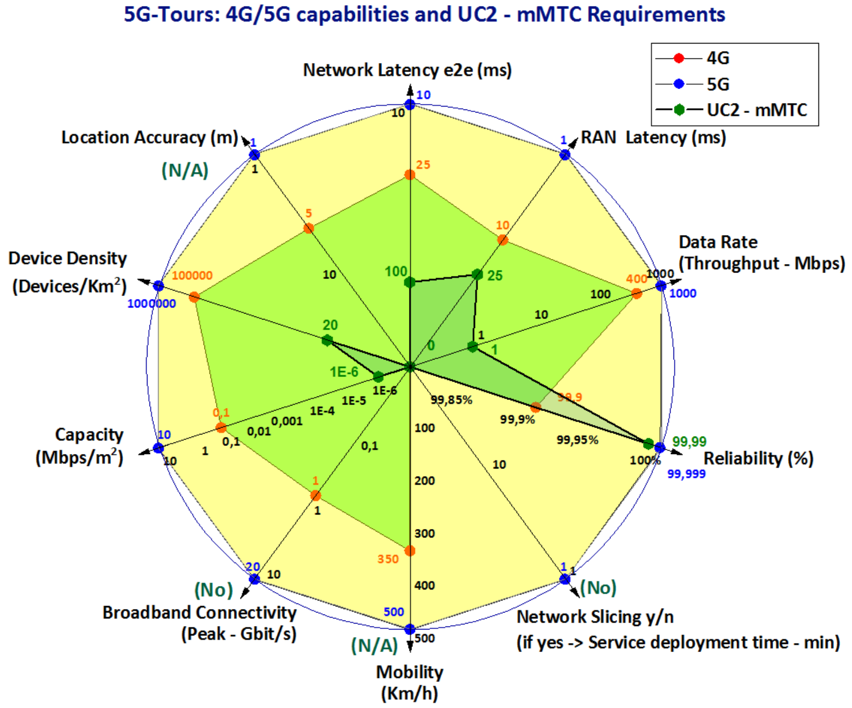


Figure 23. Radar chart for UC2 Telepresence mMTC network requirements.

4.3.2.3 Updated sequence diagram

4.3.2.3.1 UC2a Telepresence. Palazzo Madama exclusive exhibitions for all

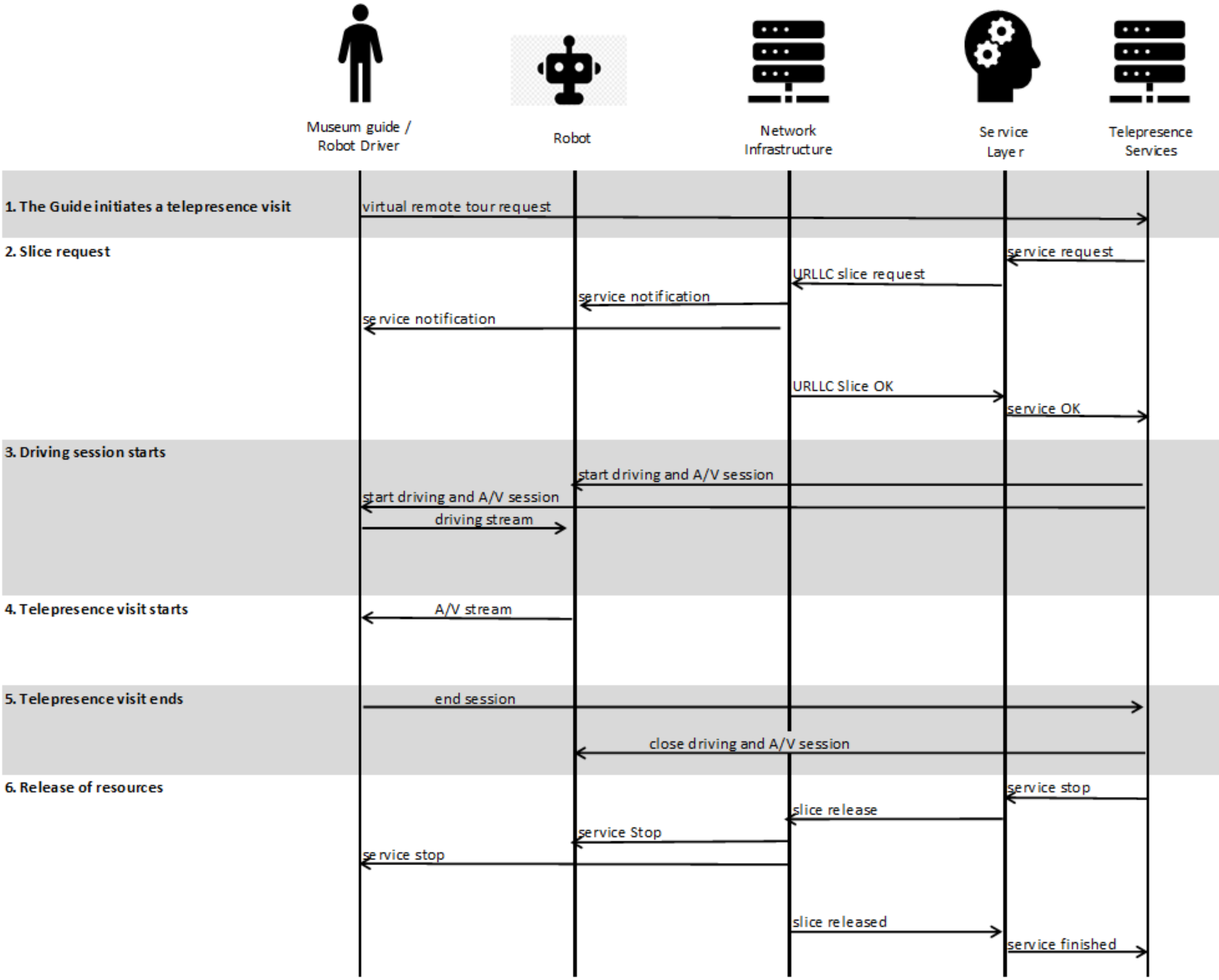
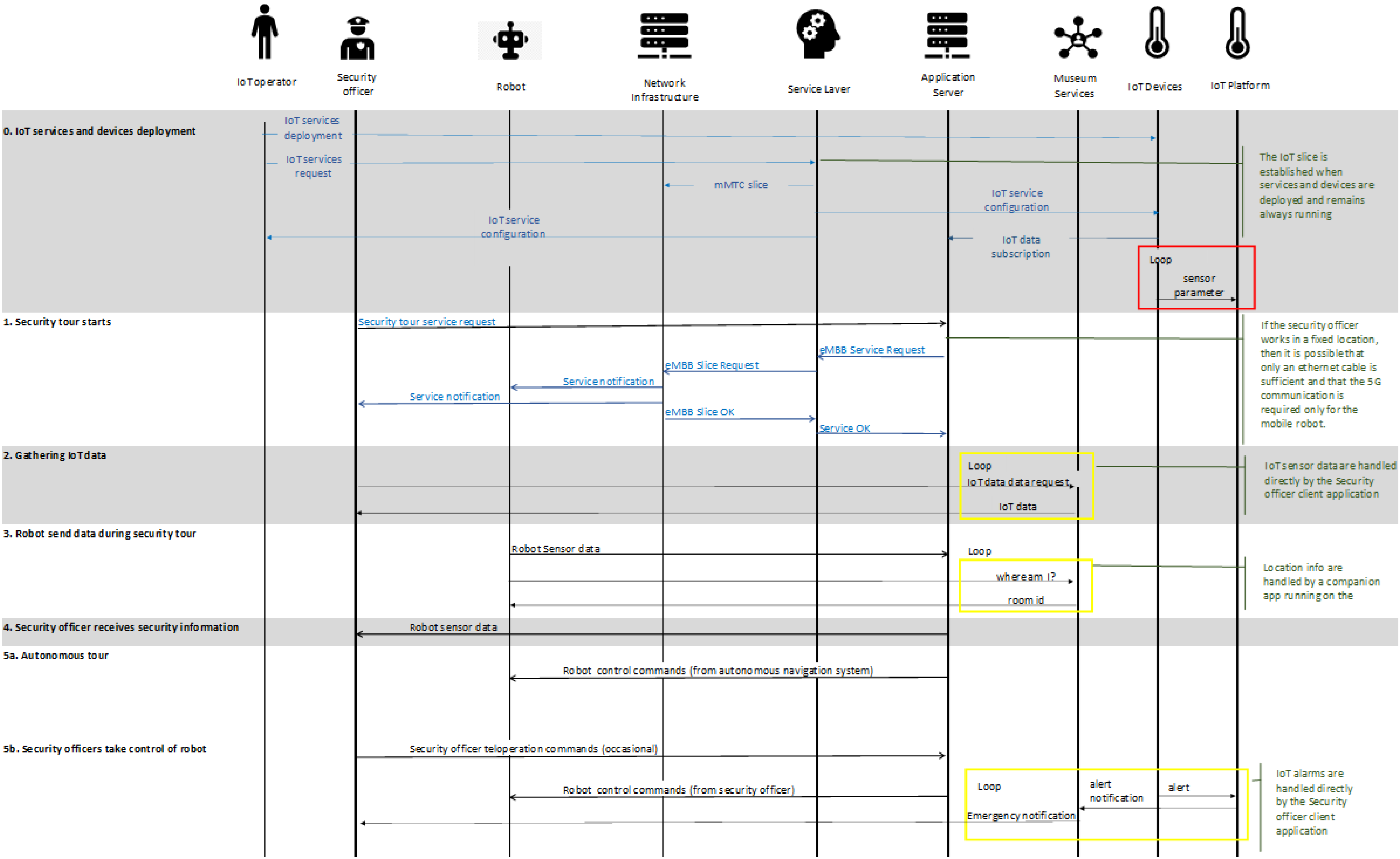


Figure 24. UC2a sequence diagram.

Note 1: We assume that the museum guide and the museum visitors are in a virtual room physically enabled at the museum. The application of this kind of installation is to improve the access to certain spaces in the museum to, for example, disabled people. The scenario presented in the diagram could be extended considering that both the visitor(s) and the guide are in a remote virtual room, so all of them have to interact with the Telepresence Service. This scenario is out of the scope of the demo to be performed during the project lifetime though.

Note 2: From the technical perspective, there is no difference between UC2a and UC2b, so the sequence diagrams are similar. In UC2b, the role of the guide (and driver of the robot) is replaced by the educator one, while the museum visitors´ by the students´ one. The big difference between the two sub-use cases is that UC2a allow the visitors to “see” the Palazzo Madama´s underground, that is a restricted access area, through the robot; UC2b is performed in the rooms of the GAM, accessible to the students. The gaming component is introduced through the way the driver used the robot to perform the Treasure Hunt.

4.3.2.3.2 UC2c Surveillance of the museum



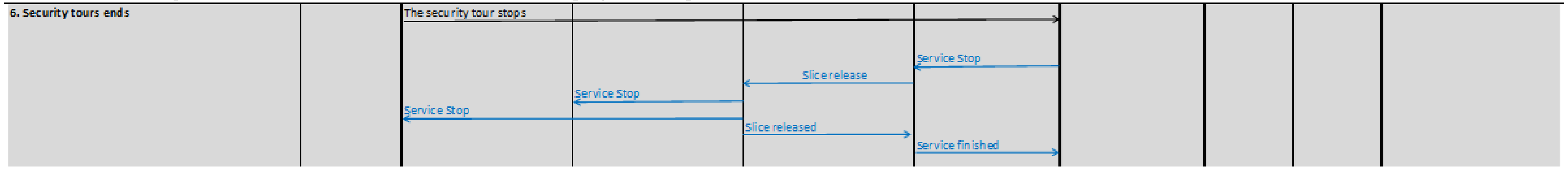


Figure 25. UC2c sequence diagram for TIM Double3 Robot.

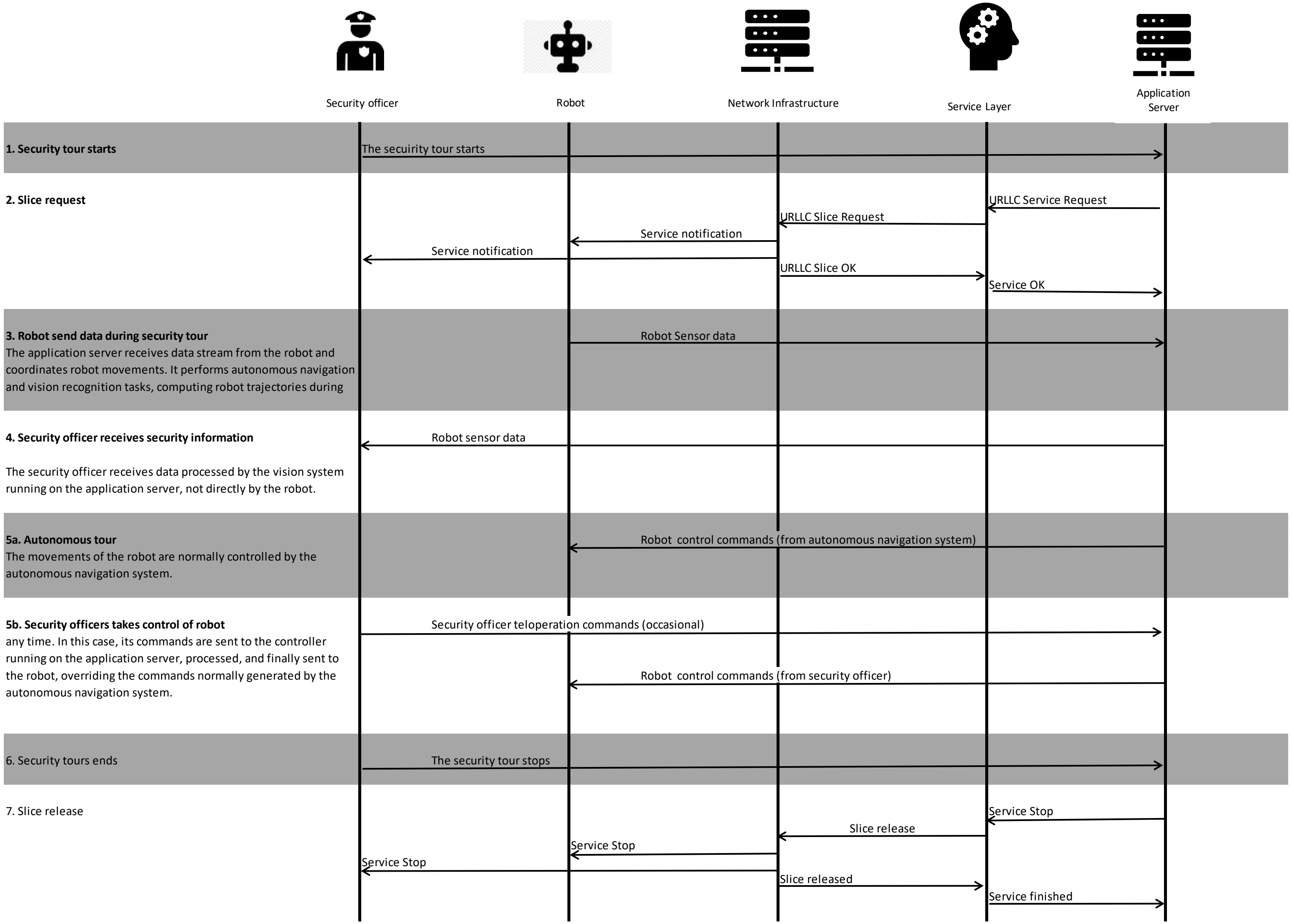


Figure 26. UC2c sequence diagram for IIT R1 Robot.

Note 1: For UC2c, two different sequence diagrams are shown, as two different types of robot are used and there are some peculiarities in each of the robot-specific applications.

4.3.2.4 NEST

As shown in the previous section dedicated to "UC specific User and Network Requirements", all the three sub-use cases that compose UC2 require the establishment of two slice types, URLLC and mMTC for the IoT sensors. The NESTs corresponding to each of these slices are shown below.

Attribute	Subparameter	URLLC	mMTC	Additional info
Availability		99.99%	99.999%	
Area of Service		IT		
	Region specification	TO, Piedmont		
Delay Tolerance		Not supported		
Deterministic Communication	Availability	Not supported		
	Periodicity	NA		
Downlink throughput per network slice instance	Guaranteed	10Mbps	600 Kbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage #Users = a single robot (ULLC) #Terminals for UC1.a AR (mMTC) = 20NB-IoT boards
	Maximum	30Mbps	2.6Mbps	
Downlink Throughput Per User	Guaranteed	10Mbps	30 Kbps	
	Maximum	30Mbps	130Kbps	
Energy Efficiency	Network slice energy efficiency	NA		
	Time frame of the measurement	NA		
Group Communication Support		Not supported		
Isolation level	Isolation	Logical Isolation		
	Physical Isolation	NA		
	Logical Isolation	Virtual resource isolation		
Location Based Message Delivery		NA		
Maximum Supported Packet Size		1500 Bytes		
Mission critical support	Mission critical support	Non-mission-critical		
	Mission critical capability support	NA		
	Mission critical service support	NA		
MMTel Support		Not supported		
NB-IoT Support		Supported		
NSC Network Functions		NA		
Number of connections		1	20	Number of connections = Number of terminals
Number of terminals		1	20	For mMTC, as terminal, we refer to boards used to sense temperature, humidity, fire, and earthquake inside the museum. Beacons are not connected to the network; they only transmit an id using BLE (Bluetooth Low Energy) that is captured by the mobile app.

Attribute	Subparameter	URLLC	mMTC	Additional info
Performance Monitoring	Availability	User Data Rate (DL and UL), RTT latency, Reliability		KPIs provided by 5G-EVE exposed through the service layer
	Monitoring	Per second		
Performance Prediction	Availability	Not supported		
	Prediction	Not supported		
Positioning Support	Availability	NA		
	Prediction	NA		
	Accuracy	NA		
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR		
Root Cause Investigation		Not supported		
Session and Service Continuity Support		SSC mode 1		Confirmed with 5G-EVE Turin
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice		
Slice Quality of Service	3GPP 5QI	80		eMBB: Low latency, eMBB applications, AR mMTC: Scalar associated to latency < 10ms
	Resource Type	Non-GBR		Value defined by 5QI= 80
	Priority Level	68		Value defined by 5QI= 80
	Packet Delay Budget (PDB)	0.01		Value defined by 5QI= 80
	Packet Error Rate (PER)	10^{-6}		Value defined by 5QI= 80
	Jitter	NA		Value defined by 5QI= 80
	Maximum Packet Loss Rate	NA		Value defined by 5QI= 80
Support for Non-IP traffic		Not supported		
Supported Device Velocity		10 km/h Pedestrian	0 km/h Stationary	
Synchronicity	Availability	Not supported		Being a TDD system, 5G supports synchronicity as per radio interface specifications; this is not anyway related to the UC but to the 5G system behaviour itself.
	Accuracy	NA		
Terminal Density		1 devices/Km^2	20 devices/km^2	
Uplink Throughput Per network slice instance	Guaranteed	10Mbps	600 Kbps	Downlink Throughput Per User * maximum number of users
	Maximum	30Mbps	3.2 Mbps	
Uplink Throughput Per User	Guaranteed	10Mbps	30 Kbps	
	Maximum	30Mbps	160 Kbps	
User Management Openness		Not supported		
User Data Access	Data access	Direct internet access		
	Tunnelling Mechanism	NA		
V2X communication mode		Not supported		
Latency from UPF to App Server		NA		

Attribute	Subparameter	URLLC	mMTC	Additional info
Network Slice Specific Authentication and Authorization (NSSAA)		Supported		

4.3.3 UC3 - Robot-assisted museum guide

4.3.3.1 High level description

This use case foresees the use of robotic technology to provide an enhanced museum visit experience both in Palazzo Madama and GAM.

R1 robot will be able to: a) provide basic information about collection highlights and temporary exhibitions as well as assist visitors during queuing time at ticket desk; and b) guide visitors moving through the museum and describing the artworks. This guided tour will be performed autonomously by the robot following a predefined path. The 5G network will be exploited to partially relocate the "intelligence" (i.e.: the computation load, from the robot to an external workstation).

4.3.3.2 UC specific User and Network Requirements

For the implementation of this UC the following requirements, from the user perspective are needed (see Table 18):

Table 18. 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 (reviewed)**
	7	**Location Information:**	High / Medium / Low Accuracy	**Low (reviewed)**
	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	**High (the robot has access to images of people) (reviewed)**
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	**No (meaning no MAC technology) (reviewed)**
	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 19, where the vertical use case requirements for the use case 2 are shown.

Table 19. UC3 – Robot-Assisted Museum Guide network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - 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	30			High		35
2	**RAN** Latency (in milliseconds) - one way	msec	12,5			High		15*
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	40			High	~15	~50
4	Reliability (%) - Min/Max	%	99,99%				99%	99,99%
5	Availability (%) - Min/Max	%	99,99%				99%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	0,5				0,1	1
7	Broadband Connectivity (peak demand)	Y/N or Gbps	N					
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	N					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y (Baseline)					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	40**				~15	~50
11	Device Density	Dev/Km^2	1				1	1
12	Location Accuracy	m	0,1				0,1	0,5

(*) Although the robot is autonomous, moving part of the computation from the robot to the network in order to have higher computational power is needed. Hence sensory data should be sent from the robot to the external machines with a maximum delay of 15ms. Similarly, the maximum delay for the control action (from the network to the robot) should be ~15ms. Larger delays in the control loop (or packets loss) may cause instability/failure of the navigation system.

(**) Capacity = 40 Mbps/Km^2 = 0,00004 Mbps/m^2

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 27:

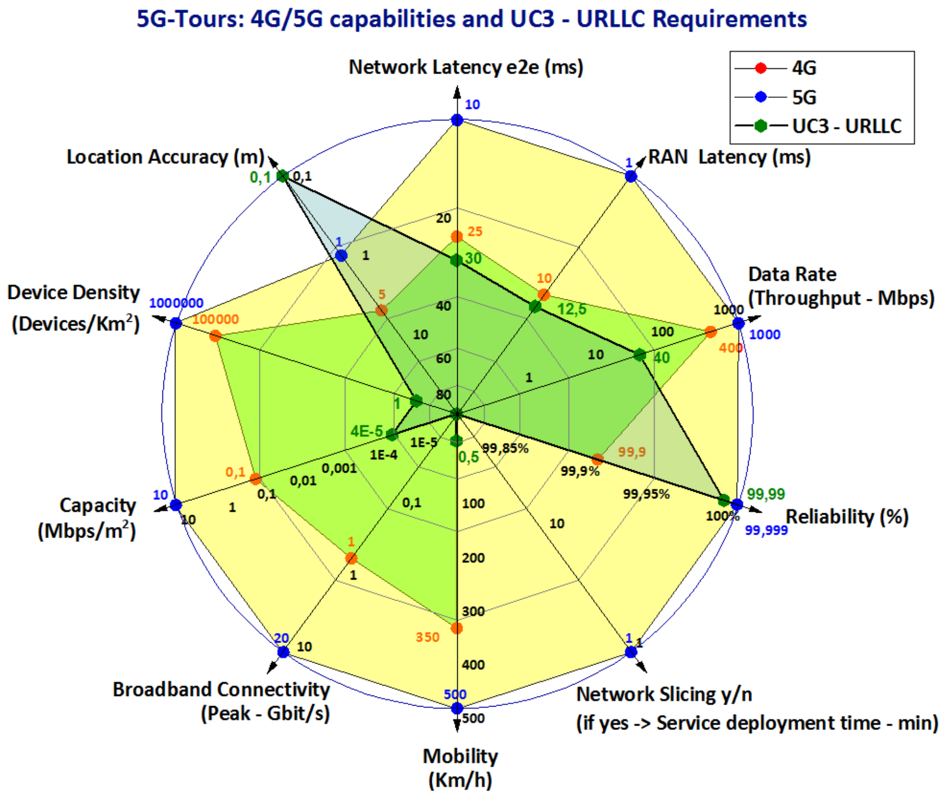


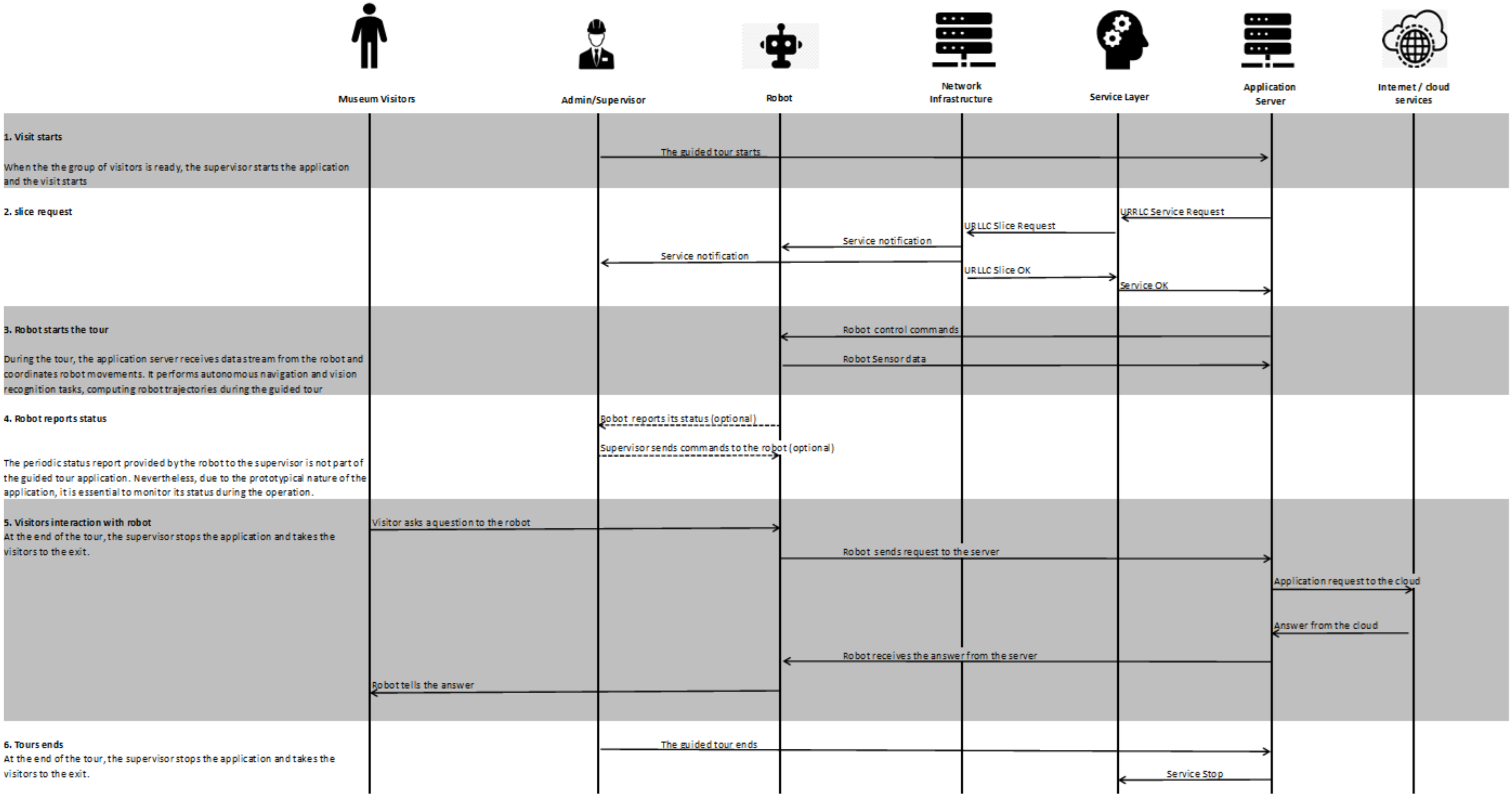
Figure 27. Radar chart for UC3 Robot-Assisted Museum Guide network requirements

Similar to the previous use case for the Robot-assisted museum guide, the Network Latency (round trip) and the RAN Latency have been revised to 30 ms and 12,5 ms respectively due to the performance improvement of the application. Nevertheless, such values are still difficult to be easily met by 4G capabilities and therefore the use of 5G is required.

Furthermore, the Location Accuracy requirement of 0,1m, 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/or other modalities like GPS (or location beacons for indoor) should also assist for acquiring the accurate position of the end user/robot. Therefore, a more complicated Location Base Service (LBS) algorithm should be investigated in order to improve of the accuracy that the 5G network will provide.

Additionally (to the Location Accuracy), Reliability dictates the use of a 5G Network for successful implementation of this use case.

4.3.3.3 Updated sequence diagram



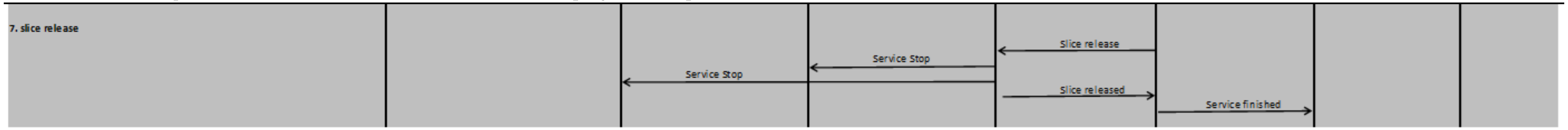


Figure 28. UC3 sequence diagram.

4.3.3.4 NEST

Attribute	Subparameter	URLLC	Additional info
Availability		99.99%	
Area of Service		IT	
	Region specification	TO, Piemonte	Indoor: Palazzo Madama, GAM
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	30 Mbps	Single Robot application
	Maximum	30 Mbs	Single Robot application
Downlink Throughput Per User	Guaranteed	30 Mbps	
	Maximum	50 Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		Not supported	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	1500 Bytes (default value)
Mission critical support	Mission critical support	Non-mission-critical	Somehow borderline. It is not as critical as health applications. In case of network missing the robot will be blocked by the operator
	Mission critical capability support	NA	
	Mission critical service support	NA	
MMTel Support		Not supported	
NB-IoT Support		NA	
NSC Network Functions		NA	
Number of connections		1	Assumption: Number of connections = Number of terminals
Number of terminals		1	
Performance Monitoring	Availability	User Data Rate, DL and UL RTT latency	Even if UC3 will rely on Commercial Network infrastructure, some KPI will be evaluated according to WP7 description.
	Monitoring	Per second	
Performance Prediction	Availability	NA	
	Prediction	NA	
Positioning Support	Availability	NA	NA for Turin infrastructure
	Prediction	NA	
	Accuracy	NA	
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR	

Attribute	Subparameter	URLLC	Additional info
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		NA	
Slice Quality of Service	3GPP 5QI	83	Low latency, URLLC
	Resource Type	Delay Critical GBR	Value defined by 5QI = 83
	Priority Level	22	Value defined by 5QI = 83
	Packet Delay Budget (PDB)	10 ms	Value defined by 5QI = 83
	Packet Error Rate (PER)	10^{-4}	Value defined by 5QI = 83
	Jitter	NA	Value defined by 5QI = 83
	Maximum Packet Loss Rate	NA	Value defined by 5QI = 83
Support for Non-IP traffic		Not supported	
Supported Device Velocity		0,5 km/h - Robot	
Synchronicity	Availability	Not supported	
	Accuracy	NA	
Terminal Density		1 devices/km2	For this specific trial the number will be 1 devices/km2 (one robot used in the museum)
Uplink Throughput Per network slice instance	Guaranteed	30 Mbps	
	Maximum	50 Mbps	
Uplink Throughput Per User	Guaranteed	30 Mbps	
	Maximum	50 Mbps	
User Management Openness		Not supported	
User Data Access	Data access	Direct internet access	
	Tunnelling Mechanism	VPN Tunnel	
V2X communication mode		Not supported	
Latency from UPF to App Server		NA	
Network Slice Specific Authentication and Authorization (NSSAA)		Supported	

4.3.4 UC4 - High quality video services distribution

4.3.4.1 High level description

This use case targets the distribution of enhanced high-quality video and immersive services for tourists to enhance the user experience when visiting a city. It is directly related to the media and entertainment vertical. Users will be able to use their smartphones, tablets, or VR devices to receive educational and informative content during their visits to the city and its museums. Video sources will be produced in collaboration with the RAI Television Production Centre. This Audio/Video (A/V) product will be used for the demos in 5G-TOURS and serve as promotional activities about the city and its culture at the same time. UC4 is divided into two sub-use cases: (*i*) use of 5G broadcast delivery services using RAI's broadcasting network, and (*ii*) development of a 5G core multicast component in UPV's laboratory. The sub-use cases are described below.

4.3.4.1.1 UC4b High quality video services distribution: 5G Broadcast delivery to massive audiences

This sub use case aims at the transmission of high-quality content in a downlink-only mode by means of the 3GPP Broadcast network provided by RAI and UPV. The video content used in the final demo will be produced inside the itinerant orchestra, use case 5, and will be broadcasted to all the tourists in the Palazzo Madama.

4.3.4.1.2 UC4c High quality video services distribution: 5G Core Multicast

This use cases entails the development of a multicast component in the 5G core available in UPV premises. The implementation of a multicast/broadcast capable 5G Core software is an on-going effort intended to be finished by the end of 2021. The goal is to implement, develop and validate a set of enhancements that will provide the 5G Core open-source software with multicast capabilities aligned with Release 17. The system will be implemented into UPV premises using Open5GCore.

4.3.4.2 UC specific User and Network Requirements

For the implementation of this UC the following requirements from the user perspective are needed (see Table 20):

Table 20. 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	No UL communication (reviewed)
Functional User Requirements	6	Mobility:	High Speed / Medium Speed / Walking-Running Speed / Stationary	Medium + walking running speed + stationary + vehicles (the vehicle scenario is foreseen) (reviewed)
	7	Location Information:	High / Medium / Low Accuracy	Low accuracy
	8	Fast Response (Low Latency):	Slow / Fast / Very Fast	Slow-Medium (reviewed)
	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

The mapping of the above user requirements into network requirements are illustrated into Table 21, where the vertical use case requirements for this use case are shown.

Table 21. UC4 – High quality video services distribution network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - 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 Mbps	High	5 Mbps	25 Mbps
4	Reliability (%) - Min/Max	%			99,9995%	High	95%	99,9995%
5	Availability (%) - Min/Max	%			99,9%	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			-	-		

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 29.

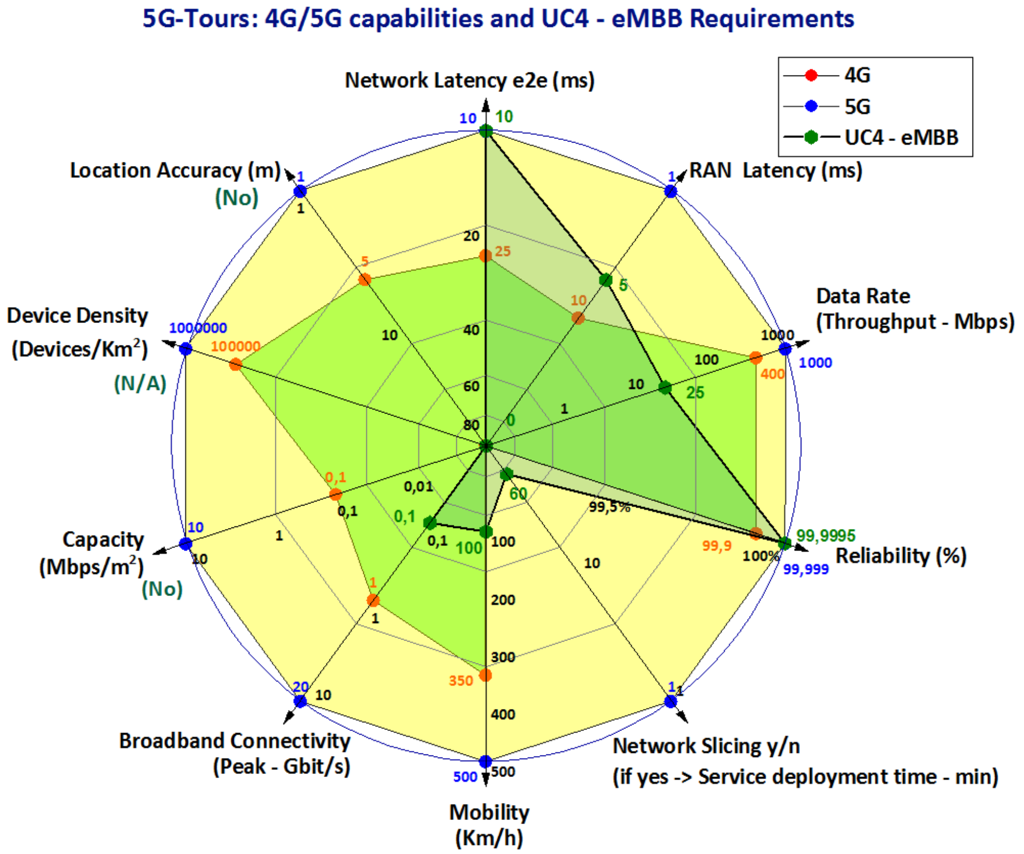


Figure 29. Radar chart for UC4 High quality video services distribution (eMBB) network requirements

The UC4 of high-quality Video Distribution appears to be easier to implement since in terms of requirements, only the RAN Latency, Network Latency, Reliability, and Slicing (60s) are the ones that need a 5G Network.

For this UC, if it was not for the E2E network latency and the RAN Latency, even an Ultra-Reliable 4G/LTE network would have sufficed for implementation of this use-case. The most important part of this UC is the need for broadcast support, which needs to be implemented in the 5G network as an additional functionality that requires the high reliability of 99,995.

4.3.4.3 Updated sequence diagram

4.3.4.3.1 UC4b High quality video services distribution. 5G Broadcast delivery to massive audiences

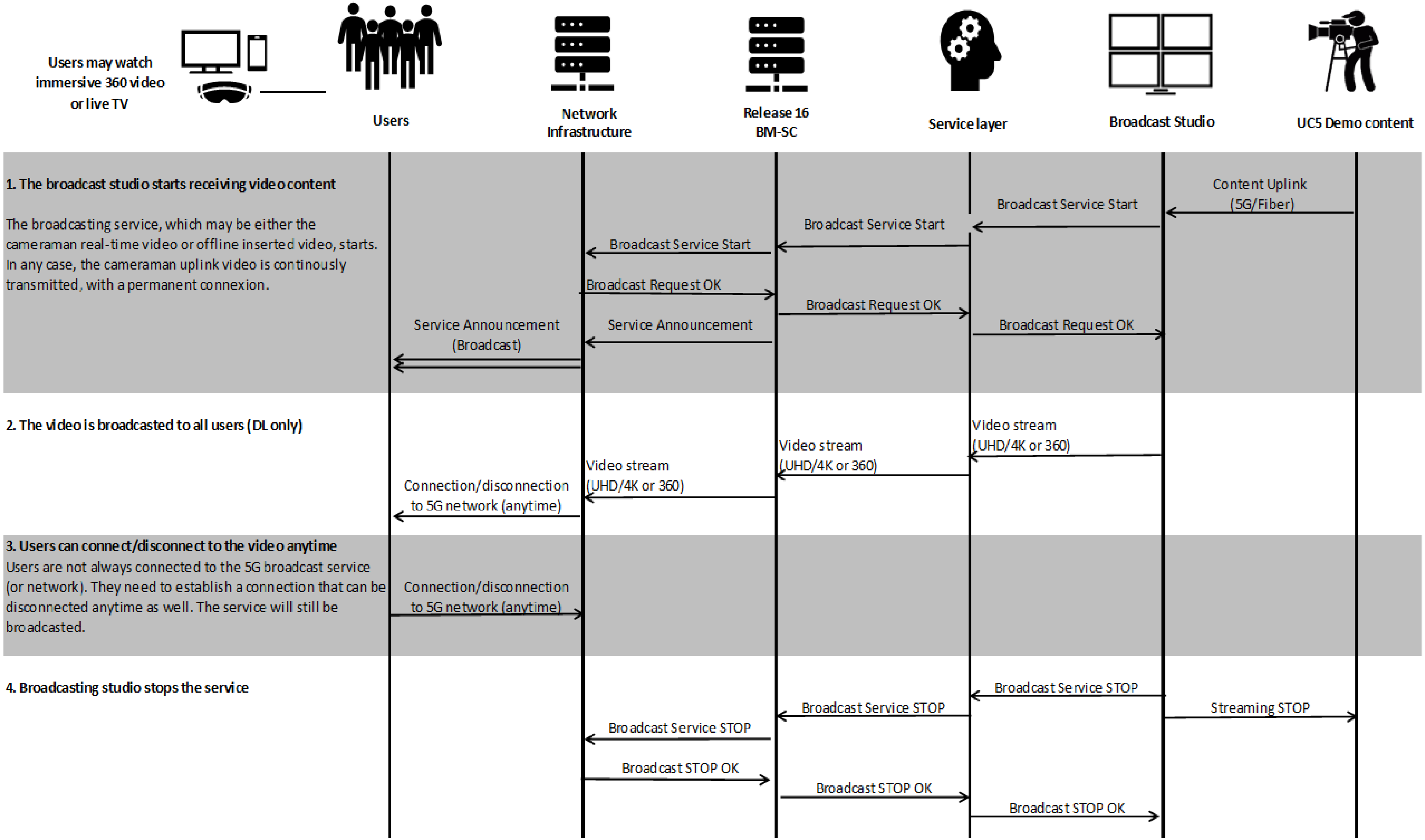


Figure 30. UC4b sequence diagram.

Notes:

- On a general basis, no network slicing is needed, since the service is ensured through 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.

4.3.4.3.2 UC4c High quality video services distribution. 5G Core Multicast

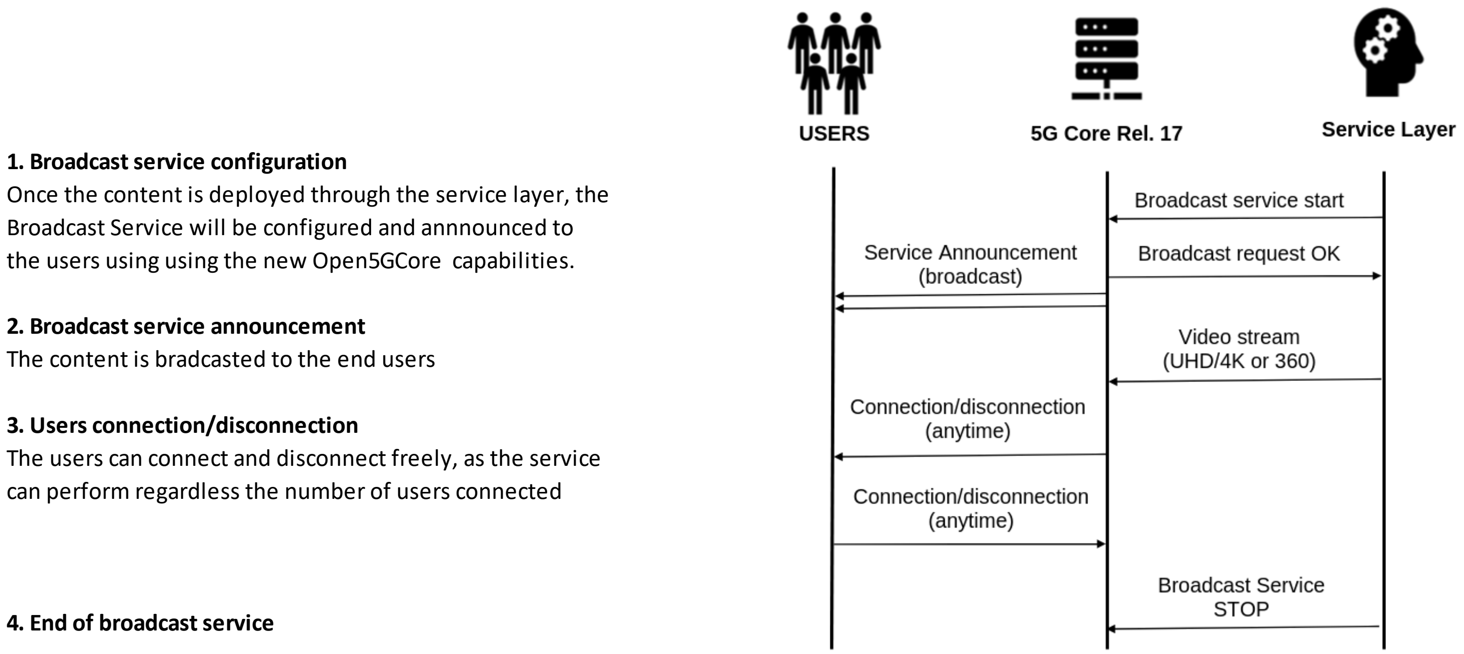


Figure 31. UC4c sequence diagram.

4.3.4.4 NEST

UC4 is split in 2 sub use cases, both addressing broadcast services. Use case 4b relies on the transmission of high-quality video content over a 5G broadcast network. This kind of "broadcast network" is intended to provide a service quite different from the services provided by usual mobile networks, such as 5G networks. In fact, 5G broadcast uses HPHT topology, used in DTT transmissions. In that case, it is not feasible to consider the slicing concept in this sub use case, because just one service/slice will be used on the same infrastructure.

The same explanation applies for sub use case 4c. In this case, we can consider the standard slice "eMBB", but this use case is just a 5G Multicast Core demo, where a multimedia content (such as a pre-recorded video) will be sent through the 5G-EVE node in Turin to the multicast interfaces. In this use case, due to the unavailability of commercial equipment able to decode this content, it won't be an end-to-end transmission, meaning that the concept of network slicing should be skipped.

4.3.5 UC5 - Remote and distributed video production

4.3.5.1 High level description

The main objective of the use case is to exploit the 5G-TOURS network features for remote television production, analysing how 5G networks could support various scenarios in which high-quality video is generated and transmitted.

Recalling the main definition of the use case, 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.

The implementation for the use case is the itinerant orchestra, in which some musicians located in the main concert hall play together with some other itinerant musicians walking in the streets while approaching the concert hall. Each itinerant musician is followed by one (or more) cameraman shooting their performance and providing cues to stay in synch with the main orchestra performance. The high-quality AV signal is transmitted via the 5G network to the main editing facility where it is properly processed and mixed with both the rest of the itinerant musicians and the orchestra located in the concert hall.

The spectators in the concert hall will watch the itinerant musicians playing and walking in the streets towards the Palazzo Madama (as real-time virtual presence) on one or more LED walls and listen to their performance via an amplification system, mixed to the local orchestra until they enter the concert hall and join the orchestra.

4.3.5.2 UC specific User and Network Requirements

For the implementation of this UC, the requirements presented in Table 22 are required, while the mapping of these user requirements into network requirements are illustrated in Table 23. In the case of UC5, no changes for the network requirements have been identified from what stated in deliverable D2.2.

The corresponding radar charts (URLLC and eMBB) of general requirements against the 4G/5G networks capabilities is shown in Figure 32 and Figure 33.

The use case needs 5G network capabilities due to the required RAN Latency (1 msec), Network Latency (15 msec), Reliability (99.9999%), and Slicing (5s).

For the URLLC slice, very low latency is needed for the RAN (1ms) as well as for the network latency (10ms), while, for the corresponding eMBB sub use case, the Network latency is relaxed to 50ms.

Table 22. 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:	Yes/No no of UEs	No
	2	Video Transmission:	Yes/No no of Channels	at least 4x 20 mbps UL continous/stable (the 15 mbps channel is ok if must, but 20mbps or higher is better) (reviewed)
	3	Voice Communication:	Yes/No	4x 128 kbps, DL (reviewed)
	4	Data Reception (DL):	High/Medium/Low	0 (reviewed)
	5	*Data Transmission (UL) :*	High/Medium/Low	High - video transmission, see above; no additional UL data transmission is foreseen
Functional User Requirements	6	Mobility:	High Speed / Medium Speed / Walking-Running Speed / Stationary	Walking-Running Speed / Stationary
	7	Location Information:	High / Medium / Low Accuracy	Low Accuracy
	8	Fast Response (Low Latency):	Slow / Fast / Very Fast	1. Very Fsat - known/guaranteed/same latency for 2 hours 2. TBD low UL latency (reviewed)
	9	Reliability/Availability:	high / medium / low	High. Stable, available in all the course of the music playetrs from A to auditorium and inside
	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 - continuos UL video tranmissions for at least 2 hours
	12	Interactivity & Space Dependency:	Dense High/Medium/Low Medium Density High/Medium/Low Sparse High/Medium/Low	Dense High - The transmissions take place from congested places (with multiple other users);
Structural User Requirements	13	*Edge Computing :*	Yes/No	No need to edge, the SDI signals should be close to MC, and the latency improvement remains negligible. (reviewed)
	14	*Edge Storage :*	Yes/No	No - Same as above (reviewed)
Service Specific (Examples)	15	*Battery Life:*	High /Medium/ Low	not very important - Liveu devices have bigger batteries (reviewed)
	16	*other*	User specified	

Table 23. UC5 – Distributed video production network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(reviewed) - 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/Km^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.

(*) Capacity = 360 Mbps/Km^2 = 0,00036 Mbps/m^2

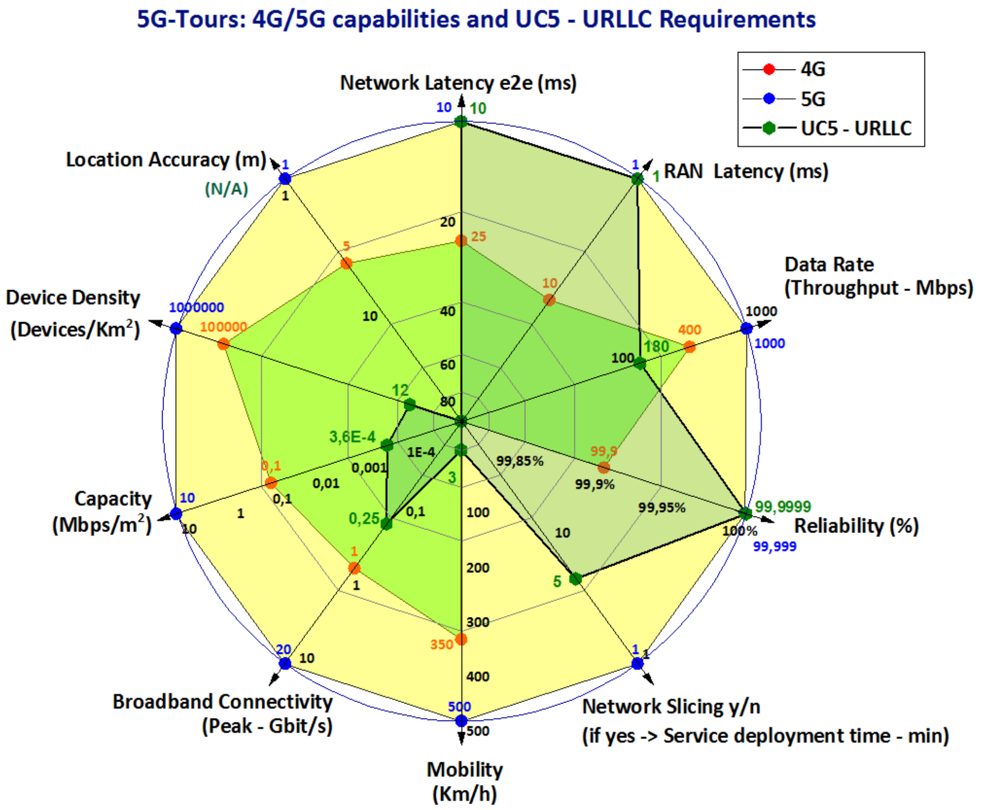


Figure 32. Radar chart for UC5 URLLC - Distributed video production network requirements.

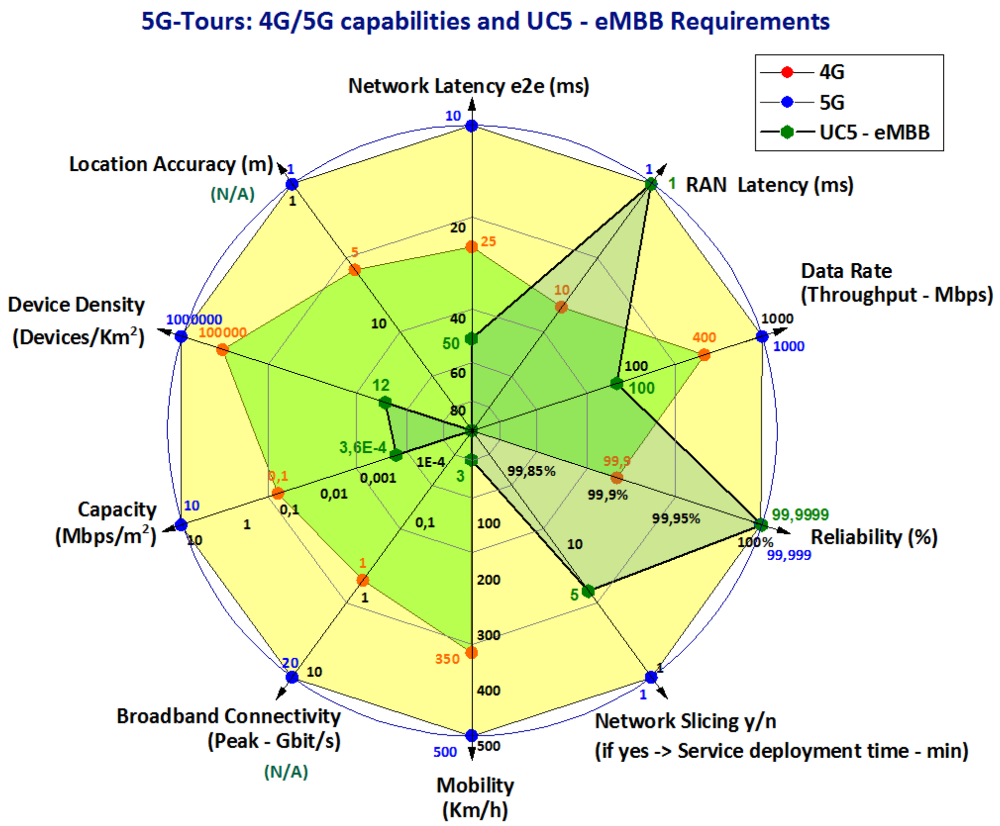
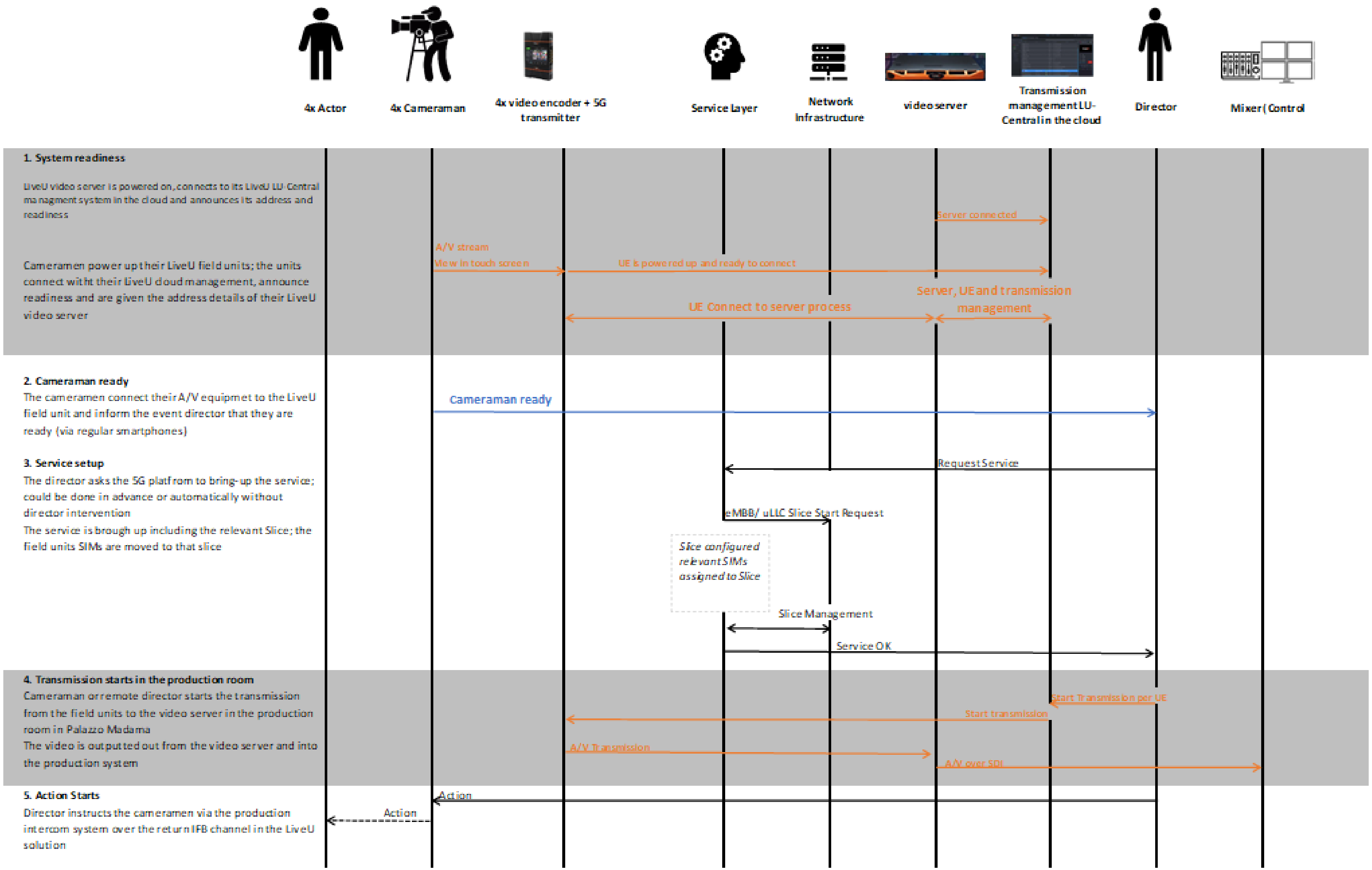


Figure 33. Radar chart for UC5 eMBB - Distributed video production network requirements.

4.3.5.3 Updated sequence diagram



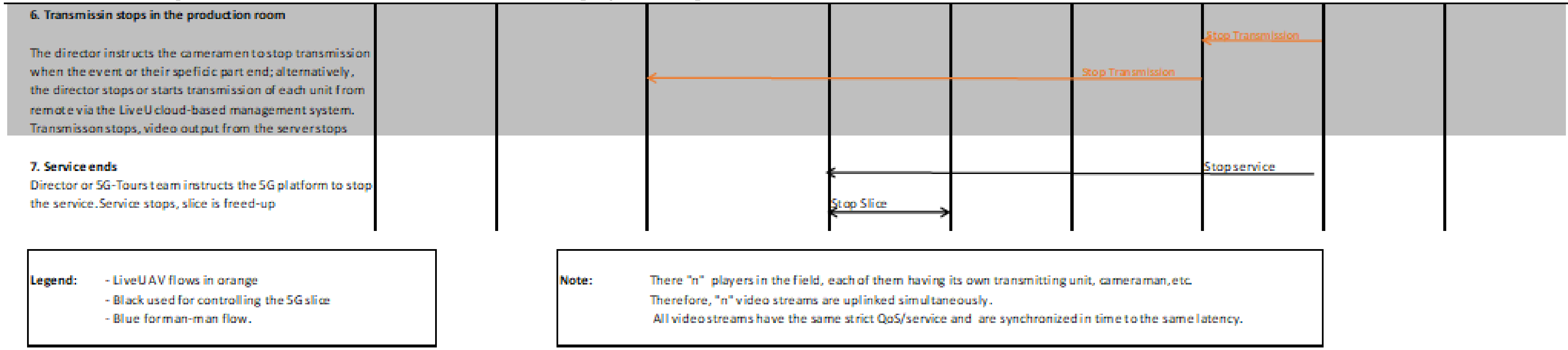


Figure 34. UC5 sequence diagram.

4.3.5.4 NEST

Attribute	Subparameter	URLLC	eMBB	Additional info
Availability		99.9999%	99.9999%	
Area of Service		IT		
	Region specification	TO, Piedmont		
Delay Tolerance		Not supported		
Deterministic Communication	Availability	Not supported		
	Periodicity	NA		
Downlink throughput per network slice instance	Guaranteed	360Mbps	200Mbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage #bakpacks is expected to be 2
	Maximum	500Mbps	NA	
Downlink Throughput Per User	Guaranteed	180Mbps	100Mbps	
	Maximum	250Mbps	NA	
Energy Efficiency	Network slice energy efficiency	NA		
	Time frame of the measurement	NA		
Group Communication Support		Not supported		
Isolation level	Isolation	Logical Isolation		
	Physical Isolation	NA		
	Logical Isolation	Virtual resource isolation		
Location Based Message Delivery		NA		
Maximum Supported Packet Size		1500 Bytes		
Mission critical support	Mission critical support	Mission-critical	Non-mission-critical	URLLC: Somehow borderline. It is not as critical as health applications, yet video production is expensive and hence this is a rather critical slice
	Mission critical capability support	Inter-user prioritization	NA	URLLC: Pre-emption is probably not required, but prioritization is
	Mission critical service support	MCVideo	NA	
MMTel Support		Not supported		
NB-IoT Support		Not supported		
NSC Network Functions		Video server		Note: this is not strictly a network function but may be run at the edge
Number of connections		2 (1)		URLLC: 1 per backpack. There will probably be 2 backpacks
Number of terminals		2 (1)		
Performance Monitoring	Availability	NA		
	Monitoring	NA		
Performance Prediction	Availability	Not supported		
	Prediction	Not supported		
Positioning Support	Availability	NA		
	Prediction	NA		

Attribute	Subparameter	URLLC	eMBB	Additional info
	Accuracy	NA		
Radio Spectrum		800 MHz (B20), 1800 MHz (B3) and 2600 MHz (B7) for E-UTRA and 3700 MHz (n78) for NR		
Root Cause Investigation		Not supported		
Session and Service Continuity Support		SSC mode 1		Confirmed with 5G-EVE Turin
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice		
Slice Quality of Service	3GPP 5QI	Custom		
	Resource Type	Delay critical GBR		
	Priority Level	1		
	Packet Delay Budget (PDB)	1ms		
	Packet Error Rate (PER)	10^{-6}		
	Jitter	4ms		
	Maximum Packet Loss Rate	10^{-6}		
Support for Non-IP traffic		Not supported		
Supported Device Velocity		10 km/h Pedestrian		URLLC: 3km/h
Synchronicity	Availability	NA		Being a TDD system, 5G supports synchronicity as per radio interface specifications; this is not anyway related to the UC but to the 5G system behaviour itself.
	Accuracy	NA		
Terminal Density		2 devices/Km^2		
Uplink Throughput Per network slice instance	Guaranteed	360Mbps	200Mbps	Downlink Throughput Per User * maximum number of users
	Maximum	500Mbps	NA	
Uplink Throughput Per User	Guaranteed	180Mbps	200Mbps	
	Maximum	250Mbps	NA	
User Management Openness		Not supported		
User Data Access	Data access	Termination in the private network		Tunnelling mechanisms used not really relevant
	Tunnelling Mechanism	NA		
V2X communication mode		Not supported		
Latency from UPF to App Server		1ms, max. 5ms	1ms	Note that these refer to end-to-end delay
Network Slice Specific Authentication and Authorization (NSSAA)		Supported		

5 The Safe City

5.1 The Platform

The use cases in the "Safe City" work package (WP5) will be trialed in **Rennes**, using the mobile network infrastructure of Orange and Nokia at BCOM's and CHU premises. Two mobile network deployments are on-going for 5G NR:

1. **Outdoors:** at the BCOM premises, for the connected ambulance, as shown in Figure 35. The Nokia 5G NR antenna will be installed on the roof of the BCOM building, using primarily the 26 GHz frequency band.
2. **Indoors**: at the Wireless Operating Room at CHU Rennes, we are using 26 GHz for data transmission and 2.6 GHz as the anchor frequency band (Figure 36) to provide high-speed, low-latency wireless access for medical imaging equipment.

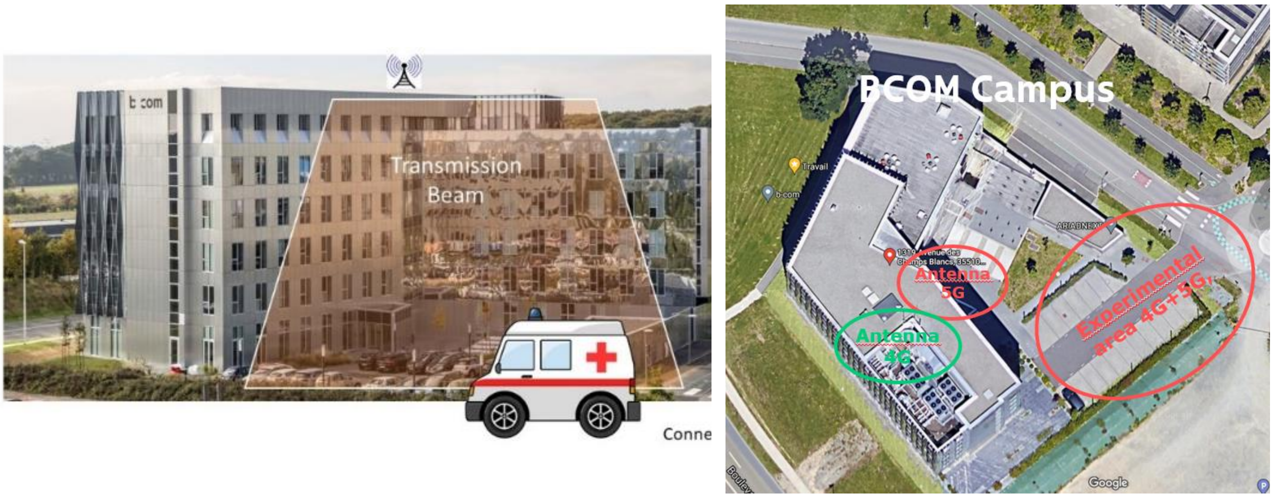


Figure 35. 5G-TOURS 5G NR NSA wireless coverage at BCOM.

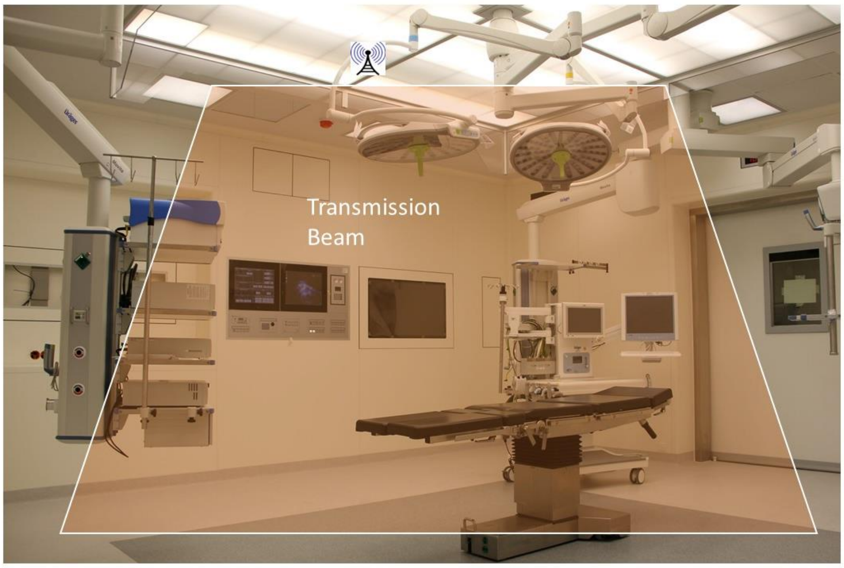


Figure 36. 5G-TOURS 5G NR wireless coverage in the Wireless Operating Room at CHU.

At the BCOM premises, the 5G base station with a local virtual User Plane Function (UPF), part of the so-called "Wireless Edge Factory" (WEF) is currently being tested and integrated. 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 is depicted in Figure 37. 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 datacenter 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 datacenter 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 datacenter has already been connected to the BCOM datacenter in the scope of the 5G-EVE project. This is also shown in Figure 37.

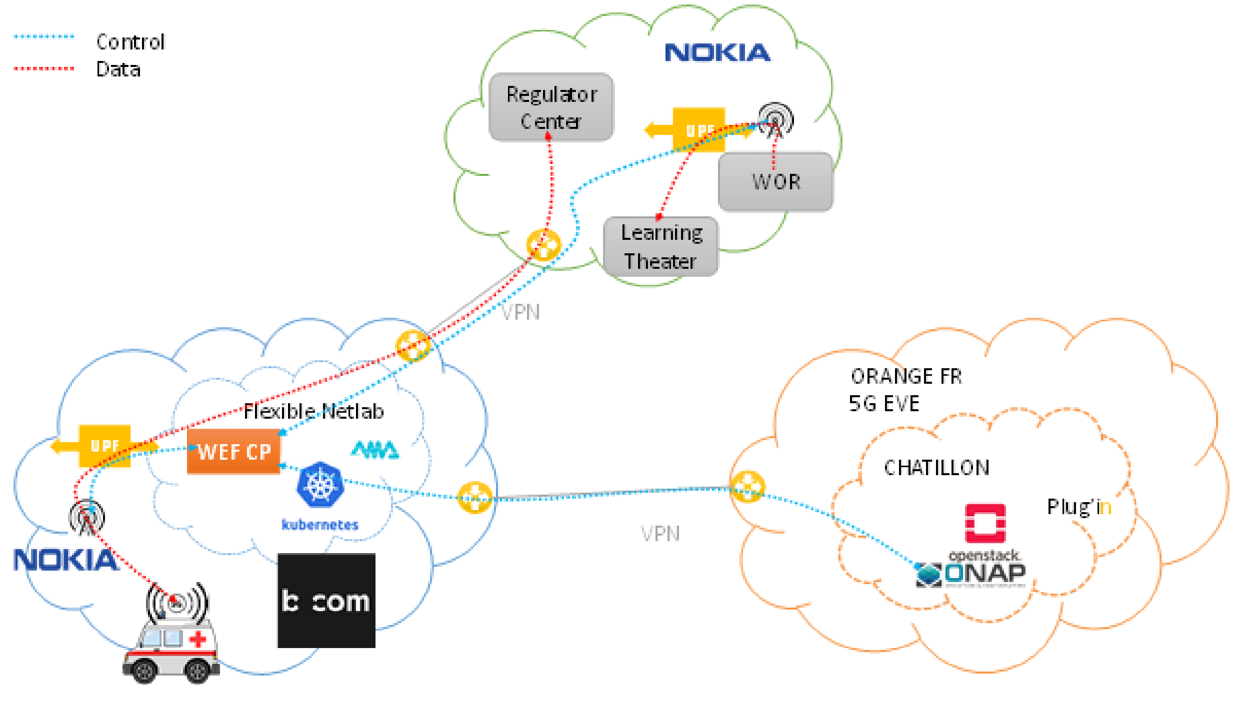


Figure 37. Overall network architecture and physical deployment of network equipment and functions.

5.2 Deployment implications

The Core Control Plane is part of the WEF solution developed by BCOM. It supports NSA mode. At the radio level, the 5G mmwave frequency (26Ghz) and the 2.6Ghz frequency for 4G are used. All medical equipment is connected to the 5G network using a mmwave device capable (CPE Askey RTL0300) supporting the n257 and B41 combination. Note that the use cases supported by the platform will have a separate user plane as specified in Figure 38.

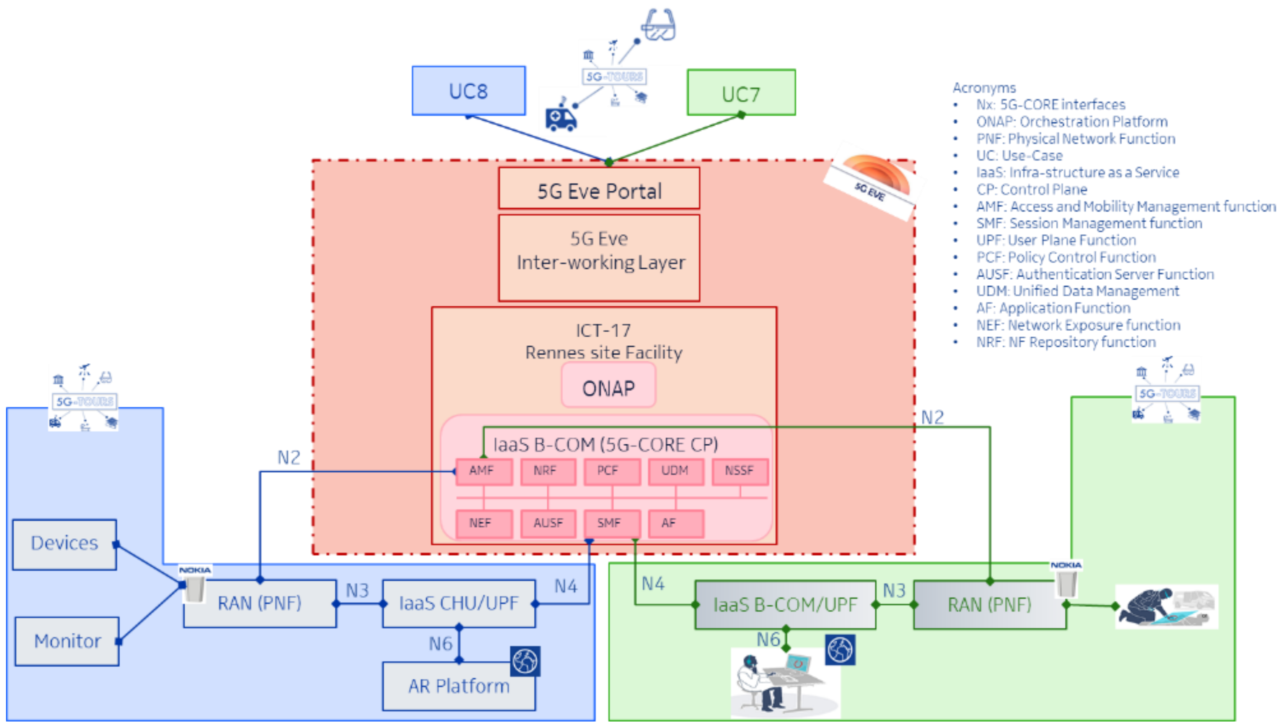


Figure 38. Integration of safe city use cases with the platform

5.3 UCs

5.3.1 UC6 - Remote health monitoring and emergency situation notification

5.3.1.1 High level description

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:

- remote health monitoring services,
- quick, reliable notifications to nearby ambulances, medical professionals, and family members in case of a health incident or a health emergency prediction; and
- the possibility to set up a video call between the medical specialist and the patient to monitor the patient's condition till the ambulance arrives.

The UC leverages wearable devices tracking a patient's vital signs and having them aggregated inside an IoT based platform named STARLIT (SmarT living plAtform powered by aRtificiaL Intelligence & robusT IoTconnectivity). STARLIT offers a dashboard for medical professionals enabling them to monitor the vital signs and status of several patients at the time. It also provides the option of setting up a video call with a patient. Alarms are raised notifying of current or potential future issues.

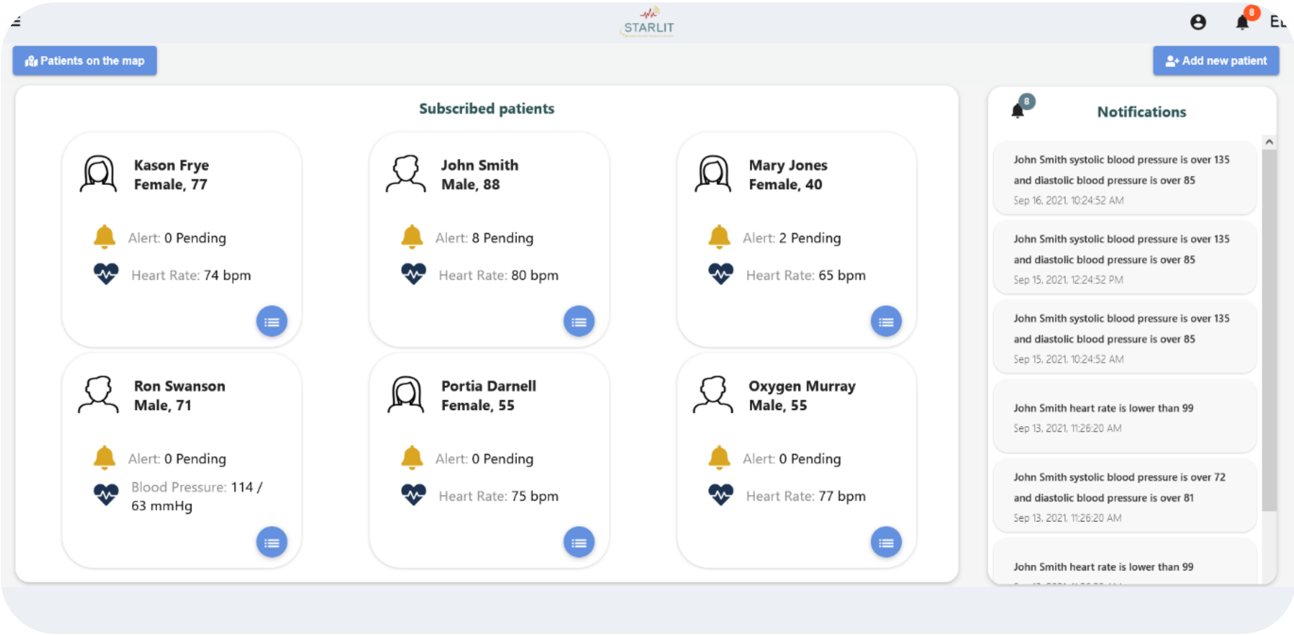


Figure 39. STARLIT Remote Health Monitoring (patients view).

5.3.1.2 UC specific User and Network Requirements

For the implementation of this UC, the requirements defined in Table 24 are needed from the user perspective.

Low latency and high reliability are required to guarantee timely interactions and delivery of data. In the case of a health incident, it is critical to ensure the timely communication between the relevant actors (healthcare and hospital staff, first responders).

The mapping of the above user requirements into network requirements are illustrated in Table 25, where the vertical use case requirements for this use case are shown.

The corresponding radar charts of general requirements against the 4G/5G networks capabilities are shown in Figure 40, Figure 41, and Figure 42.

Table 24. 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	1 x medical specialist to mobile phone WebRTC video 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) - (reviewed)
	2	**Video Transmission:**	Yes/No no of Channels	Smart glasses WebRTC video to medical specialist 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) Mobile phone video to medical specialist 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) - (reviewed)
	3	**Voice Communication:**	Yes/No	WebRTC voice communications during video call : 100 kbps (reviewed)
	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	Can range from Stationary to walking speed to all of the metrics. The user has a wearable that is always on in all situations (user at home, user walking, user in a car, etc.) (reviewed)
	7	**Location Information:**	High / Medium / Low Accuracy	Low (reviewed)
	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	

Table 25. Remote health monitoring and emergency situation notification network requirements.

	5G-Tours - Use Cases: direct specific Technical requirements	Units	(reviewed) - 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	100	100	High	10	100
2	**RAN** Latency (in milliseconds) - one way	msec	5	10	10	High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		1<	50	High	1	50
4	Reliability (%) - Min/Max	%	99,99%	99,99%	99,99%	High		
5	Availability (%) - Min/Max	%	99,99%	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		No	0,1	High	0,1	0,1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N		Y	Y	Medium	1	1
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y (baseline)	Y	Medium	N/A	N/A
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			12			12
11		Dev/Km^2					N/A	N/A
12	Location Accuracy	m		5	5	High	5	5

(*) Although walking speeds can vary greatly depending on many factors such as height, weight, age, terrain, surface, load, culture, effort, and fitness, the average human walking speed at crosswalks is about 5 km/h. The use case considers that monitored people may be walking or they can be moving with some sort of vehicle (e.g. bicycle, car, etc.). Hence, we start from an average walking speed (5 Km/h) for the minimum speed and consider up to the speed of a moving vehicle on a highway (100K m/h).

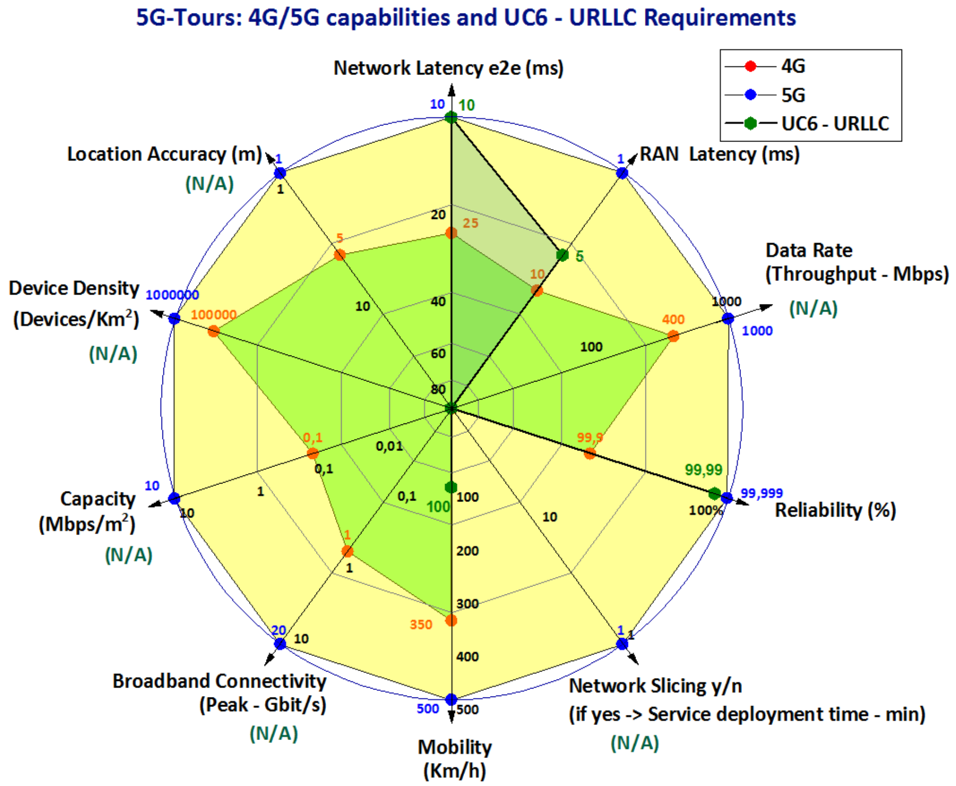


Figure 40. Radar chart for UC6 - Remote health monitoring and emergency situation notification network requirements (URLLC).

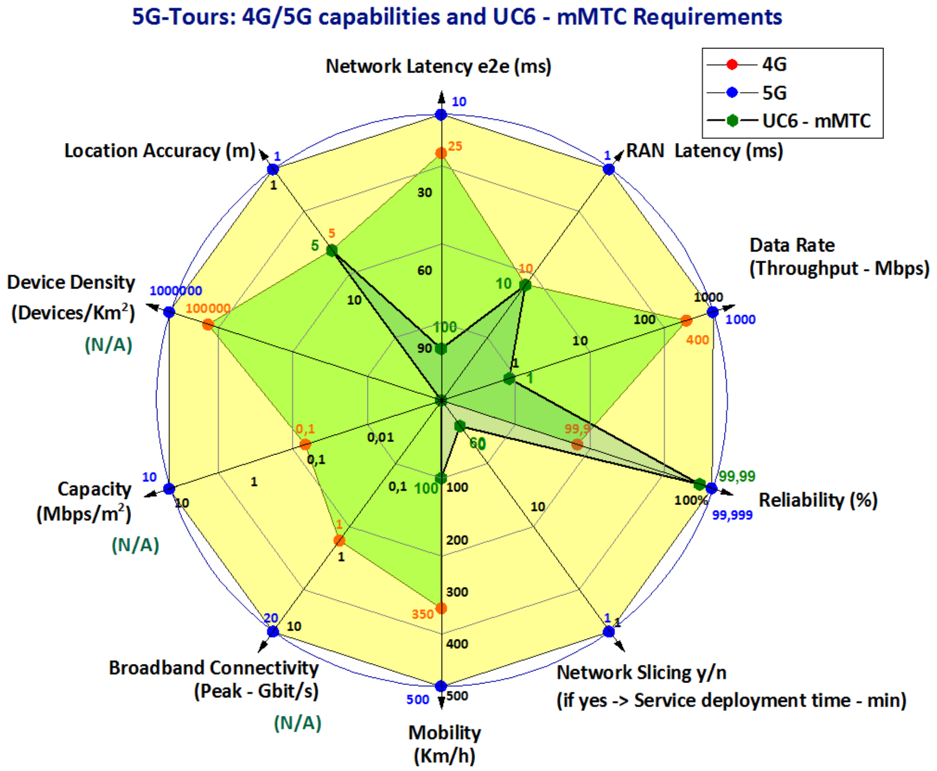


Figure 41. Radar chart for UC6 - Remote health monitoring and emergency situation notification network requirements (mMTC).

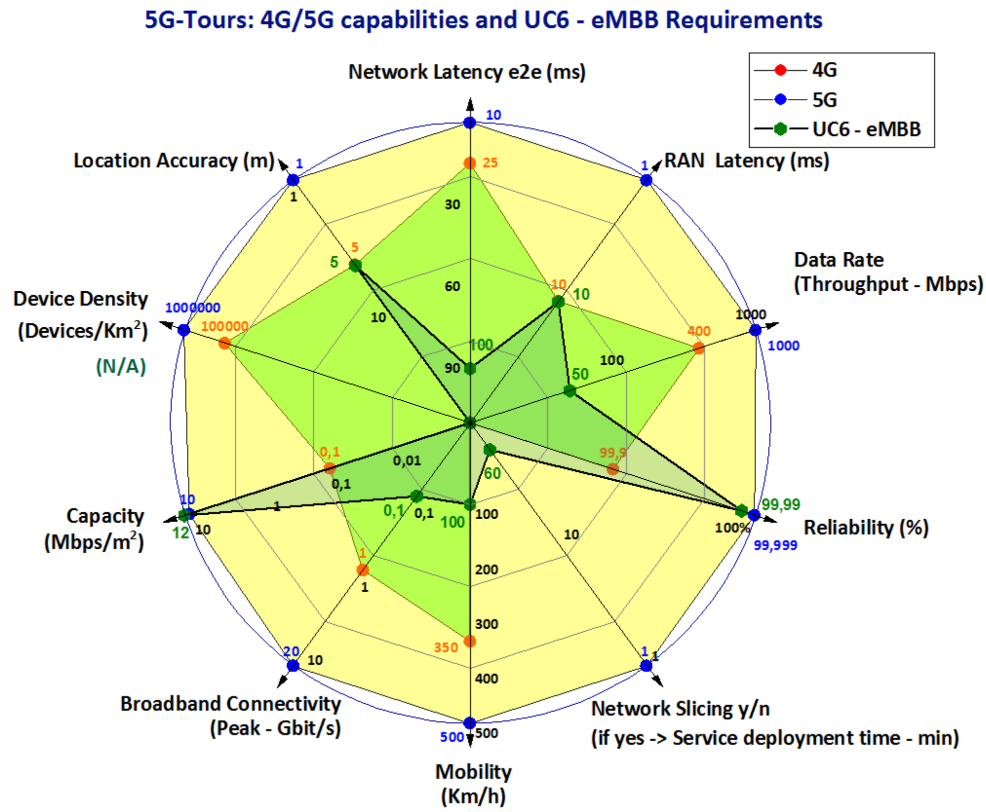


Figure 42. Radar chart for UC6 - Remote health monitoring and emergency situation notification network requirements (eMBB)

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 of 4 nines (99,99%), Low RAN and Networks Latencies for the URLLC, and Slicing (60s) are the primary requirements of the Remote Health Monitoring use case that indicate the need of a highly Reliable 5G Network.

In addition to the above, Capacity requirement, in some cases (for eMBB), stretches the 5G Network requirements to the limit (12). 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, even the stringent Capacity requirement can be achieved with 5G technology.

5.3.1.3 Updated sequence diagram

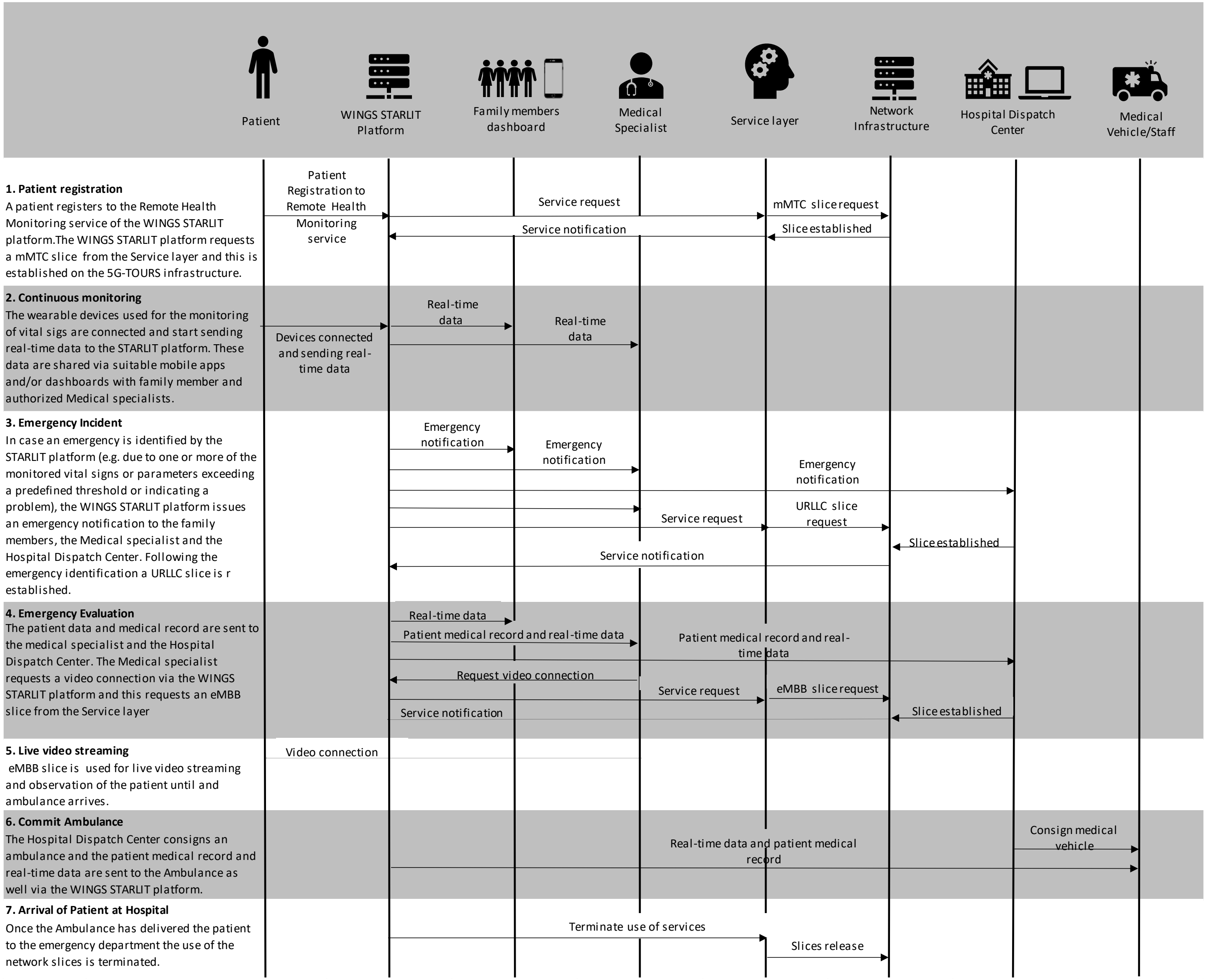


Figure 43. UC6 sequence diagram.

5.3.1.4 NEST

Attribute	Subparameter	mMTC	URLLC	eMBB	Additional info
Availability		99.99%			
Area of Service		GR			
	Region specification	GR-I			
Delay Tolerance		Supported			
Deterministic Communication	Availability	Not supported			
	Periodicity	NA			
Downlink throughput per network slice instance	Guaranteed	10Mbps	10Mbps	20Mbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage Number of users in the trial = 10 (mMTC, URLLC) Number of users in the trial = 2 (eMBB)
	Maximum	50Mbps	50Mbps	1000Mbps	
Downlink Throughput Per User	Guaranteed	1Mbps	1Mbps	10Mbps	
	Maximum	5Mbps	5Mbps	50Mbps	
Energy Efficiency	Network slice energy efficiency	NA			
	Time frame of the measurement	NA			
Group Communication Support		Single Cell Point to Multipoint (SCPTM)			
Isolation level	Isolation	Logical Isolation			
	Physical Isolation	NA			
	Logical Isolation	Virtual resource isolation			
Location Based Message Delivery		NA			
Maximum Supported Packet Size		1500 Bytes			
Mission critical support	Mission critical support	Mission-critical			
	Mission critical capability support	Local Control			
	Mission critical service support	MCData	MCData	MCVideo	
MMTel Support		NA			
NB-IoT Support		NA			
NSC Network Functions		UPF, AUSF			
Number of connections		10		2	
Number of terminals		10		2	
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)			
	Monitoring	Metric Collection Per 5seconds, Metric Monitoring Per Minute			

Attribute	Subparameter	mMTC	URLLC	eMBB	Additional info
Performance Prediction	Availability	NA			
	Prediction	NA			
Positioning Support	Availability	OTDOA (LTE and NR)			
	Prediction	Per second			
	Accuracy	1m			
Radio Spectrum		NB-IoT bands + 5G bands (at 3.5GHz)			
Root Cause Investigation		Not supported			
Session and Service Continuity Support		SSC mode 1			
Simultaneous use of the network slice		Can be used simultaneously with any network slice			
Slice Quality of Service	3GPP 5QI	70	82	80	
	Resource Type	Non-GBR	Delay Critical GBR	Non-GBR	
	Priority Level	55	19	68	
	Packet Delay Budget (PDB)	200ms	10ms	10ms	
	Packet Error Rate (PER)	10^{-6}	10^{-4}	10^{-6}	
	Jitter	< 1/10 of Latency = 30 ms BUT preferably between 5-6 ms			
	Maximum Packet Loss Rate	10^{-6}	10^{-4}	10^{-6}	
Support for Non-IP traffic		Not supported			
Supported Device Velocity		120 km/h Vehicular			
Synchronicity	Availability	Between BS and UE			
	Accuracy	2s			
Terminal Density		10 devices/Km^2		2 devices/Km^2	
Uplink Throughput Per network slice instance	Guaranteed	10Mbps	10Mbps	20Mbps	Downlink Throughput Per User * maximum number of users
	Maximum	50Mbps	50Mbps	1000Mbps	
Uplink Throughput Per User	Guaranteed	1Mbps	1Mbps	10Mbps	
	Maximum	5Mbps	5Mbps	50Mbps	
User Management Openness		Not supported			
User Data Access	Data access	Direct Internet access			
	Tunnelling Mechanism	NA			
V2X communication mode		Not supported			
Latency from UPF to App Server		<0,150s preferably between 25 -30ms			
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported			

5.3.2 UC7 - Teleguidance for diagnostics and intervention support

5.3.2.1 High level description

The goal of this use case is to 1) 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; 2) improve the outcome for patients on the short and longer term as well as their wellbeing; 3) reduce the workload and stress for all care providers and improve their effectiveness; and 4) 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. A 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. Thanks to 5G technology that will provide higher bandwidth and data transfer rate, in addition to a lower latency compared to 4G, remote collaboration scenarios are possible between care providers, where an expert guides a remote doctor or paramedic in performing an ultrasound exam or an ultrasound guided intervention with telesonography solutions.

The solution developed for this use case is built on streaming live video, live ultrasound images, in addition to voice communication, leveraging the capability of new 5G cellular networks to give the high-quality video and reliable medical feeds to the emergency care regulators for best decision making.

5.3.2.2 UC specific User and Network Requirements

For the implementation of this UC, the following requirements from the user perspective are needed:

Table 26. 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:**	Yes 2 streams from hospital to ambulance	**2 x Hospital to mobile phone WebRTC video 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed)** (reviewed)
	2	**Video Transmission:**	Yes 3 streams from ambulance to hospital	**Smart glasses WebRTC video to hospital 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed)** **WebRTC Video screensharing of ultrasound mobile application to hospital 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed)** **Mobile phone video to hospital 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed)** (reviewed)
	3	**Voice Communication:**	Yes	**WebRTC voice communications during video call (except for screensharing) : 5 x 100 kbps** (reviewed)
	4	**Data Reception (DL):**	High: for AR type applications Medium for EMR transmission Low for live patient vitals duch as ECG	**Ultrasound Webrtc data reception : 30 Mbps** (reviewed)
	5	Data Transmission (UL):	Reception and transmission are reversed between ambulance and hospital	**Ultrasound Webrtc data transmission : 30 Mbps** (reviewed)
Functional User Requirements	6	**Mobility:**	Medium Speed: driving ambulance Stationary: Ambulance at the point of incident	**130 km/h and 0 km/h** (reviewed)
	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	**MTBF: > 1 Month** (reviewed)
	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	**Few devices in an emergency area of ~200m2** **Interaction emergency staff and distant medical regulator and medical experts** (reviewed)
Structural User Requirements	13	***Edge Computing :***	Yes/No: Edge could be relevant if located in the ambulance	**No** (reviewed)
	14	***Edge Storage :***	Yes/No: Edge could be relevant if located in the ambulance	**No** (reviewed)
Service Specific (Examples)	15	***Battery Life:***	Low	**Smart glasses and ultrasound are connected to a battery powered 5G smartphone** (reviewed)
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated in Table 27, where the use case requirements are shown.

Table 27. UC7 – Teleguidance for diagnostics and intervention support network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - 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	50				50	100
2	**RAN** Latency (in milliseconds) - one way	msec	10				10	25
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	150				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	140				0	140
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	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	24				5	30
12	Location Accuracy	m	5				5	25

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 44 below.

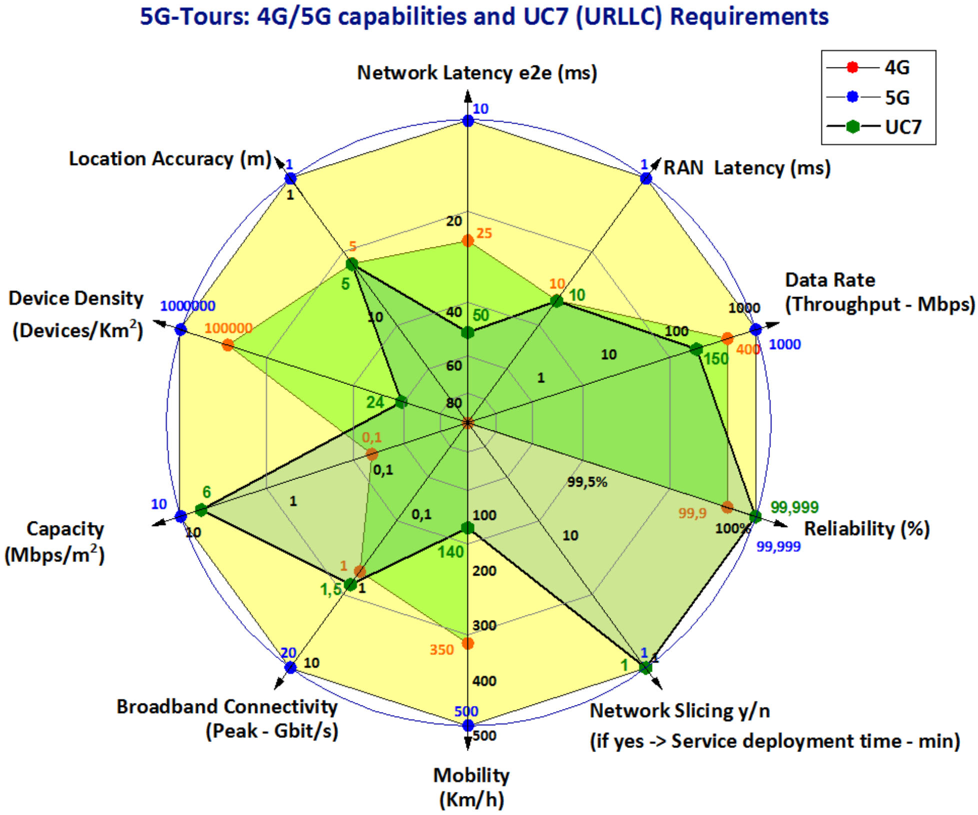
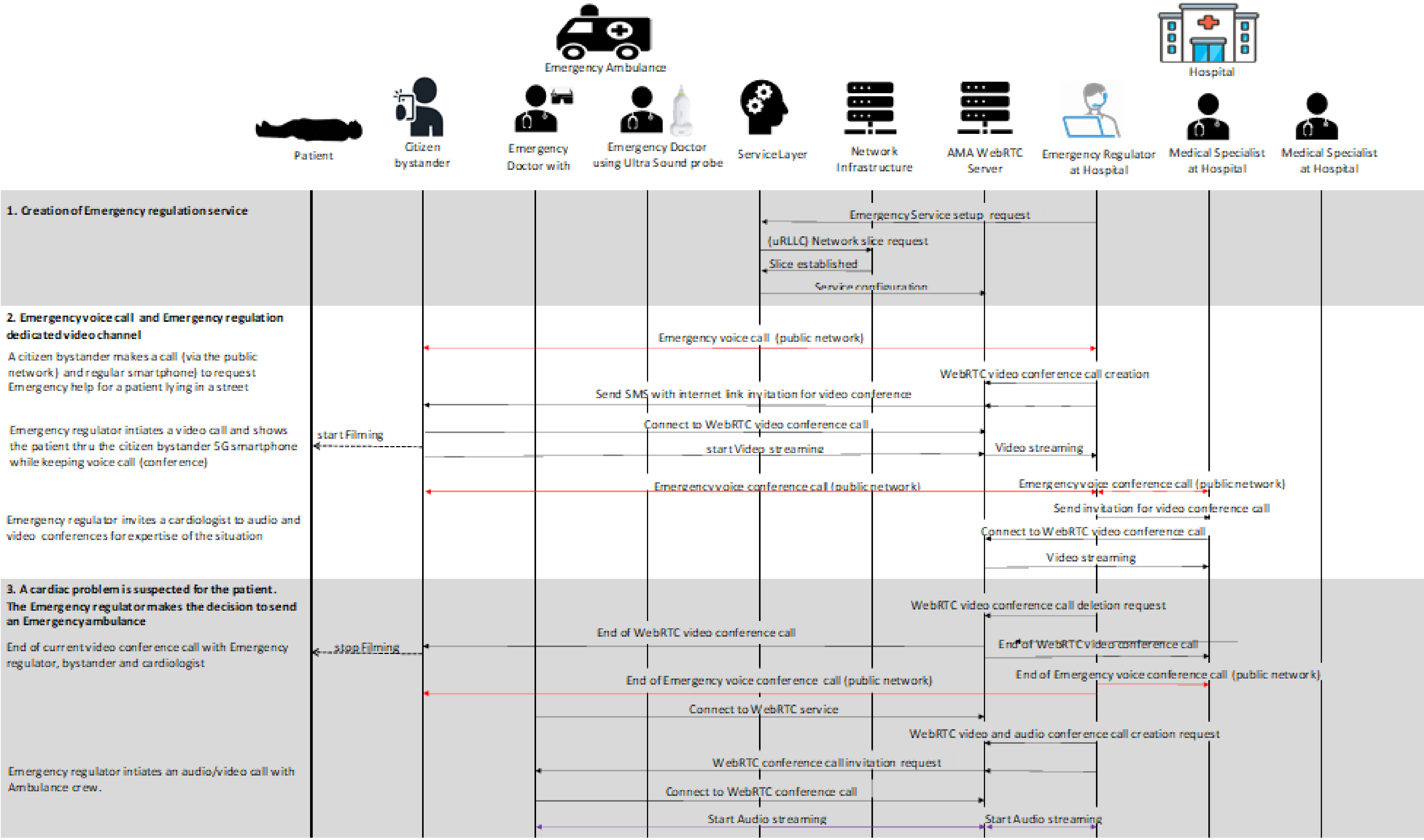


Figure 44. Radar chart for UC7 - Teleguidance for diagnostics and intervention support network requirements.

From the ten primary requirements of the Teleguidance use case, 6 requirements such as Device Density, Location accuracy, Network and RAN latencies and Mobility can be satisfied with 4G. All the rest (Broadband Connectivity, Capacity, Reliability, and Network Slicing) indicate that a 5G Network is needed to successfully implement the use case.

5.3.2.3 Updated sequence diagram



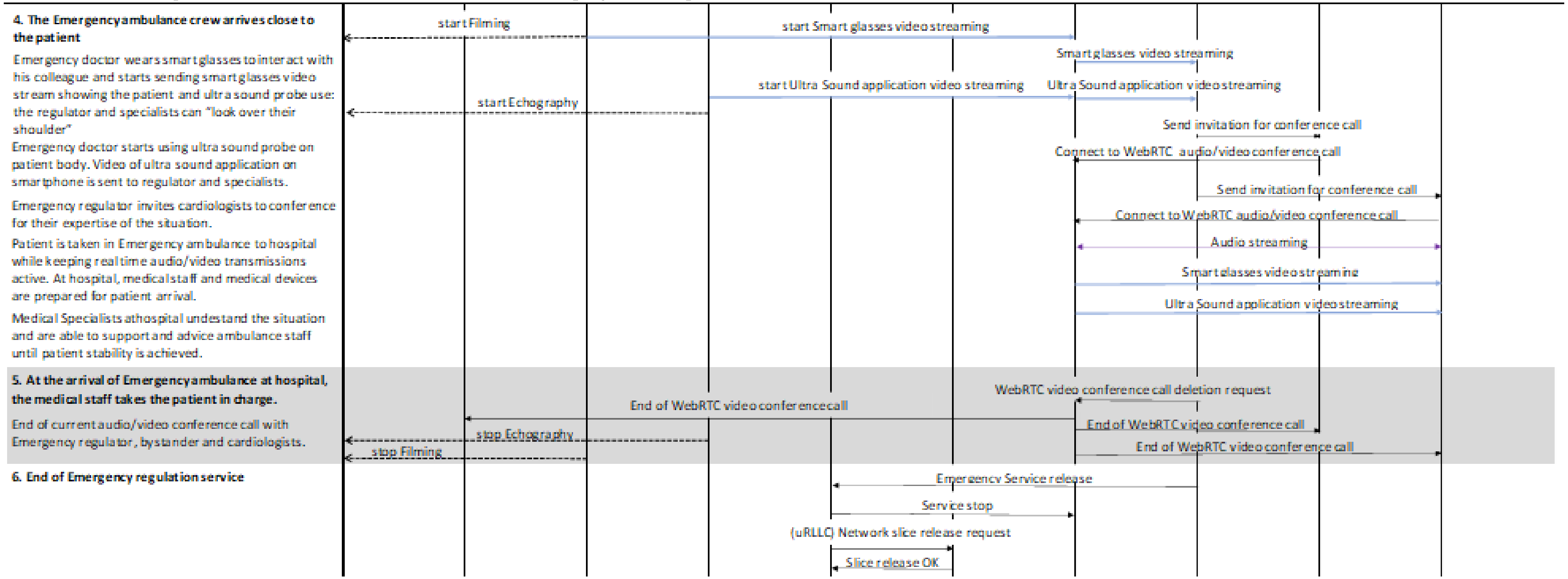


Figure 45. UC7 sequence diagram.

5.3.2.4 NEST

Attribute	Subparameter	URLLC	Additional info
Availability		99.9999%	
Area of Service		FR	
	Region specification	Rennes	
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	300Mbps	Calculated like: Downlink Throughput Per User * number of users Number of users in the trial = 2
	Maximum	2000Mbps	
Downlink Throughput Per User	Guaranteed	150 Mbps	
	Maximum	1000Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		Not supported	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Tenant / Service isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Mission-critical	
	Mission critical capability support	Local control	
	Mission critical service support	MCData	
MMTel Support		Not supported	
NB-IoT Support		Not supported	
NSC Network Functions		WEF (core network) RAN (from Nokia) Video server AR platform AMA's XpertEye	
Number of connections		2	
Number of terminals		2	
Performance Monitoring	Availability	Not supported	This UC will require a deployment of new infra that extends 5GEVE, so no monitoring
	Monitoring	NA	
Performance Prediction	Availability	NA	
	Prediction	NA	
Positioning Support	Availability	NA	
	Prediction	NA	
	Accuracy	NA	
Radio Spectrum		26GHZ (mmWave)	
Root Cause Investigation		Not supported	

Attribute	Subparameter	URLLC	Additional info
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice	
Slice Quality of Service	3GPP 5QI	70	Mission Critical Data
	Resource Type	Delay Critical GBR	
	Priority Level	1	Very high priority
	Packet Delay Budget (PDB)	Min. 1ms, Max. 5ms	
	Packet Error Rate (PER)	Min. 10^{-2}, Max. 10^{-6}	
	Jitter	10ms	
	Maximum Packet Loss Rate	Min. 10^{-2}, Max. 10^{-6}	
Support for Non-IP traffic		Not supported	
Supported Device Velocity		120 km/h - Vehicular	
Synchronicity	Availability	Between BS and UE & UE and UE	
	Accuracy	10 seconds	
Terminal Density		2 devices/Km^2	Theoretically, as provided in network requirements, 24 devices/Km^2
Uplink Throughput Per network slice instance	Guaranteed	270,000 Kbps	Uplink Throughput Per User*maximum number of users
	Maximum	270,000 Kbps	
Uplink Throughput Per User	Guaranteed	135,000 Kbps	One of the devices in the setup using compression (a minimal value from a partner)
	Maximum	135,000 Kbps	
User Management Openness		Not supported	
User Data Access	Data access	Termination in the private network	
	Tunnelling Mechanism	VPN Tunnel	
V2X communication mode		Not supported	
Latency from UPF to App Server		Min.: 1 ms, Max.: 5 ms	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

5.3.3 UC8 - Wireless operating room

5.3.3.1 High level description

The goal of the use case is to demonstrate the impact of 5G inside the operating room. This use case will face very low latency requirements and important amount of video data to be transferred. The scenario for the trial corresponding to this use case considers a situation where a patient must undergo a cardiac intervention procedure based on live, simultaneous X-Ray and ultrasound imaging.

The procedure follows an accident that was in fact due to an acute heart failure happening to the tourist patient secondary to a rupture from an acute heart rhythm dysfunction. 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 Augmented Reality application that generates a guidance image displayed on a monitor, which is 5G connected. 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 previously undergone a surgery in his country, Italy, by a cardiologist who is able to interact with his Rennes colleague to improve the quality of the procedure, via a teleconference performed using smart glasses. During the patient intervention, this cardiologist is travelling in Athens for business, and he is able to follow the cardiac intervention and interact with the cardiologist from Athens.

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 amphitheater close to the TherA-Image room.

The videos of the ultrasound probe, the smart glasses and live medical imaging are transferred as wireless video over IP, thanks to the recent DICOM-RTV standard, enabling synchronized real-time communication of video and associated metadata. However, the data stream from the X-Ray, which is a fixed device in the Operating Room and can't move from different operating rooms inside the hospital, will be wired connected to the AR platform.

5.3.3.2 UC specific User and Network Requirements

For the implementation of this UC, the following requirements from the user perspective are needed (see Table 28):

Table 28. 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	**Remote physician WebRTC video to mobile phone : 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) (reviewed)**
	2	**Video Transmission:**	Yes	**Smart glasses WebRTC video to remote physician : 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) (reviewed)**
	3	**Voice Communication:**	Yes	**WebRTC voice communications during video call : 100 kbps (reviewed)**
	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	**Smart glasses are connected to a battery powered 5G smartphone**
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated in the following Table 29, where the vertical use case requirements are shown.

Table 29. UC8 – Wireless operating room network requirements.

	5G-Tours - Use Cases: direct specific Technical requirements	Units	(Reviewed) - 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	2000
4	Reliability (%) - Min/Max	%	99,999%					
5	Availability (%) - Min/Max	%	99,999%					
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					

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 46 below.

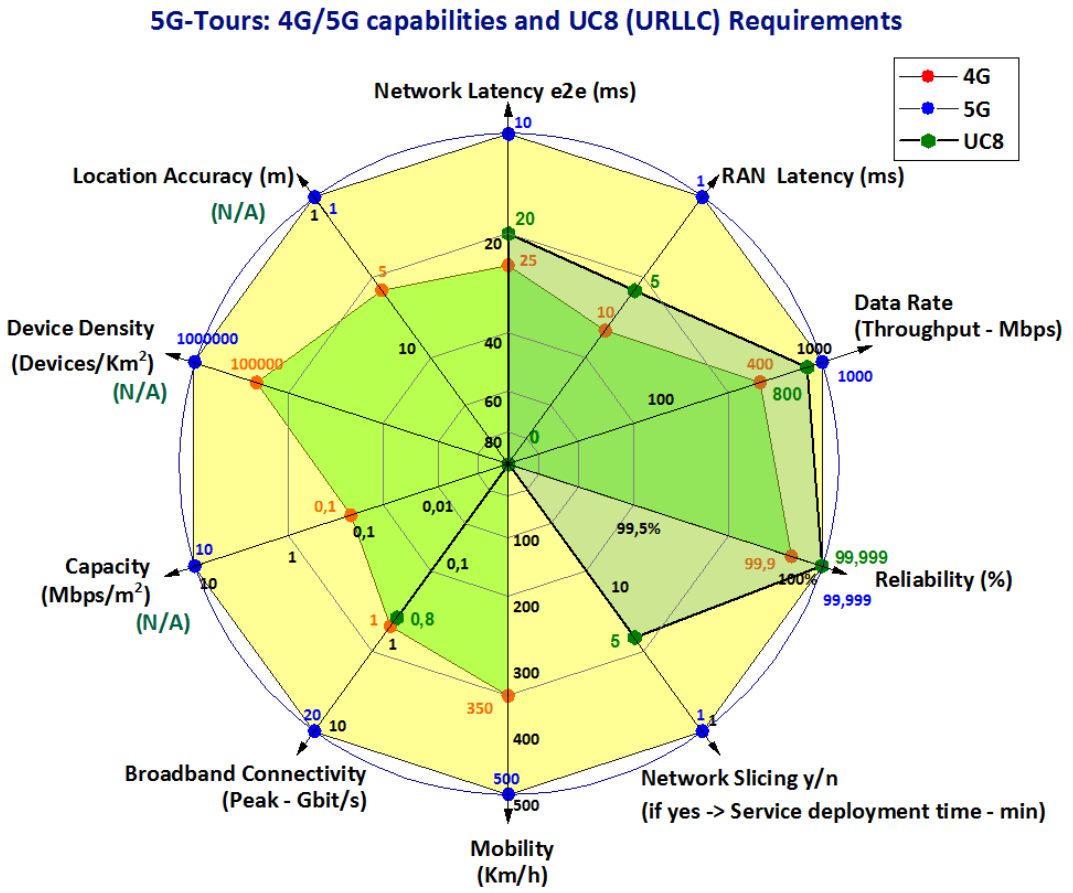


Figure 46. Radar chart for UC8 – Wireless operating room network requirements.

The Wireless Operating Room use case focuses primarily on the High Reliability of 5 nines (99.999%). This together with the Network Latency (20 ms), RAN Latency (5 ms), Data Rate (800Mbs), Reliability (5 “nines”), and demand for Network Slicing (in 5sec), clearly indicate the need for a 5G Network infrastructure.

5.3.3.3 Updated sequence diagram

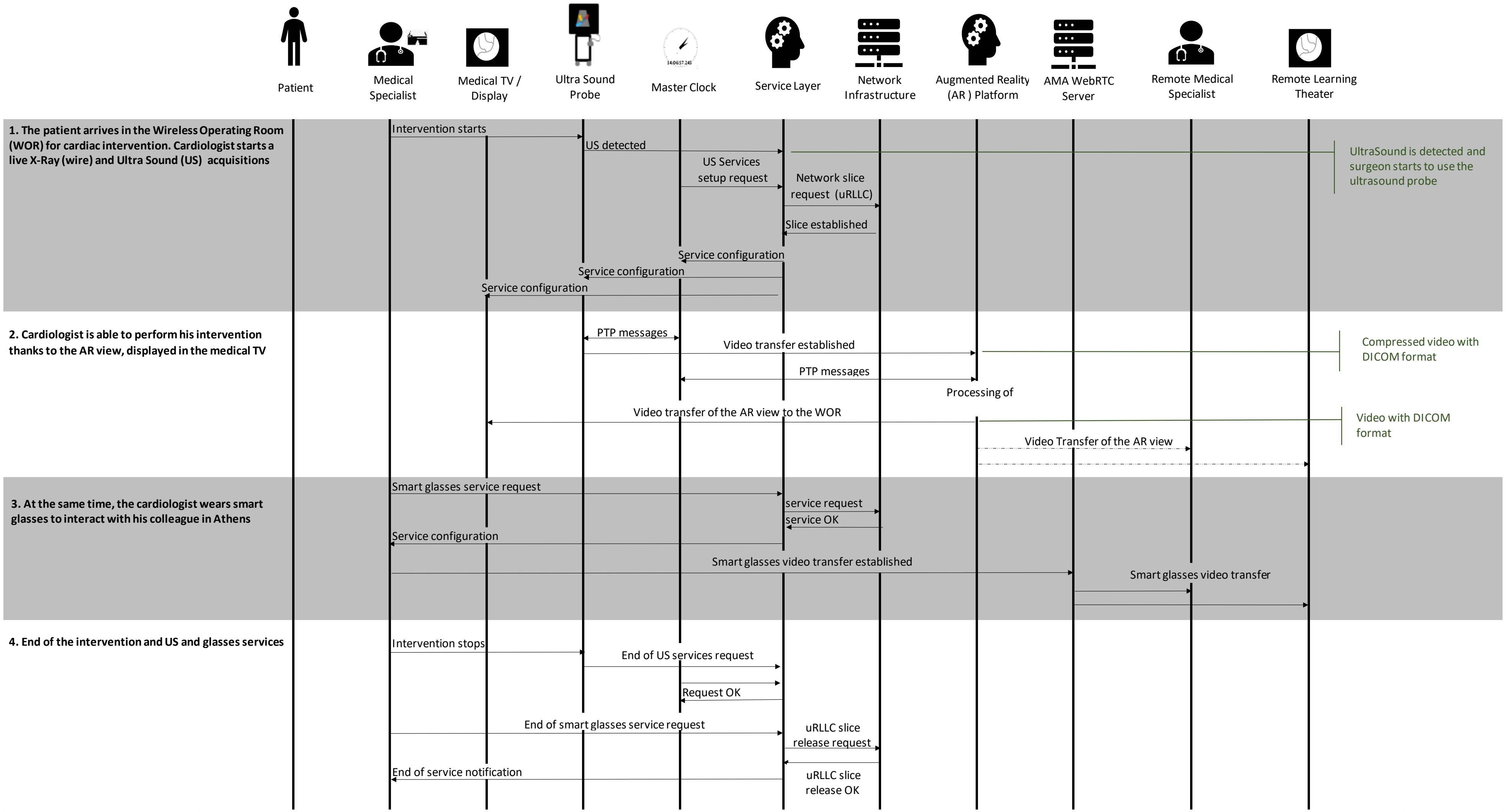


Figure 47. UC8 sequence diagram.

5.3.3.4 NEST

Attribute	Subparameter	URLLC	Additional info
Availability		99.9999%	
Area of Service		FR	
	Region specification	Rennes	
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	600Mbps	Calculated like: Downlink Throughput Per User * number of users UC8 will support only one UE in downlink path (i.e., from the AR platform to the monitor through one CPE) and two for uplink path.
	Maximum	2000Mbps	
Downlink Throughput Per User	Guaranteed	6000 Mbps	
	Maximum	2000Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		Single Cell Point to Multipoint (SCPTM)	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual Resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Mission-critical	
	Mission critical capability support	Local control	
	Mission critical service support	MCData	
MMTel Support		Not supported	
NB-IoT Support		Not supported	
NSC Network Functions		RAN UPF (User Plane function) WEF (core network)	
Number of connections		2 (4)	Assumption: Number of connections = Number of terminals
Number of terminals		2 (4)	Total of 2 devices (and may be 2 backup devices if needed) with CPE equipment
Performance Monitoring	Availability	NA	This UC will require a deployment of new infra that extends 5GEVE, so no monitoring
	Monitoring	NA	
Performance Prediction	Availability	Not supported	
	Prediction	Not supported	
Positioning Support	Availability	NA	
	Prediction	NA	

Attribute	Subparameter	URLLC	Additional info
	Accuracy	NA	
Radio Spectrum		Band B38/B41 and N257	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Cannot be used simultaneously with any another network slice	
Slice Quality of Service	3GPP 5QI	70	Mission Critical Data
	Resource Type	Delay Critical GBR	
	Priority Level	1	Very high priority
	Packet Delay Budget (PDB)	Min. 1ms, Max. 5ms	
	Packet Error Rate (PER)	Min. 10^{-2}, Max. 10^{-6}	
	Jitter	10ms	
	Maximum Packet Loss Rate	Min. 10^{-2}, Max. 10^{-6}	
Support for Non-IP traffic		Not supported	
Supported Device Velocity		Stationary	
Synchronicity	Availability	Between BS and UE	
	Accuracy	10 seconds	
Terminal Density		3 devices/Km^2	2 CPE, 1 smartphone (if available with the frequency), will be used in the operating room
Uplink Throughput Per network slice instance	Guaranteed	60Mbps	Guaranteed Downlink Throughput Per User*maximum number of users 2 devices for uplink path
	Maximum	100Mbps	
Uplink Throughput Per User	Guaranteed	30Mbps	
	Maximum	50Mbps	
User Management Openness		Not supported	
User Data Access	Data access	Network Local Traffic (no internet access)	
	Tunnelling Mechanism	VPN Tunnel	
V2X communication mode		Not supported	
Latency from UPF to App Server		Min.: 1 ms, Max.: 5 ms	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

5.3.4 UC9 - Optimal ambulance routing

5.3.4.1 High level description

As the next step following the health monitoring use case (UC6), this use case 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 use case 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. WINGS's platform, STARLIT, is exploited in order to calculate the optimal route both from the ambulance dispatch location to the emergency location as well as from the emergency location to the nearest (or in another way most appropriate) hospital, while taking into account relevant patient data. Information taken into consideration in this respect refers to traffic conditions, regulations and other mobility related factors. Moreover, for the optimization procedure, it will be taken into account if the patient's condition demands rich data exchange, in which case, a steady 5G coverage during the journey is needed (e.g., in case that the patient needs an on-the-fly treatment through a high-definition video streaming).

5.3.4.2 UC specific User and Network Requirements

For the implementation of this UC the following requirements in Table 30 are needed from the user perspective.

Table 30. 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	**Yes 1 x medical specialist to mobile phone WebRTC video 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) (reviewed)**
	2	**Video Transmission:**	Yes/No no of Channels	**Yes 2 streams Smart glasses WebRTC video to medical specialist 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed)** **Mobile phone video to medical specialist 1280x720 vp8 codec at 30 fps : 2 Mbps (compressed) (reviewed)**
	3	**Voice Communication:**	Yes/No	**Yes WebRTC voice communications during video call : 100 kbps (reviewed)**
	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	**Can range from Stationary (when ambulance is stopped) to High Speed (reviewed)**
	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 in Table 31.

Table 31. UC9– Optimal ambulance rooting room network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - 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		100	High	10	100
2	**RAN** Latency (in milliseconds) - one way	msec	5		25	High	5	25
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			50	High	10	50
4	Reliability (%) - Min/Max	%	99,99%		99,99%	High		
5	Availability (%) - Min/Max	%	99,99%		99,99%	High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	>=50Km/h		>=50Km/h	High	10	50
7	Broadband Connectivity (peak demand)	Y/N or Gbps	Y (1)		Y (1)	High	1	1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y		Y	High	1	1
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y		Y	Medium		
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	5		5	High	5	5

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 48 and Figure 50.

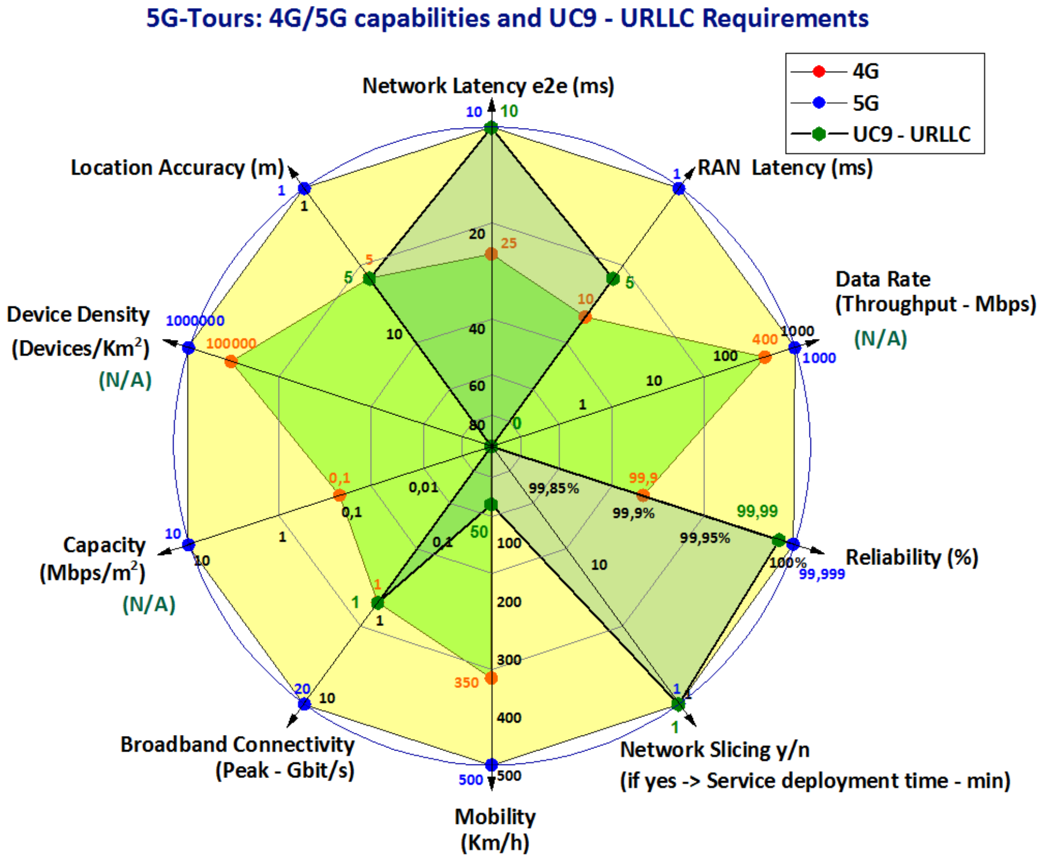


Figure 48. chart for UC9 – Optimal ambulance rooting network requirements (URLLC).

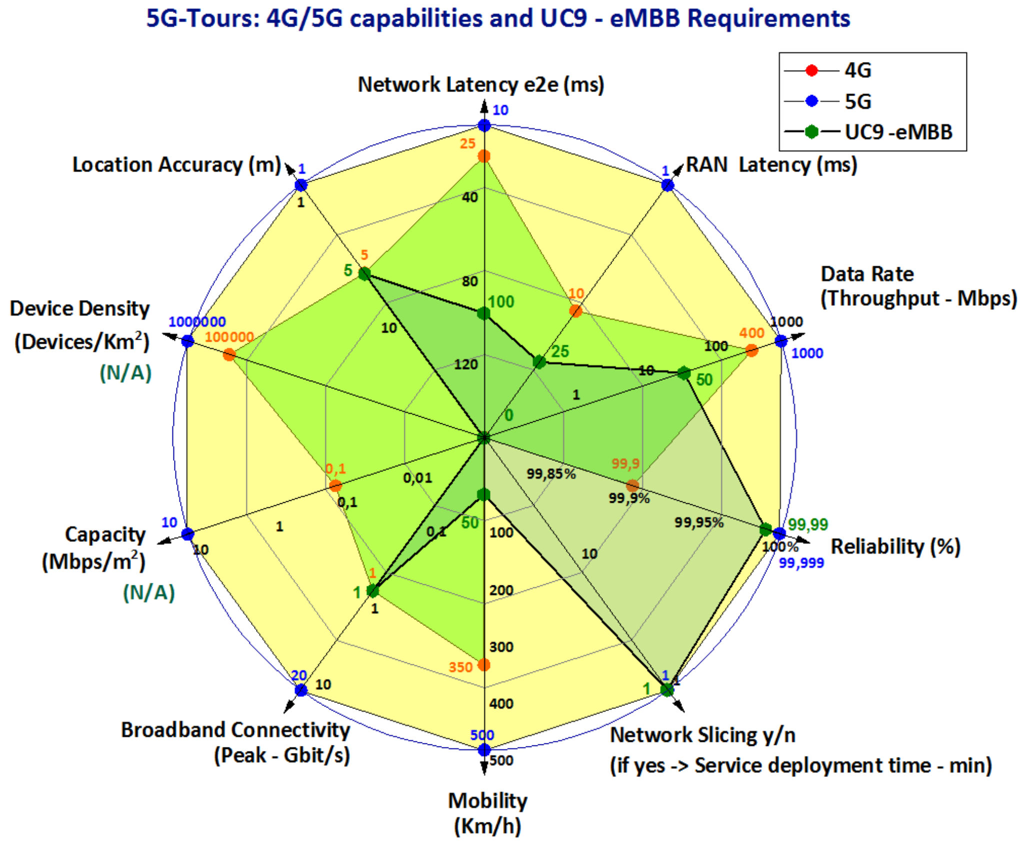


Figure 49. chart for UC9 – Optimal ambulance rooting network requirements (eMBB).

For the Optimal Ambulance Routing use case – URLLC, the following requirements Network Latency, RAN Latency, Reliability, and dedicated Network Slice indicate the need for 5G technology. All the other can be covered by 4G. Moreover, for eMBB slice, the two latencies are also relaxed to 100ms and 25ms, since initially were overestimated, so they can be fulfilled also from a 4G network.

5.3.4.3 Updated sequence diagram

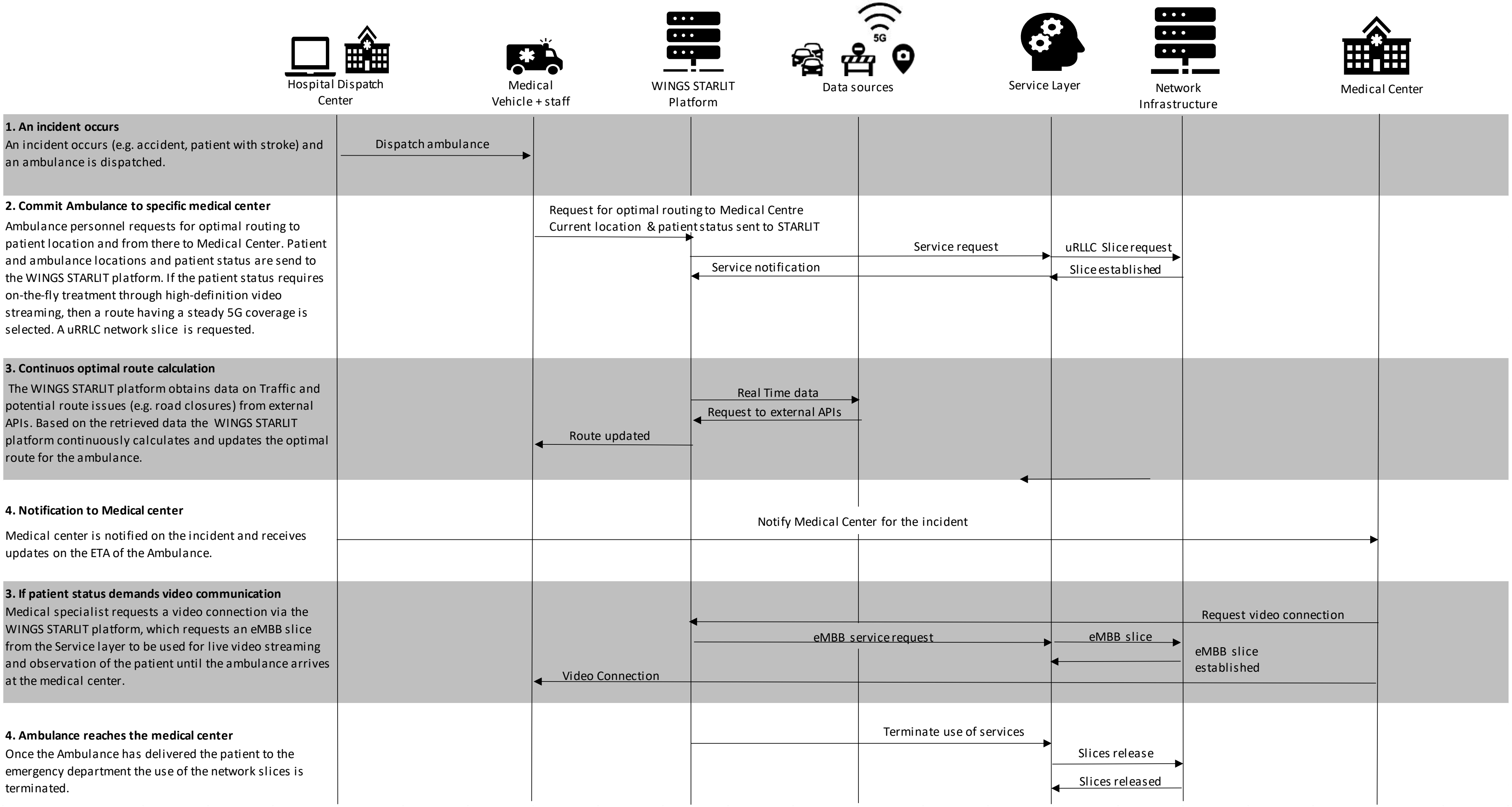


Figure 50. UC9 sequence diagram.

5.3.4.4 NEST

Attribute	Subparameter	URLLC	eMBB	Additional info
Availability		99.99%	99.99%	
Area of Service		GR		
	Region specification	GR-I		
Delay Tolerance		Not supported		
Deterministic Communication	Availability	Not supported		
	Periodicity	NA		
Downlink throughput per network slice instance	Guaranteed	10Mbps	20Mbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage Number of users in the trial = 2
	Maximum	50Mbps	100Mbps	
Downlink Throughput Per User	Guaranteed	5Mbps	10 Mbps	
	Maximum	25Mbps	50Mbps	
Energy Efficiency	Network slice energy efficiency	NA		
	Time frame of the measurement	NA		
Group Communication Support		Single Cell Point to Multipoint (SCPTM)		
Isolation level	Isolation	Logical Isolation		
	Physical Isolation	NA		
	Logical Isolation	Virtual resource isolation		
Location Based Message Delivery		NA		
Maximum Supported Packet Size		1500 Bytes		
Mission critical support	Mission critical support	Mission-critical	Mission-critical	
	Mission critical capability support	Local control		
	Mission critical service support	MCData	MCVideo	
MMTel Support		NA		
NB-IoT Support		Supported		
NSC Network Functions		UPF, AUSF		
Number of connections		2		
Number of terminals		2		
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)		
	Monitoring	Metric Collection Per 5seconds, Metric Monitoring Per Minute		
Performance Prediction	Availability	NA		
	Prediction	NA		
Positioning Support	Availability	OTDOA (LTE and NR)		
	Prediction	Per second		

Attribute	Subparameter	URLLC	eMBB	Additional info
	Accuracy	1m		
Radio Spectrum		NB-IoT bands + 5G bands (at 3.5GHz)		
Root Cause Investigation		Passive investigation		The performance diagnosis module will inform the NSC, so it is passive, no active
Session and Service Continuity Support		SSC mode 1		
Simultaneous use of the network slice		Can be used simultaneously with any network slice		
Slice Quality of Service	3GPP 5QI	70	80	
	Resource Type	Non-GBR	Non-GBR	
	Priority Level	55	68	
	Packet Delay Budget (PDB)	200ms	10ms	
	Packet Error Rate (PER)	10^{-6}	10^{-6}	
	Jitter	< 1/10 of Latency = 30ms BUT preferebly between 5-6ms		
	Maximum Packet Loss Rate	10^{-6}		
Support for Non-IP traffic		Not supported		
Supported Device Velocity		120 km/h - Vehicular		
Synchronicity	Availability	Between BS and UE		
	Accuracy	2s		
Terminal Density		2 devices/Km^2		
Uplink Throughput Per network slice instance	Guaranteed	10 Mbps	20 Mbps	Downlink Throughput Per User * maximum number of users
	Maximum	50 Mbps	100 Mbps	
Uplink Throughput Per User	Guaranteed	5 Mbps	10 Mbps	
	Maximum	25 Mbps	50 Mbps	
User Management Openness		Not supported		
User Data Access	Data access	Direct Internet access		
	Tunnelling Mechanism	NA		
V2X communication mode		Not supported		
Latency from UPF to App Server		<0,150s preferably between 25 -30s		
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported		

6 The Mobility Efficient City

6.1 The Platform

The main objective of WP6 is to carry out the implementation of the mobility-related use cases trials taking place in the node of Athens. The aim of these use cases is to demonstrate how 5G is expected to enhance applications related to mobility within a city covering various set-ups, such as the improvement of airport logistics by means of video-enhanced ground vehicles, the evacuation of the airport in case of an emergency, smart parking applications, or the constructive mobility of students for education purposes. As it happens with the rest of the use case specific WPs, while the foreseen use cases are presented from a touristic-oriented/cultural perspective, the underlying functionality addresses the needs of both tourists and citizens.

In the context of the implementation of the Mobility Efficient City of 5G-TOURS project, the node of Athens is developed as an extension of the existing 5G-EVE Greek Site infrastructure. 4 UCs are implemented at the AIA premises, relying on the extended 5G-EVE network which comprises by the following components:

On site H/W installations and integrations at OTE premises:

- 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 of the Turin 5G-EVE site through a secure tunnel and the portal of the 5G-EVE.
- A Kafka bus server, for the needs of keeping the metrics of the KPIs, is installed and interconnected with central Kafka server.

On-site H/W installations and integrations at AIA premises:

- 2 outdoor and 4 indoor antennas designed and installed by NOKIA, that utilise the spectrum band of 3450-3500MHz, 40MHz bandwidth.
- All the antennas are connected via optical fibre with the NOKIA’s Base Band Units (BBU) at the airport.
- OTE L2/L3 switch is interconnected to the OTE IP Core, using a 10 Gbps capacity line, in order to interconnect 5G-EVE Greek site infrastructure located at OTE Labs in Psalidi-Attika with AIA.
- Smart devices are used, and specific innovative applications developed for the implementation of the 4 UCs (Smartphones, tablets, AR/VR headsets, IP-cameras, IoT chipsets and sensors, etc.).
- Also, KPI measuring probes are installed between antennas and the BBU, as well as between the BBU and OTE’s Core-switch (at AIA). Finally, a probe is also be placed before NOKIA’s platform (EPC) at OTE-Labs. These probes are used for measuring network performance and service layer metrics in real time in order to validate KPIs of the network.

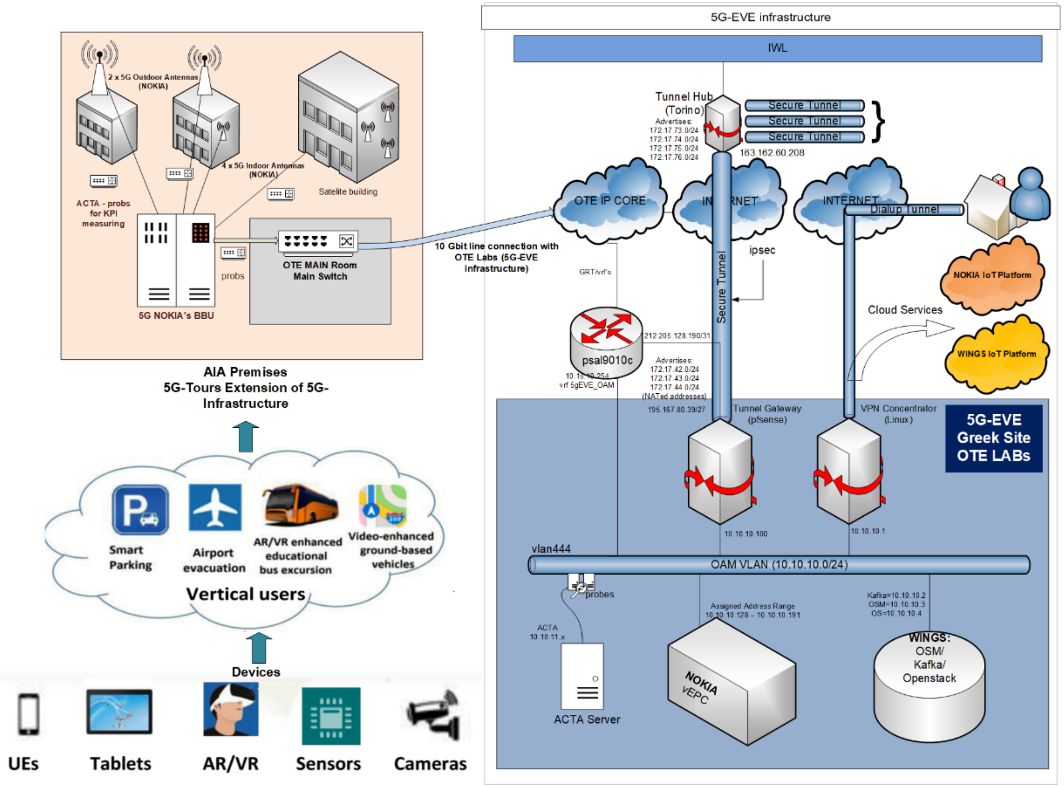


Figure 51. Mobility Efficient City Platform – Athens Node.

The deployment of the Mobility Efficient City platform at the Athens node is depicted in Figure 51, while the probes installed in Athens node are depicted in Figure 52.

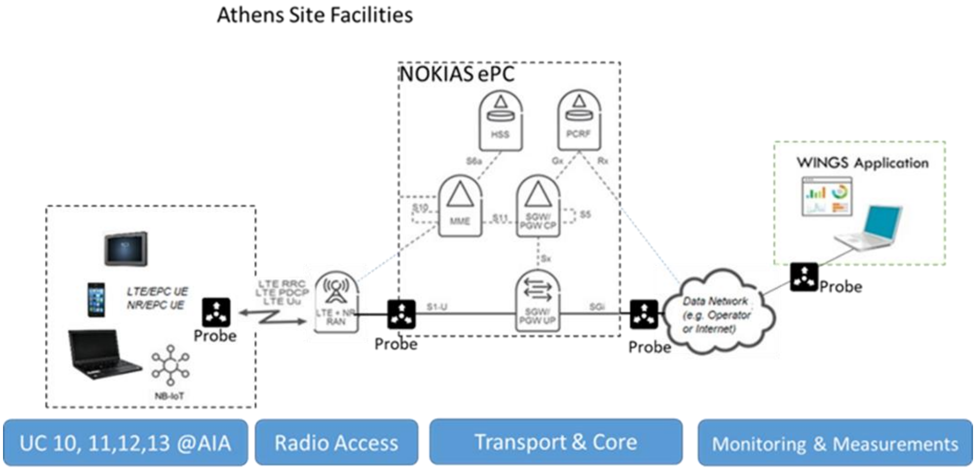


Figure 52. Probes installed to Athens node.

The four UCs that are implemented at the AIA premises are the following:

- UC10 - Smart airport parking management.
- UC11 - Video-enhanced ground-based moving vehicles.
- UC12 - Emergency airport evacuation.
- UC13 - Excursion on an AR/VR-enhanced bus.

Two more use cases from WP5 will be hosted in the Greek Site – Athens node:

- UC 6 - Remote Health Monitoring.

- UC 9 - Optimal Ambulance Routing

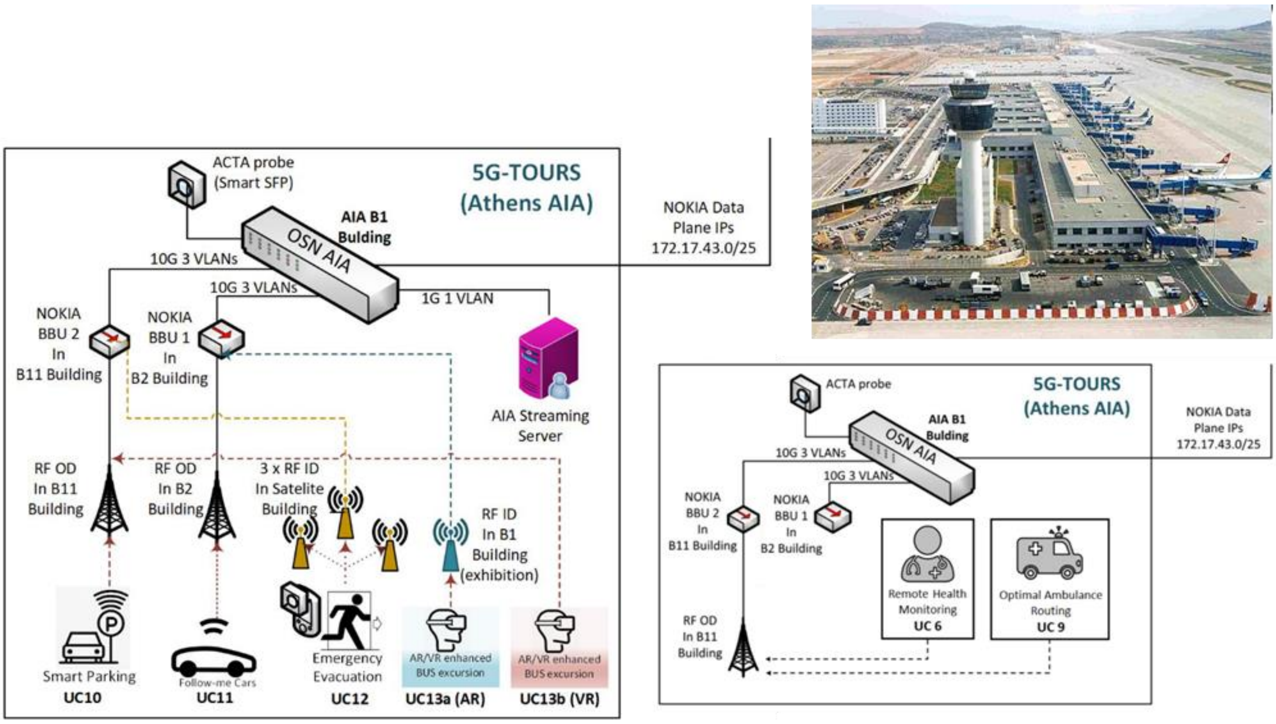


Figure 53. The extended Athens node in Athens International Airport and the six UCs.

6.2 Deployment implications

The trial platform is a virtual 4G/5G Core Network compatible with the 5G NSA standard. The UCs experimentation will not implement any slicing features (e.g.: slices onboarding, slices management, etc.) at the CN and/or radio access levels, since these are not supported by the Rel-15 network devices. Nevertheless, the deployed platform provides a real pre-commercial implementation of the UCs, demonstrating how a 5G network supports the technical and performance requirements posed by the Mobility Efficient City use cases. Deployment to 5G Stand Alone (SA) network is planned in a later step for experimental purposes.

6.3 UCs

6.3.1 UC10 - Smart airport parking management

6.3.1.1 High level description

The AIA area accommodates three short and long-term parking lots for AIA visitors and travellers, altogether occupying an area of around 13 km^2. The parking process at AIA can be very time-consuming and, therefore, stressful, especially when time until flight departure is limited. At the same time, purposeless and untargeted driving does not favour the environment from an emission perspective.

This use case will allow the AIA parking users to obtain real time information on available and occupied spaces. This will be achieved by the installation of 5G-enabled (i.e., communicate using a 5G technology) parking sensors. This way, the drivers will be able to locate the available parking spaces directly through a mobile application and will be guided there via the optimal route. The smart parking management will contribute to the emission reduction by decreasing unnecessary vehicle movements to locate a free parking space.

Situation example: On a peak day for AIA, approximately 20 vehicles can become congested in the parking facility of the B17 building. It would appear, that upon arrival, to park within the facility, the vehicles begin to search for an adequate parking spot, ideally near the entrance. Unfortunately, this, with so many vehicles simultaneously in search of the ideal spot and rushing to park, inevitably causes congestion. A vehicle driving in the wrong direction, by accident or to get a spot before another vehicle gets to it first, can end up colliding with the second vehicle, which had been driving in the correct direction.

The developed service aims to minimize the time spent finding an available parking spot within the parking facility of AIA, simultaneously optimizing the management and monitoring of the facility from the side of the respective authority. Specifically, an app-based service has been developed, which enables the user of the app to inspect the available parking places within the respective parking facility and get a recommendation for a parking slot, according to the specified criteria (e.g., the one closest to the entrance of the facility).

6.3.1.2 UC specific User and Network Requirements

The user requirements presented in Table 32are required for the implementation of this UC, while the mapping those user requirements into network requirements are illustrated in Table 33.

Table 32. 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	**High (reviewed)**
	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	**Fast (reviewed)**
	9	**Reliability/Availability:**	high / medium / low	**High**
	10	**Security / Privacy:**	Baseline /Medium /High / Ultra-High grade	**Medium (reviewed)**
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	

Table 33. Smart airport parking management network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) 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		100	100	High	10	100
2	**RAN** Latency (in milliseconds) - one way	msec		5	10	High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		10	50	High	10	50
4	Reliability (%) - Min/Max	%		95,00%	99,99%	Medium	95	99
5	Availability (%) - Min/Max	%		95,00%	99,99%	Medium	95	99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		50		High	5	50
7	Broadband Connectivity (peak demand)	Y/N or Gbps		0,1	0,1	High	0,1	0,1
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N		Y	Y	Medium	1	1
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y	Y	Medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		0,1	12	Medium	0,1	12
11	Device Density	Dev/Km^2		100K		High	1K	100K*
12	Location Accuracy	m		(n/a)	(n/a)	High	5	5

(*) 1 parking space = 10m^2 => 1 Km^2 = 100.000 parking spaces

The corresponding radar charts of general requirements against the 4G/5G networks capabilities are shown in Figure 54 and Figure 55 below.

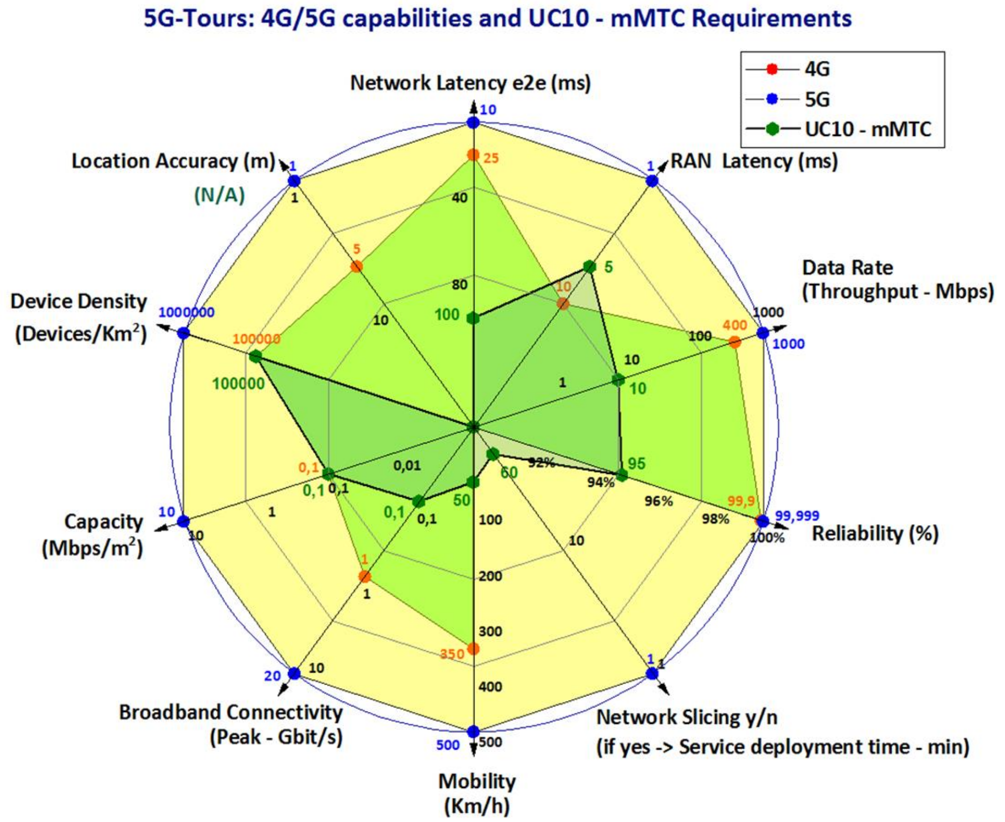


Figure 54. Radar chart for UC10 – Smart airport parking management network requirements (mMTC).

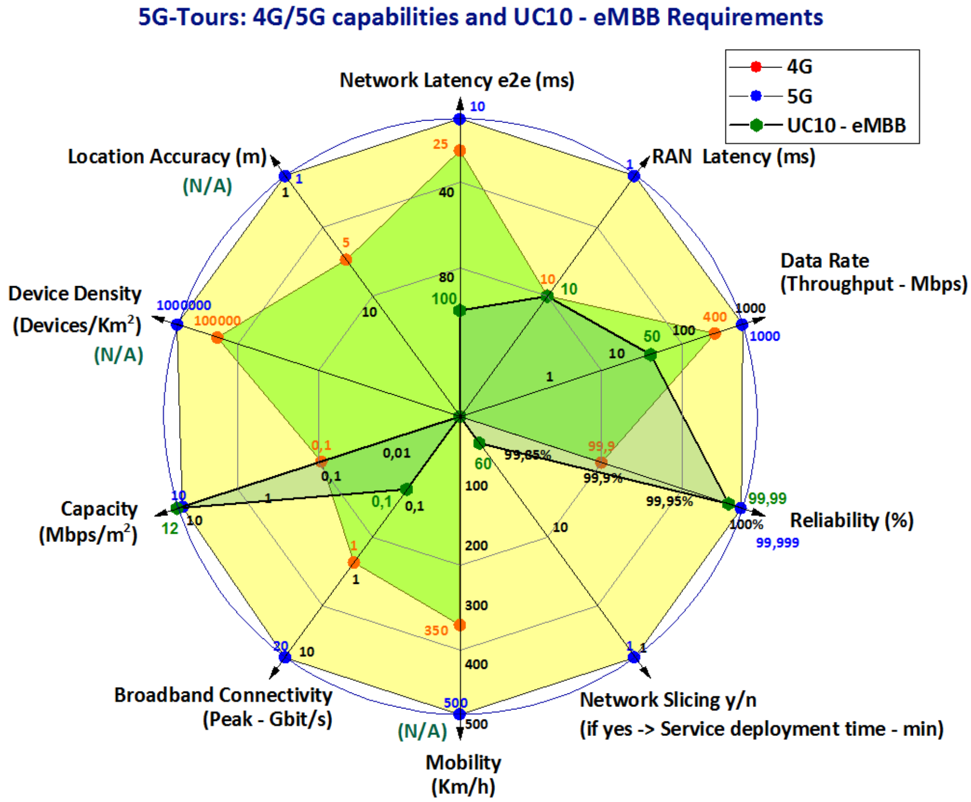


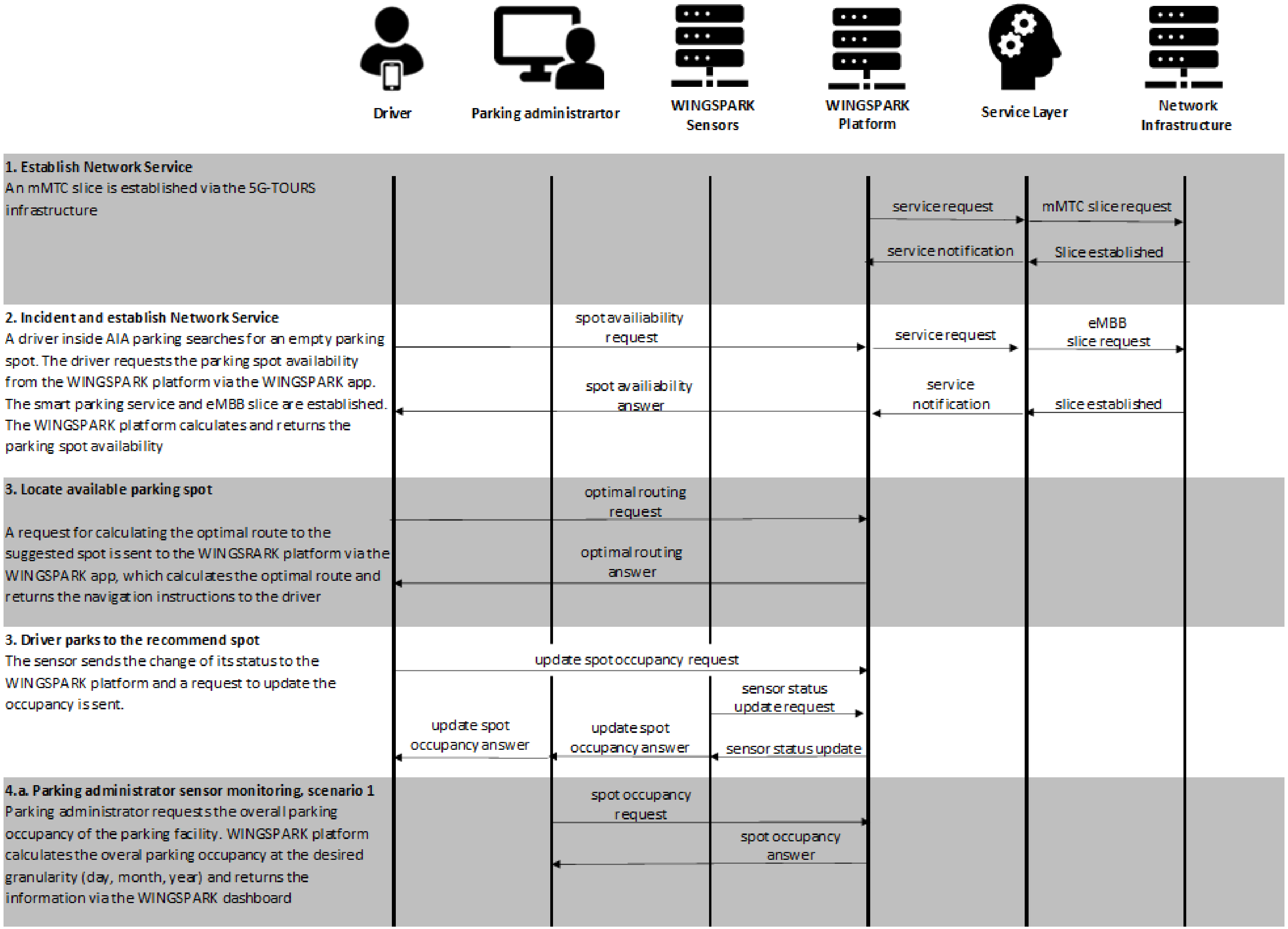
Figure 55. Radar chart for UC10 – Smart airport parking management network requirements (eMBB).

For UC10, Reliability and Availability requirements are being relaxed compared with the previous values in D2.2. Speed is, in general, limited in and out of parking area, however, the mobility KPI maximum value could be increased to 40 - 50 Km/h. Moreover, Latency is also 10-100 ms. Throughput is 10-50 Mbps for a single device and Broadband connectivity is 0.1 Gbps (i.e.: 100 Mbps for whole area).

Although with respect to E2E latency, Throughput, Mobility, Reliability, Broadband Connectivity, Capacity and Device Density for mMTC and E2E and RAN latency, Throughput, and Broadband Connectivity for eMBB even existing 4G/LTE and 4G+ technology/network will suffice; when it comes to RAN latency and Slicing (for mMTC), and Reliability and Slicing (for eMBB) a 5G network is required.

In addition to the above, Capacity requirement in some cases (for eMBB) stretches the 5G Network requirements to the limit (12). 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, even the stringent capacity requirement can be achieved with 5G technology.

6.3.1.3 Updated sequence diagram



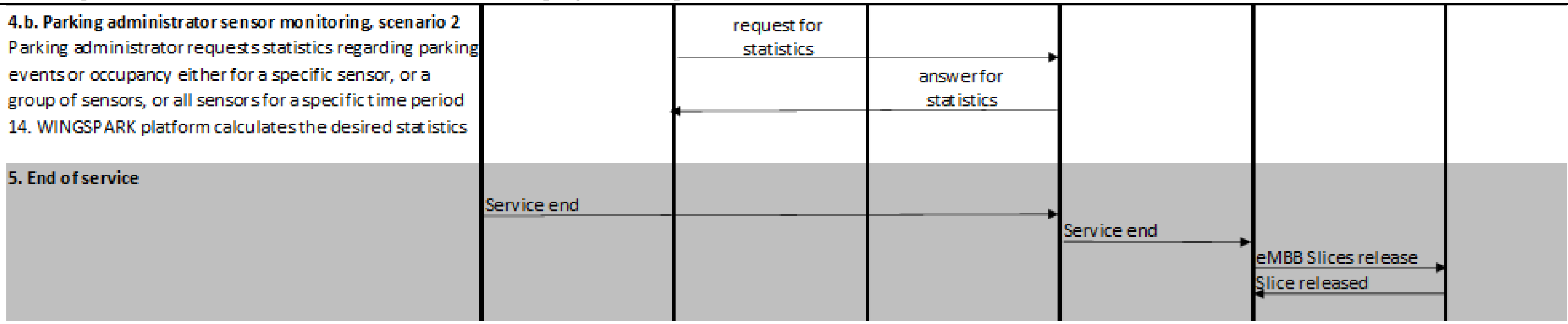


Figure 56. UC10 sequence diagram.

6.3.1.4 NEST

Attribute	Subparameter	eMBB	mMTC	Additional info
Availability		99.99%	95.99%	
Area of Service		GR		
	Region specification	GR-I		
Delay Tolerance		Supported		
Deterministic Communication	Availability	Not supported		
	Periodicity	NA		
Downlink throughput per network slice instance	Guaranteed	300 Mbps	10Mbps	Calculated like: Guaranteed Downlink Throughput Per User * number of users / terminals available for trial We also assume concurrent usage Number of users in the trial = 30 (eMBB) Number of users in the trial = 50 NB-IoT board (mMTC)
	Maximum	1.5Gbps	500Mbps	
Downlink Throughput Per User	Guaranteed	10Mbps	0.2Mbps	
	Maximum	50Mbps	10Mbps	
Energy Efficiency	Network slice energy efficiency	NA		
	Time frame of the measurement	NA		
Group Communication Support		Single Cell Point to Multipoint (SCPTM)		
Isolation level	Isolation	Logical Isolation		
	Physical Isolation	NA		
	Logical Isolation	Virtual resource isolation		
Location Based Message Delivery		NA		
Maximum Supported Packet Size		1500 Bytes		
Mission critical support	Mission critical support	Non-mission-critical		
	Mission critical capability support	NA		
	Mission critical service support	NA		
MMTel Support		Not supported		
NB-IoT Support		Not supported	Suported	
NSC Network Functions		UDM		
Number of connections		30	100	
Number of terminals		30	100	
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)		
	Monitoring	Metric Collection Per 5seconds, Metric Monitoring Per Minute		
Performance Prediction	Availability	NA		
	Prediction	NA		

Attribute	Subparameter	eMBB	mMTC	Additional info
Positioning Support	Availability	NA		
	Prediction	NA		
	Accuracy	NA		
Radio Spectrum		NB-IoT bands		
Root Cause Investigation		Passive investigation		The performance diagnosis module will inform the NSC, so it is passive, no active
Session and Service Continuity Support		SSC mode 1		
Simultaneous use of the network slice		Can be used simultaneously with any network slice		
Slice Quality of Service	3GPP 5QI	5	7	
	Resource Type	Non-GBR	Non-GBR	
	Priority Level	10	70	
	Packet Delay Budget (PDB)	0.1	0.1	
	Packet Error Rate (PER)	10^{-6}	10^{-3}	
	Jitter	0.01		
	Maximum Packet Loss Rate	10^{-6}	10^{-3}	
Support for Non-IP traffic		Not supported		
Supported Device Velocity		120 km/h Vehicular	0 km/h Stationary	
Synchronicity	Availability	NA		
	Accuracy	NA		
Terminal Density		30 UE/Km^2	100 devices/ Km^2	
Uplink Throughput Per network slice instance	Guaranteed	300 Mbps	20 Mbps	Downlink Throughput Per User * maximum number of users
	Maximum	1.5 Gbps	100 Mbps	
Uplink Throughput Per User	Guaranteed	10 Mbps	10 Mbps	
	Maximum	50 Mbps	50 Mbps	
User Management Openness		Not supported		
User Data Access	Data access	Direct Internet access		
	Tunnelling Mechanism	NA		
V2X communication mode		Not supported		
Latency from UPF to App Server		<0,150s preferably between 25 -30s		
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported		

6.3.2 UC11 – Video-enhanced ground-based moving vehicles

6.3.2.1 High level description

In respect to the issues and concerns of the follow-me vehicles (efficiency of provisions for aircraft during their arrival and departure from parking positions, staff's misdemeanours, such as exceeding the speed limit or smoking, safety hazards such as fuel spillages, etc.), 5G technologies, via the installation of high definition cameras on the follow-me vehicles, will be utilized to transmit live video feeds from the area where the incident is taking place not only to the Airport Services Operations Centre (ASOC), but also to other concerned third parties and stakeholders such as Police, Civil Protection, HCAA (Hellenic Civil Aviation Administration), Fire Brigade operation centres, etc. This will most certainly coordinate and expedite the response to needs and emergencies as they occur and will maintain the safety of the Apron area.

This use case will be implemented via the installation of high-definition cameras on the follow-me vehicles, which will feed live video feeds to the ASOC as well as to other concerned third parties and stakeholders. Enhancing the ground-based moving vehicles with technologies that provide real time notification on the Apron situation at any given time is of great value to the airport in sustaining an efficient and safe operation, for the customers (Airlines) for whom, safety and avoiding flight delays is vital, as well as other stakeholders (emergency resource personnel – Police, Ambulance Services, Fire Brigade) in efficiently responding to emergencies.

Situation example: On September 10th, 2021, during the night shift at 01:20 hours, an Airside Monitoring Inspection Specialist (AMIS) is driving northbound on the Apron and encounters two vehicles which have just collided, and the drivers appear to be slightly injured. The AMIS proceeds to notify the ASOC to summon the assistance of the necessary emergency resource personnel. As the AMIS continues to carry out its duties and is driving along the airside service road, she notices that there is a fuel spillage on the tarmac near parking position B3. At the same time, there is a ground services employee who is about to light a cigarette and the AMIS proceeds to promptly inform this employee that smoking is prohibited on the tarmac. During the peak morning hours at approximately 04:30 – 07:30, where there are several arrivals and departures that the AMIS must facilitate, thus the AMIS are unable to accommodate all arriving and departing aircrafts by inspecting their positions which results in aircraft departure delays. The late departure of aircraft from Aircraft parking stands delays also, the arriving aircraft as their parking position has not been vacated.

The follow-me vehicles also access on-demand service and provide the follow-me services for aircraft, which leads aircraft to their parking position. 5G technologies will be used to provide, on-demand and/or live video streaming or upload recorded data later in order to monitor and oversee the activity at the airport airside area, and attend incidents, emergencies and critical events.

This will result in a dramatic increase of the situational awareness of the stakeholders responsible for the running of the airport operations. Moreover, in case of an emergency or a developing incident, the ASOC or other operating centres will be able to have an immediate overview and decide the required mitigation actions in a timely manner, regardless of the area of the airport where the incident is taking place, and irrespectively of whether the ASOC has direct viewing capability of the area or not.

6.3.2.2 UC specific User and Network Requirements

For the implementation of this UC, the requirements in Table 34 from the user perspective are needed. Note that no updates have been made to the UC11 user requirements with respect what presented in deliverable D2.2.

The mapping of the user requirements into network requirements are illustrated in the following Table 35 and the corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 57.

Table 34. 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	**High**
	5	***Data Transmission (UL)* :**	High/Medium/Low	
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	

Table 35. UC11 – Video enhanced ground based moving vehicles network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) 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

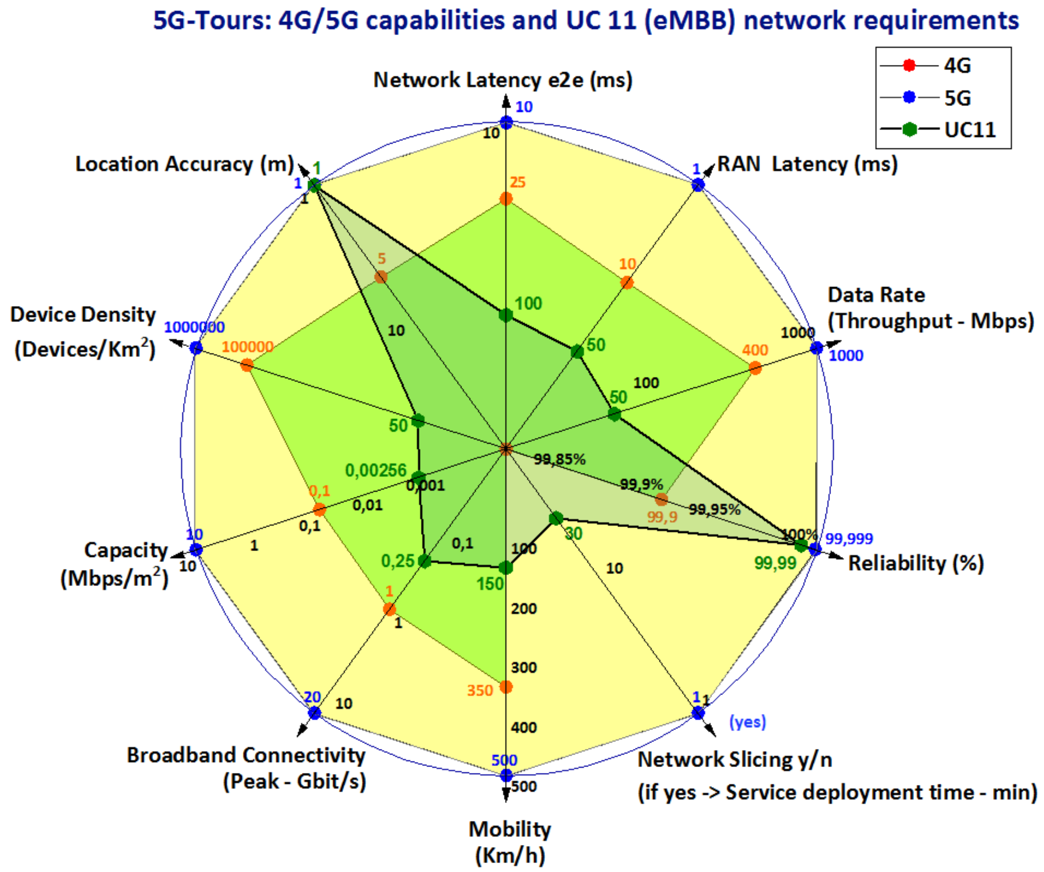


Figure 57. Radar chart for UC11 – Video-enhanced ground-based moving vehicles network requirements.

Although, Reliability and Availability requirements could be flexible, they remain critical for the coordination and awareness in critical situations in the Control Room of the airport. So, the four nines of reliability are the adequate value. UC11 should benefit from the additional capabilities of 5G with regards to Reliability, Location Accuracy, and Network Slicing requirements.

For this UC only Reliability, Network Slicing and Location accuracy can easily be satisfied by a 5G network. The remaining requirements are covered normally by 4G/LTE technology. So, this UC11 can potentially serve as an example of a utilisation of a service that, although it does not strictly require 5G, verticals benefit from such deployed capabilities as a marginal cost increment for their high utility benefit.

6.3.2.3 Updated sequence diagram

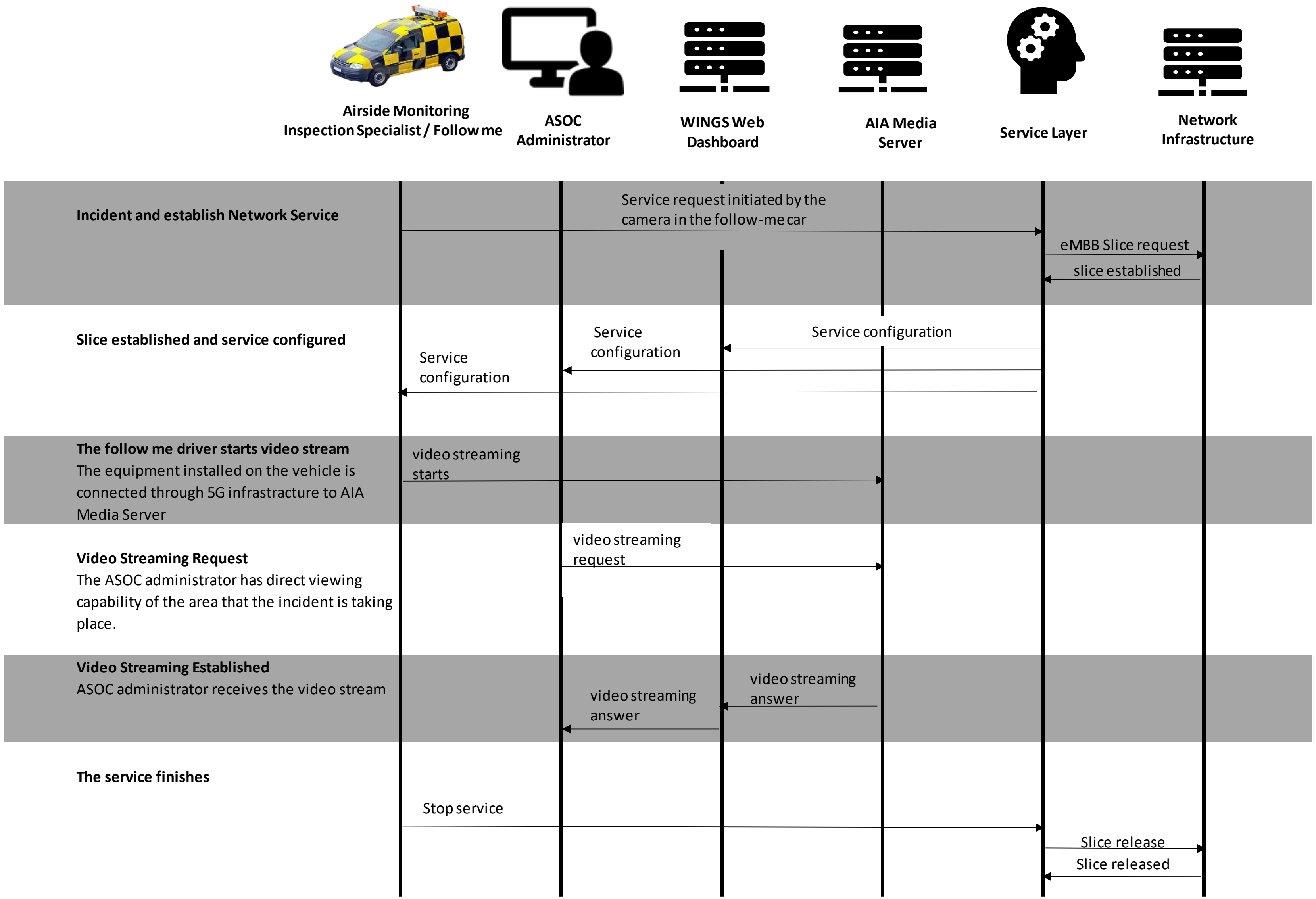


Figure 58. UC11 sequence diagram.

6.3.2.4 NEST

Attribute	Subparameter	eMBB	Additional info
Availability		99.999%	
Area of Service		GR	
	Region specification	GR-I	Athens International Airport (AIA) dedicated area for 5G-TOURS follow me car resting
Delay Tolerance		Supported	Based on [12], it must be <300ms, preferably 50-60 ms
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	6 Mbps	There will be 3-6 moving vehicles that will transmit HD video to the Airport Control Centre
	Maximum	12 Mbs	
Downlink Throughput Per User	Guaranteed	1 Mbps	The traffic will mainly be upstream. The downstream will mainly be Control traffic (Control Signals for the Cameras, Voice Instructions for Drivers, etc.) Assumption 1 Mbps per Vehicle
	Maximum	2 Mbps	
Energy Efficiency	Network slice energy efficiency	Not supported	
	Time frame of the measurement	Not supported	
Group Communication Support		Single Cell Point to Multipoint (SCPTM)	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Tenant/Service Isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Non-mission-critical	
	Mission critical capability support	NA	
	Mission critical service support	NA	
MMTel Support		Not supported	It will depend on how the Voice Communication to the Drivers from the Control Centre will be implemented. Via IMS/Voice using UE terminals or via Dedicated Channel within the Service Application
NB-IoT Support		Supported	
NSC Network Functions		No special NF deployed for this specific Use Case	
Number of connections		3 / 6	There will be a 5G Router per Vehicle (3 Vehicle → 3 Routers → 3 Terminals). In each router a Camera (that provides situation awareness) will be connected (via Ethernet cable). Furthermore, a Smart Phone will be connected to teach Router (via Wi-Fi). This will allow bidirectional communication with
Number of terminals		3	

Attribute	Subparameter	eMBB	Additional info
			the driver in each vehicle. So, if we consider the connection as single one (one per 5G router), then we have 3 devices and 3 connections. If we consider 2 connections per 5G-Router (1-Camera + 1 smart phone), each supplying different service per connection, we have 6 connections. It is a matter of definition.
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)	Currently, Nokia's AMF doesn't provide Control Plane KPIs per second - special configuration needed to stream out KPI(s). For the needs of the tests, a set of monitoring probes deployed by ACTA will be used. The probes can capture metrics/KPIs with high and configurable granularity (seconds/minutes).
	Monitoring	Metric Collection Per 2 seconds (configurable) Metric Monitoring Per Minute (configurable)	
Performance Prediction	Availability	NA	
	Prediction	NA	
Positioning Support	Availability	OTDA (LTE & NR)	
	Prediction	Per second	
	Accuracy	1 meter	
Radio Spectrum		NR @3,5 GHz (band n78)	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Can be used simultaneously with another network slice	
Slice Quality of Service	3GPP 5QI	3	
	Resource Type	Non-GBR	
	Priority Level	30	
	Packet Delay Budget (PDB)	50 ms	
	Packet Error Rate (PER)	10^{-3}	
	Jitter	< 1/10 of Latency = 30ms Preferably between 0.5-1ms	
	Maximum Packet Loss Rate	NA	
Support for Non-IP traffic		Not supported	
Supported Device Velocity		Vehicular up to 120 km/h	
Synchronicity	Availability	Not supported	
	Accuracy	Not supported	
Terminal Density		50 devices/km2	The number of devices that will participate in the trials will be fewer than 50. 6 Devices with SIM cards will participate: 3x5G-routers and 3xSmartphones.
Uplink Throughput Per network slice instance	Guaranteed	60 Mbps	Guaranteed Downlink Throughput Per User*maximum number of users 2 devices for uplink path
	Maximum	132 Mbps	

Attribute	Subparameter	eMBB	Additional info
Uplink Throughput Per User	Guaranteed	10 Mbps	
	Maximum	50 Mbps	This can exceed 300 Mbps but it is limited by the channel bandwidth to be used. Although we initially asked for 100 MHz channel, eventually a 40 or 60 MHz
User Management Openness		Not supported	
User Data Access	Data access	Local traffic ONLY (no internet access)	
	Tunnelling Mechanism	VPN Tunnel Label based routing or IPsec Tunnel	
V2X communication mode		Not supported	
Latency from UPF to App Server		< 0,150s, preferably between 25 -30ms	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

6.3.3 UC12 - Emergency airport evacuation

6.3.3.1 High level description

The main goal of this use case is to exploit the 5G capabilities for assisting current evacuation plans in large crowded indoor public spaces and, thus, reduce the possibility or magnitude of casualties. The idea of this scenario is to support occupants to be safely guided to the nearest exit, after an unattended item is left, for example, at Gate A36 of the STB and based on the current protocols an evacuation is deemed necessary.

The overall objective is to validate whether the 5G capabilities can complement existing processes and capabilities by providing automated guidance for the evacuation route to residents and regular users of the facility to visitors, travellers, and possible vulnerable people who are not aware of the facility. Real time data such as numbers of evacuees within an area, persons trapped, assistance to impaired people, visualization of real-time flows of people will be evaluated to assess the impact of 5G technology.

The evacuation of an Airport Terminal in case of an emergency is fundamental for ensuring the protection of human lives and reducing as much as possible, the number of casualties. The elements of panic that may ensue during an evacuation process may result in unnecessary and severe repercussions. In previous incidents where evacuation procedures were initiated and handled with the use of simple technologies such as tetra and telephone, uncontrolled evacuees have been found scattered beyond the designated muster areas.

In respect to efficient and rapid evacuation in cases of security emergencies (security threats, threatening phone calls, etc.) or other related emergencies (fire, natural disaster, etc.), 5G technologies may enhance the evacuation process and, thus, reduce the possibility or magnitude of casualties. Evacuating in a quick and organized fashion by automated dynamic emergency routes from the affected area up to the muster areas, is of the utmost importance. 5G provides the capability to obtain real-time data from the emergency environment which is to be evacuated, such as numbers of occupants within the area, persons trapped in isolated areas of the building and about the real-time flow management of the evacuees.

Furthermore, this use case can accommodate for incidents that have complex and dynamic evacuation requirements such as a fire spreading or a terrorist attack, that require dynamic information to be conveyed to evacuees.

Airport terminals are very large and complex public venues with many travellers, visitors and employees. Airport evacuations in general, are currently based on pre-established plans and procedures to be executed during the emergency.

AIA is the main gateway to Athens and Greece in general. On a daily basis, AIA serves approximately fifty to sixty thousand passengers travelling through the airport, while, during the peak traffic days, this number can reach approximately one hundred thousand or even more, including visitors and employees.

The Airport's objective is to process this crowd in an efficient and safe manner, while, at the same time, have in place the relevant plans, tools and processes required to mitigate any emergency. An efficient and effective evacuation is one of the mitigation measures that are of particular importance in security incidents or even in the case of fire, gas leakage, etc.

This scenario describes the way airports (in general) and other large-scale public infrastructures, can exploit 5G capabilities to bring in place an effective evacuation plan where personalized, dynamic, and smart instructions can be provided in a reliable, instantaneous and massive-scale manner. In the context of this use case, a section of AIA will be provided, and around 50-60 volunteers (actors) will participate in an evacuation exercise. Naturally, such an emergency situation will call for low latency communications with high reliability of being realized, which means that a URLLC slice will have to be allocated so as to ensure that all travellers and AIA personnel are notified and guided to the most appropriate exit immediately. A detailed 3D digital model of the section to be evacuated along with all objects contained therein (such as seats, desks, and monitors) is already developed and fed into the evacuation support system. Emergency exits will all be recorded and fed into the system supporting the evacuation procedure along with information on their exact location as well as their capacity, if they are accessible, etc.

Initially, the Evacuation use case participants will be notified with a message to their mobile device about the emergency situation, while from that point on, they will be receiving further notifications on regular time intervals. Guidance will be provided in a personalized manner, taking into consideration the design of the physical space, any obstacles that might exist, the current occupancy, the capacity of the evacuation routes and the travellers' individual needs and limitations, such as their age, health status and mobility capabilities, etc. The location of the travellers will be also tracked to provide more targeted guidance especially for evolving events such as a fire spreading or an evacuation route becoming unavailable. The system can also be explored for early detection of passenger movement anomalies that can signify evolving emergency and timely alarm airport response units. Enhanced location services will be made available through the 5G network.

6.3.3.2 UC specific User and Network Requirements

For the implementation of this UC, from the user perspective the requirements in Table 36 are needed.

The mapping of those user requirements into network requirements are illustrated into the following Table 37.

Table 36. 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	**Medium 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	**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 battery life refers to the Samsung S20 mobile phones. Based on average battery consumption from the mobile application during the evacuation, it is supposed that the "Medium" value is the suitable one. 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´ mobiles becomes critical for survival in this UC, this could have translated into a desire to ensure batteries do not fail during evacuation.

Table 37. UC12 – Emergency airport evacuation network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) 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				15	100
2	**RAN** Latency (in milliseconds) - one way	msec	10				10	20
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	500				100	500 *
4	Reliability (%) - Min/Max	%	99,9999				99,999	99,9999
5	Availability (%) - Min/Max	%	99,99				99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10				0	10**
7	Broadband Connectivity (peak demand)	Y/N or Gbps	10				1	10
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	0			high	1	5
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	20				2	20***
11	Device Density	Dev/Km^2	1000K				1000K	1000K*****
12	Location Accuracy	m	<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

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 59 below.

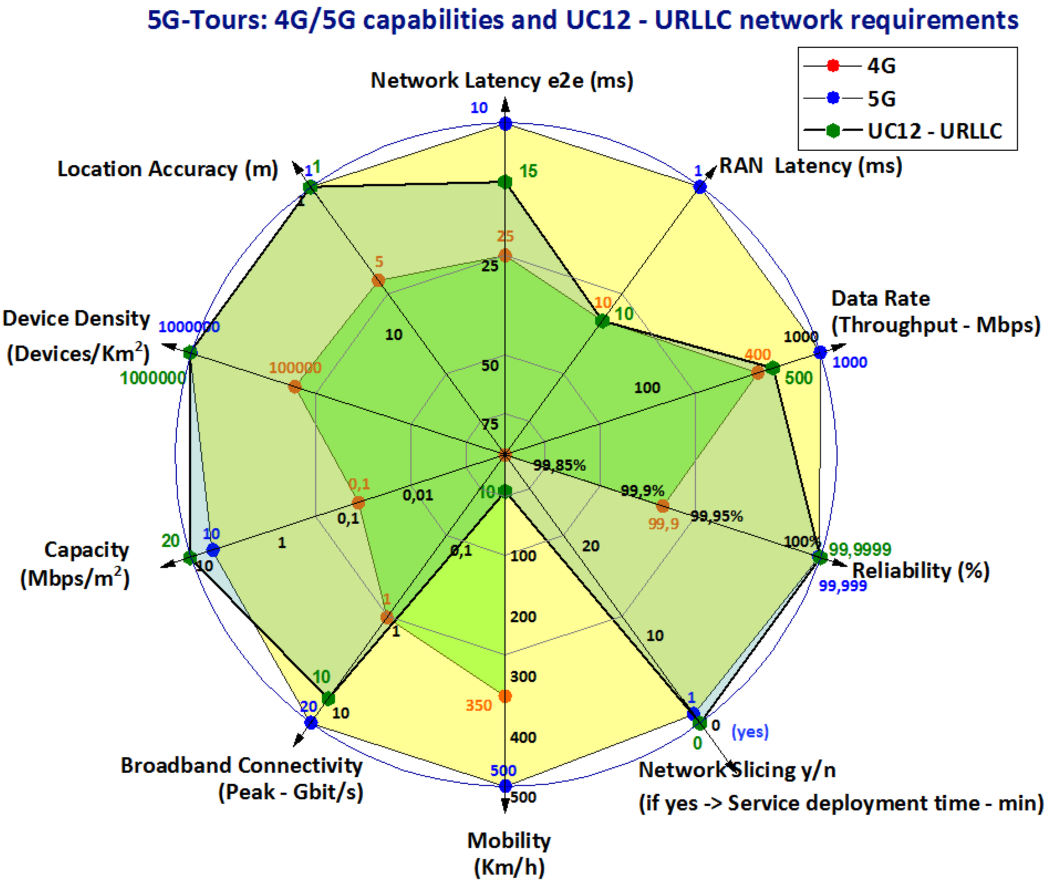


Figure 59. Radar chart for UC12 URLLC – Emergency airport evacuation network requirements.

Evacuation is an emergency situation so the relevant Network Slice would be always available. This means that service deployment time should be near to zero and the priority for network slicing can be high.

For UC12, a 4G/LTE network will only be able to satisfy the RAN Latency, and Mobility. Advanced 5G Network should be well utilized with respect to Broadband Connectivity, Throughput, Device Density, Reliability, Network Slicing, E2E Latency, Location Accuracy, and Capacity.

It is interesting to observe that the UC12 Capacity requirements (for 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.

Moreover, ultra-high Reliability of 6 “nines” exceeds the 5G Network requirements more than the limit. This is due to the very critical and emergent service of evacuation in the Athens International Airport. This service must be always up and running. In addition to that, the corresponding URLLC slice must be continuously deployed. This means that a slice should be pre-defined in order to be used when needed (slicing requirement to “0s”).

6.3.3.3 Updated sequence diagram

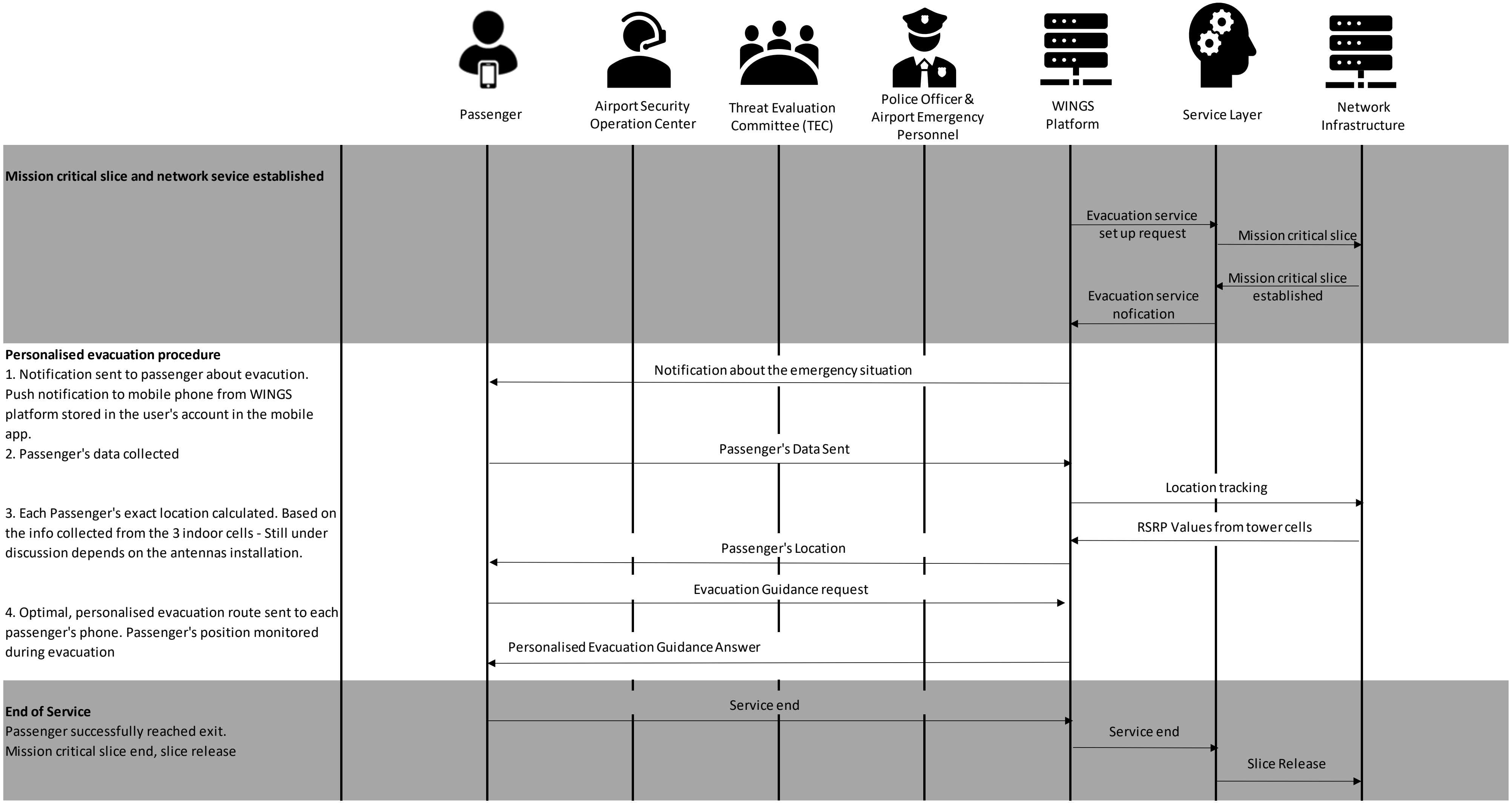


Figure 60. UC12 sequence diagram.

6.3.3.4 NEST

Attribute	Subparameter	URLLC	Additional info
Availability		99.999%	
Area of Service		GR	
	Region specification	GR-I	Athens International Airport (AIA) dedicated area for 5G-TOURS follow me car resting
Delay Tolerance		Not supported	Based on [12], it must be <300ms, preferably 50-60ms
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	10000 Mbps	
	Maximum	NA	
Downlink Throughput Per User	Guaranteed	500 Mbps	
	Maximum	NA	
Energy Efficiency	Network slice energy efficiency	Not supported	
	Time frame of the measurement	Not supported	
Group Communication Support		Multicast	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Mission-critical	
	Mission critical capability support	Local control	
	Mission critical service support	MCData	
MMTel Support		Supported, not needed	
NB-IoT Support		Supported, not needed	
NSC Network Functions		UPF, AUSF	
Number of connections		20	
Number of terminals		20	
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)	
	Monitoring	Metric Collection Per 5 seconds (configurable) Metric Monitoring Per Minute (configurable)	
Performance Prediction	Availability	NA	
	Prediction	NA	
Positioning Support	Availability	OTDA (LTE & NR)	
	Prediction	Per second	
	Accuracy	1 meter	

Attribute	Subparameter	URLLC	Additional info
Radio Spectrum		NB-IoT bands + 5G bands (at 3.5GHz)	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Can be used simultaneously with another network slice	
Slice Quality of Service	3GPP 5QI	70	
	Resource Type	Non-GBR	
	Priority Level	55	
	Packet Delay Budget (PDB)	200 ms	
	Packet Error Rate (PER)	10^{-6}	
	Jitter	< 1/10 of Latency = 30ms Preferably between 5-6ms	
	Maximum Packet Loss Rate	10^{-6}	
Support for Non-IP traffic		Not supported	
Supported Device Velocity		10 km/h - Pedestrian	
Synchronicity	Availability	Between BS and UE	
	Accuracy	1	
Terminal Density		8 devices/km2	20*0,2 =8 UE/Km2
Uplink Throughput Per network slice instance	Guaranteed	10000 Mbps	
	Maximum	NA	
Uplink Throughput Per User	Guaranteed	500 Mbps	
	Maximum	NA	
User Management Openness		Not supported	
User Data Access	Data access	Local traffic ONLY (no internet access)	
	Tunnelling Mechanism	NA	
V2X communication mode		Not supported	
Latency from UPF to App Server		<0.100s, preferably between 10-15s	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

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

6.3.4.1 High level description

This UC aims at demonstrating the value of the 5G technology for groups of people travelling (e.g., on a bus) to visit a site of interest, enabling the provision of good quality digital experiences to the travellers both during the transportation to and from the destination and during the visit.

In concrete, the UC focuses on a group of 20-25 students from Ellinogermaniki Agogi (EA) school travelling by bus to Athens International Airport (AIA) to visit an exhibit that will be hosted in the public arrivals area of the airport. The target customer in this use case is primarily the school, and, by extension, more generally anyone who transports groups of people visiting a site of interest – most notably actors in the tourism industry.

The demonstration of this UC can be divided into three main steps:

1. **Students travelling to the Athens Airport**

On a school bus, students will be traveling to the Airport, where they will visit an exhibit in the arrivals area. On their way, students will use the end-user devices (5G mobile phone + VR) to enter a 3D VR space, where they will be able to explore and interact with various digital assets. The duration of the pre-visit VR experience is about 5-10 minutes and is comprised of the following parts:

a. **Profiling minigame,** whose purpose is to offer personalized experiences to each student. Each student will be asked 3-4 questions, which will be disguised in a mini game. The answers will condition the way the app will work for that user.
b. **Video introducing the visit experience.** The students will watch a video introducing what they will see and learn about during their visit to the Myrtis exhibit. The duration of the video will be about 3-5 minutes.
c. **Video introducing the gamified aspects.** With a short video, students will be informed that, after the visit, during their bus journey back to school, they will participate in a game-based test of what they have seen and learned during 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 later they can show their achievements and win relevant prizes/emblems. The duration of the video will be around 1-2 minutes.

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

In the public area of the arrivals´ hall in Athens airport, there will be a big poster (3m height - 1,5 m wide) which will include the image of Myrtis and augmented reality tags for the travelers arriving in Athens. There, students will use the end-user devices to point to different parts of the banner and so trigger AR content on their screens. The AR content offered to each user will be personalized on the basis of the input the user will have provided in the profiling minigame. The duration of the AR experience will be approximately of 10-15 minutes and is comprised of the following parts:

d. **Rich information about Myrtis and Athens through AR.** 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.
e. **Gamified AR experience:** While exploring the exhibit, 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).
f. **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 recognize it and register it on the student's list. This will unlock the next tip leading to the next object.

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

On the school bus once again, traveling back to their school after their visit to the exhibit in the airport, students will use the end-user devices to enter a 3D VR space, where they will be able to interact with various digital assets. The duration of the post-visit VR experience is about 5-10 minutes and it is comprised of the following parts:

g. **The knowledge quiz.** In the VR environment, students will participate in a game-based test 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 evidences 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.
h. **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.

6.3.4.2 UC specific User and Network Requirements

For the implementation of this UC the following requirements, from the user perspective are needed (see Table 38):

Table 38. 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	**No**
	8	**Fast Response (Low Latency):**	Slow / Fast / Very Fast	**Fast** (reviewed)
	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	**Medium** (reviewed)
	16	***other***	User specified	

The mapping of the above user requirements into network requirements are illustrated into the following Table 39, where the vertical use case requirements for this use case are shown.

Table 39. UC13 – Excursion on an AR/VR enhanced bus network requirements.

5G-Tours - Use Cases: direct specific Technical requirements		Units	(Reviewed) - 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

UC13 network requirements have not changed with respect to the ones presented in deliverable D2.2.

The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 61 below.

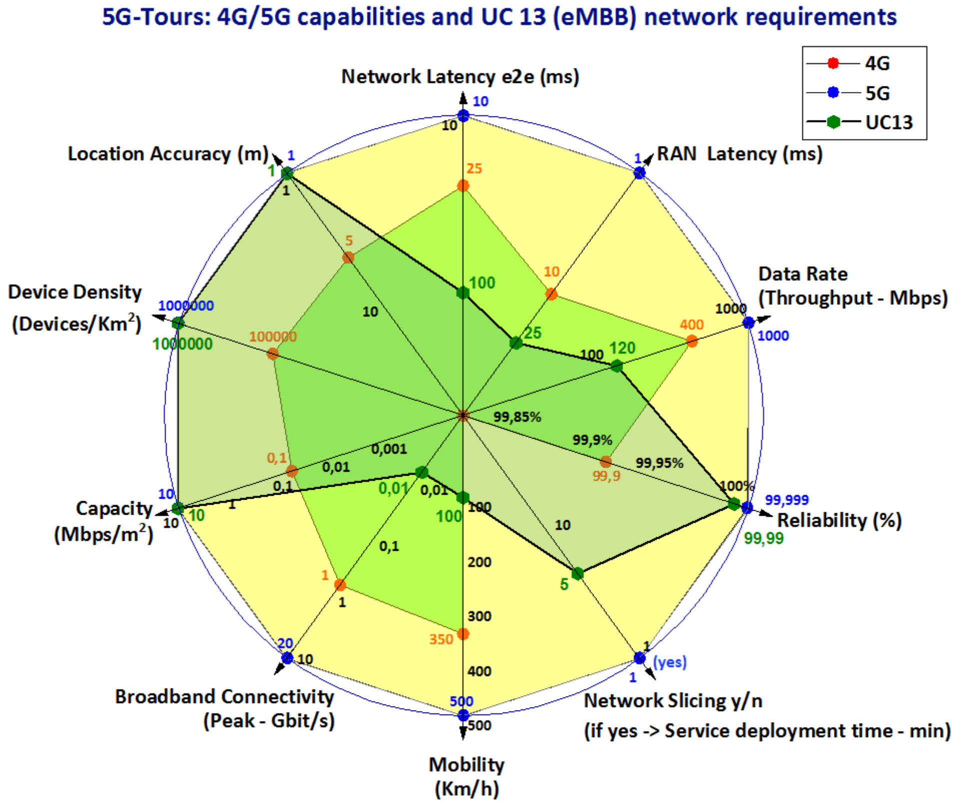
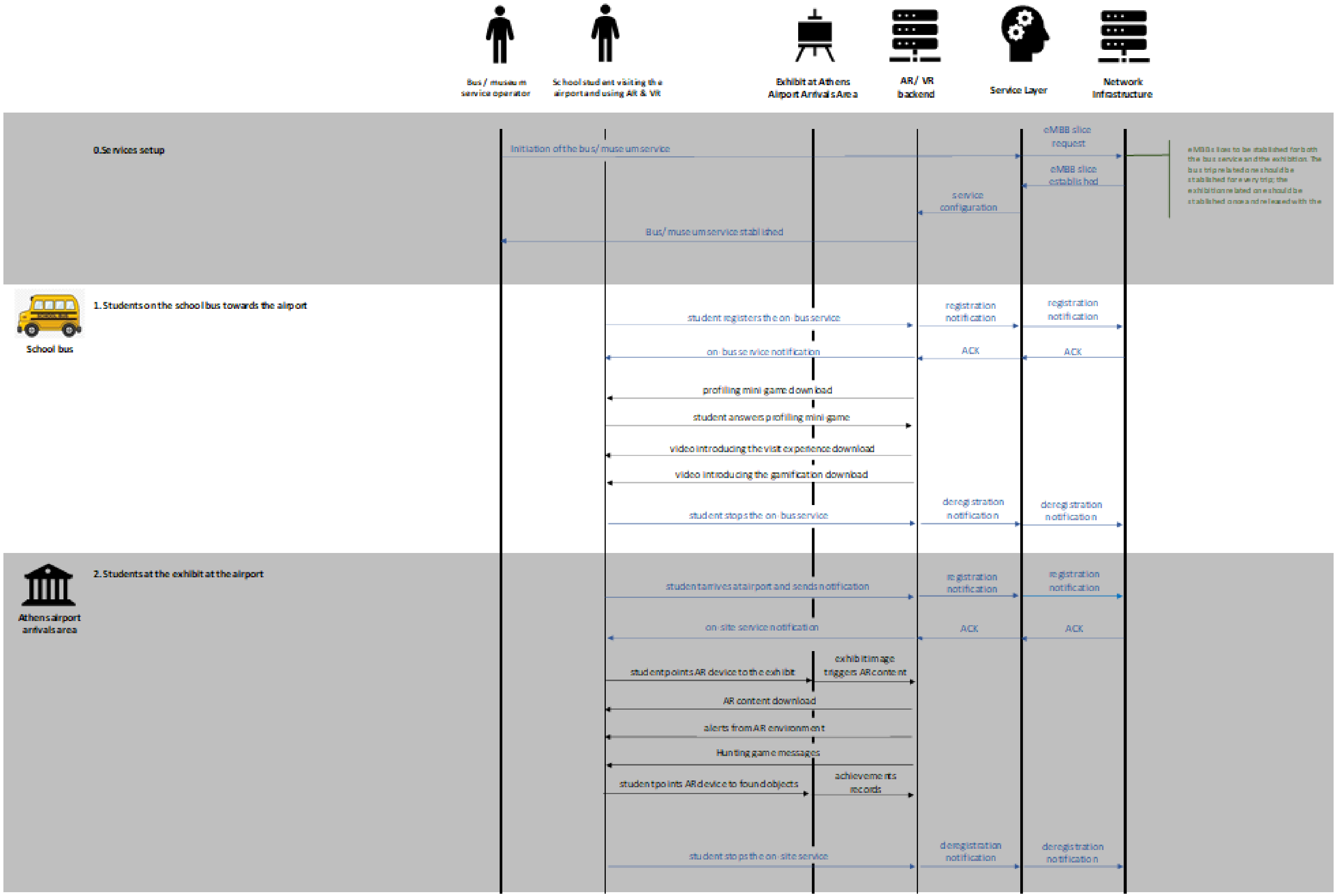


Figure 61. Radar chart for UC13 – Excursion on an AR/VR enhanced bus network requirements.

Half of 5G-TOURS UC13 requirements need a 5G network for the service implementation. The following require 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 resolution and quality, the required Broadband Connectivity (0,01Gbps), Latency (both E2E network latency (100ms) and RAN (25ms)) as well as Throughput (120 Mbps) will stretch existing 4G/LTE 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.

6.3.4.3 Updated sequence diagram



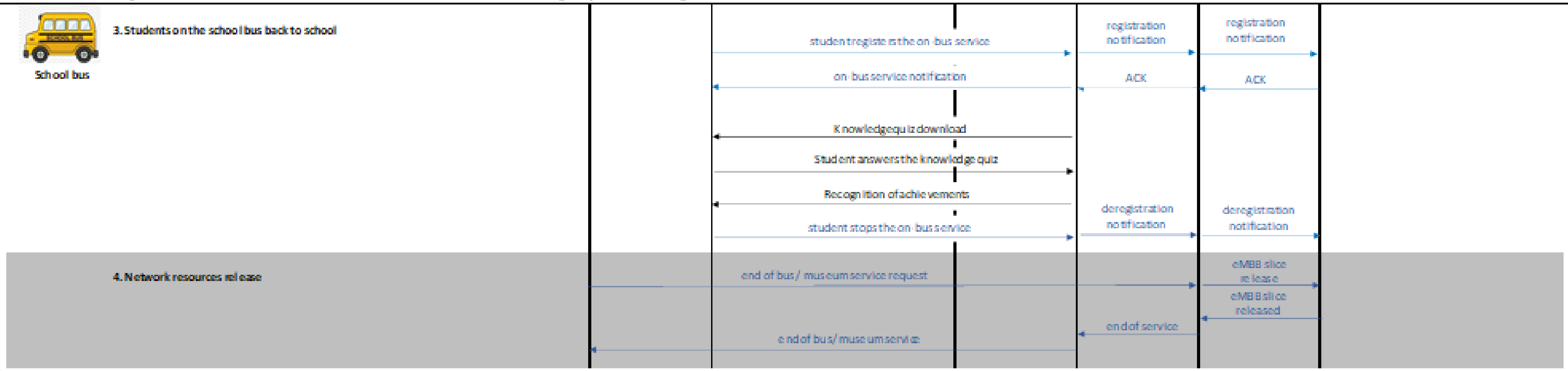


Figure 62. UC13 sequence diagram.

6.3.4.4 NEST

Attribute	Subparameter	eMBB	Additional info
Availability		99.99%	
Area of Service		GR	
	Region specification	GR-I	Athens International Airport (AIA) dedicated area for 5G-TOURS follow me car resting
Delay Tolerance		Not supported	
Deterministic Communication	Availability	Not supported	
	Periodicity	NA	
Downlink throughput per network slice instance	Guaranteed	2240 Mbps	Number of users = 30
	Maximum	3600 Mbps	
Downlink Throughput Per User	Guaranteed	80 Mbps	
	Maximum	120 Mbps	
Energy Efficiency	Network slice energy efficiency	NA	
	Time frame of the measurement	NA	
Group Communication Support		NA	
Isolation level	Isolation	Logical Isolation	
	Physical Isolation	NA	
	Logical Isolation	Virtual resource isolation	
Location Based Message Delivery		NA	
Maximum Supported Packet Size		1500 Bytes	
Mission critical support	Mission critical support	Non-mission-critical	
	Mission critical capability support	NA	
	Mission critical service support	NA	
MMTel Support		NA	
NB-IoT Support		Not supported	
NSC Network Functions		NA	
Number of connections		30	
Number of terminals		30	
Performance Monitoring	Availability	RTT latency, Service availability, Service reliability, Throughput (UP/DL)	
	Monitoring	Metric Collection Per 2 seconds (configurable) Metric Monitoring Per Minute (configurable)	
Performance Prediction	Availability	Not supported	
	Prediction	Not supported	
Positioning Support	Availability	NA	
	Prediction	NA	
	Accuracy	NA	

Attribute	Subparameter	eMBB	Additional info
Radio Spectrum		NR @3,5 GHz (band n78)	
Root Cause Investigation		Not supported	
Session and Service Continuity Support		SSC mode 1	
Simultaneous use of the network slice		Can be used simultaneously with another network slice	
Slice Quality of Service	3GPP 5QI	80	
	Resource Type	Non-GBR	
	Priority Level	68	
	Packet Delay Budget (PDB)	0.01	
	Packet Error Rate (PER)	10^{-6}	
	Jitter	NA	
	Maximum Packet Loss Rate	NA	
Support for Non-IP traffic		Not supported	
Supported Device Velocity		Vehicular up to 120 km/h	
Synchronicity	Availability	Not supported	
	Accuracy	NA	
Terminal Density		30 devices/km2	
Uplink Throughput Per network slice in-stance	Guaranteed	<300 Mbps	
	Maximum	<300 Mbps	
Uplink Throughput Per User	Guaranteed	<10 Mbps	
	Maximum	<10 Mbps	
User Management Openness		Not supported	
User Data Access	Data access	Direct internet access	
	Tunnelling Mechanism	NA	
V2X communication mode		Not supported	
Latency from UPF to App Server		NA	
Network Slice Specific Authentication and Authorization (NSSAA)		Not supported	

7 Economic drivers for 5G-TOURS use cases in commercial deployments

This chapter reports the quantification of benefits and economic drivers for the 5G-TOURS use cases.

7.1 Framework for understanding economic and commercial potential of 5G-TOURS use cases

The benefits analysis and economic drivers for the 5G-TOURS use cases has been undertaken within WP2 of 5G-TOURS and specifically T2.3. Figure 63 shows the connection between T2.3 and the other work package 2 tasks also reported in this deliverable. T2.1, 2.2 and 2.4 all define the service requirements for each of the use case and investigate the implications that these service requirements may have on network deployment. Based on these service definitions, T2.3 then considers who might use and benefit from these services in commercially deployment networks.

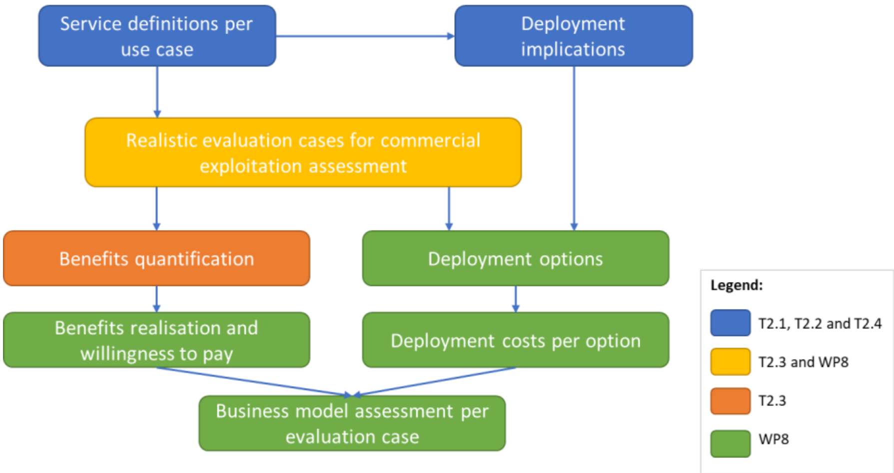


Figure 63. Relationship between tasks within WP2 and WP8.

T2.3 is different from the other tasks in WP2 in that it must consider the services provided under the 5G-TOURS use cases beyond the project testbeds. Instead, T2.3 must consider where the 5G-TOURS use cases and their related services would be deployed in large scale commercial networks and who, in these settings, would use and benefit from these.

There is a close relationship between T2.3 and the commercial exploitation and business model analysis threads of work in WP8. Any business model requires quantification of revenues and costs. Revenues will be linked to willingness of users to pay for a service which in turn are linked to the benefits derived from that service. In this way, T2.3 feeds into the business model analysis. Additionally, the service requirements and deployment implications developed by the other parts of WP2 will feed into the network dimensioning and cost analysis aspect of the business model work in WP8.

7.2 Evaluation cases used for assessing benefits and commercial exploitation

As highlighted in the previous section, T2.3 must consider the 5G-TOURS use cases in the context of large-scale commercial networks rather than the limited context of the testbeds. This is also the case for WP8 considering the business models applicable to the use cases. For this purpose, we have defined 5 different “evaluation cases”. Each evaluation case is based around a specific geographic setting that some combination of the 5G-TOURS use cases might realistically be delivered within. This gives a practical scenario to quantify the number of users impacted, potential benefits generated, willingness to pay and revenues against. It also allows a network dimensioning exercise to be performed against which costs can be attributed for different deployment approaches.

These are all crucial elements of the business model analysis of WP8 and in understanding the return on investment of different wireless strategies.

The evaluation cases have been developed considering:

- The coverage areas of different use cases, with some being more localised than others.
- The most likely physical setting where the use cases will be used (i.e., a museum, airport, city, or hospital).
- The potential to deliver multiple use cases from a single infrastructure set and maximise the return on investment for the deploying party.

Figure 64 maps the 5G-TOURS use cases to the geographic coverage area and setting that these use cases are most likely to be consumed in. Some use cases have the potential to be delivered and consumed in different settings. For example, AR guides could be supported on a wireless network specific to an individual museum and only accessible to visitors to that venue. However, AR guides could also be delivered on a city-wide network via a wider area wireless network covering part or all the city. This citywide network might also be used to deliver other 5G-TOURS use cases such as remote video production, high quality video distribution, smart ambulance, and remote health services.

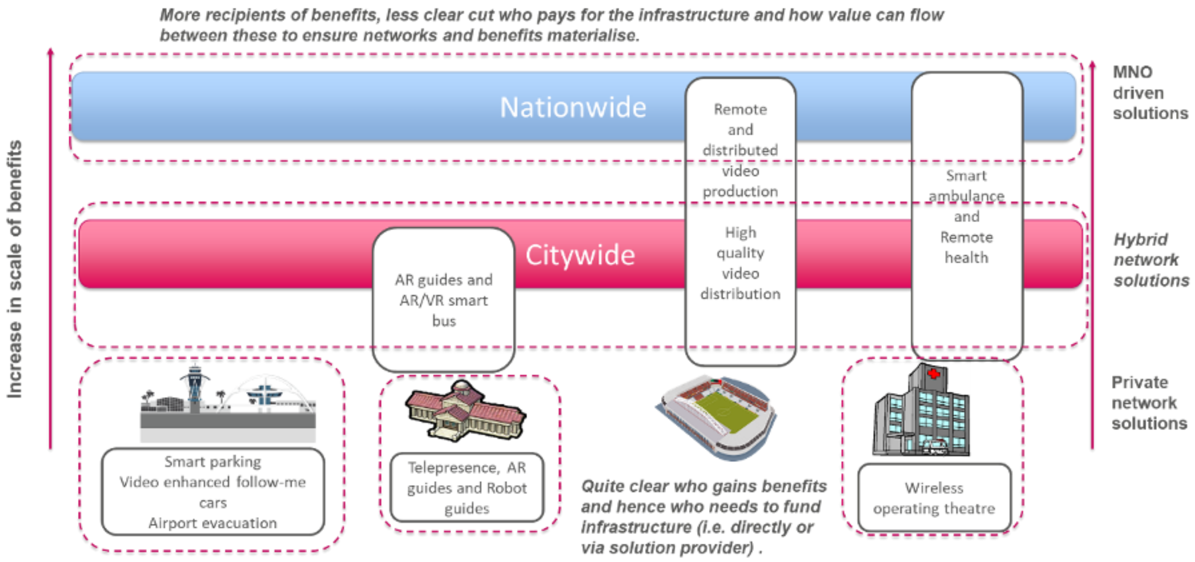


Figure 64. Mapping of 5G-TOURS use cases to physical settings and evaluation cases.

Table 40. Summary of evaluation cases.

	Physical setting	Use cases considered
Evaluation case 1	Athens airport	• Smart airport parking management • Video-enhanced ground-based moving vehicles • Emergency Evacuation
Evaluation case 2	Museums in Turin	• Telepresence • XR immersive museum experience • Robot-assisted museum guide and monitoring
Evaluation case 3	Rennes Hospital	• Wireless operating theatre
Evaluation case 4	City of Turin	• XR immersive city tour experiences • Excursion on an AR/VR-enhanced bus • Remote healthcare • Smart ambulances • Remote video production • High quality video distribution
Evaluation case 5	Italy	• Remote healthcare • Smart ambulances • Remote video production • High quality video distribution

Five evaluation cases are considered in our analysis of benefits and reported on in the remainder of this chapter. These evaluation cases are summarised on Table 40.

7.2.1 Underlying 5G take-up forecasts in the Evaluation cases

We adopt a common approach across the use cases to calculating the economic benefits. We:

- Identify the key sources of value for each use case.
- Estimate the maximum scope for efficiency gains (or the addressable market) related to each source of value. For example, the wireless operating theatre can reduce the rate of surgical complications which in turn reduces mortality and the rate of subsequent readmissions to hospital.
- Estimate the proportion of the potential efficiency gain that the use case can deliver.
- Apply a 5G take-up forecast for each use case which may vary according to the revenue stream.

The 5G take-up forecast for each revenue stream depends on whether the service in question is:

- Business to Business (B2B), e.g.: the purchaser of 5G connectivity is a vertical (hospital, airport, broadcaster) or city;
- or Business to Business to Consumer (B2B2C) where the purchaser of 5G connectivity is the final consumer, e.g.: of an immersive tourism experience.

To aid comprehension of the approach, we set out the family of 5G take-up forecasts we use in Figure 65 below.

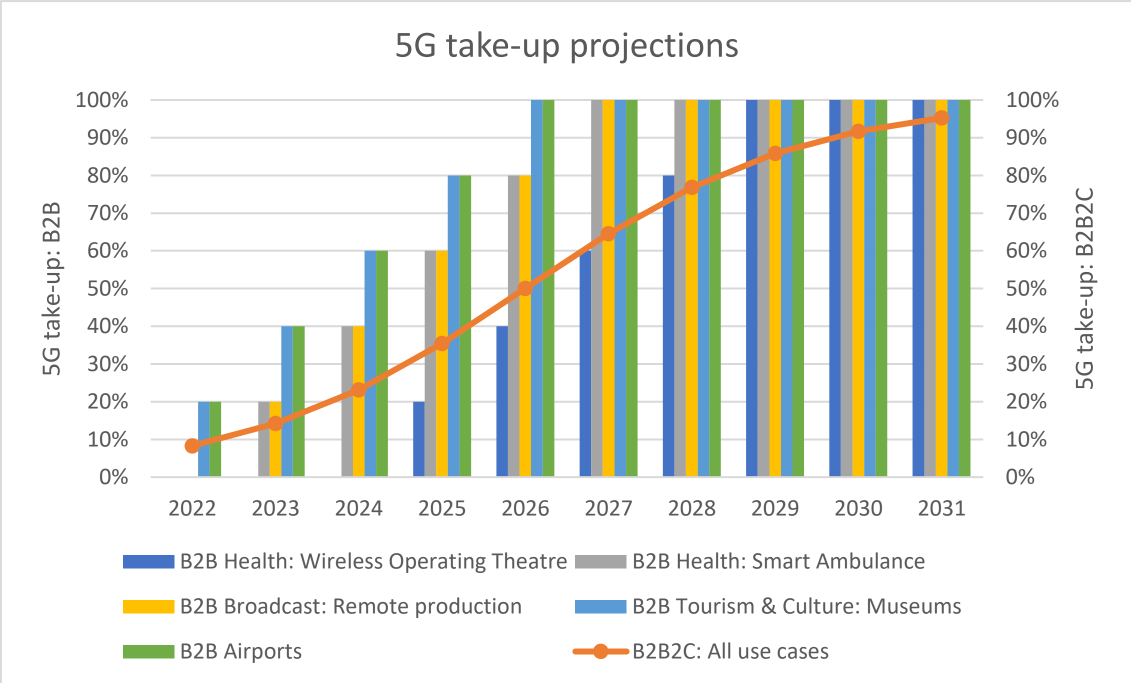


Figure 65. 5G take-up projections: B2B2C and B2B services (campus or citywide).

The B2B take-up curves assume that the business has decided there is a viable business case for 5G and it subsequently takes 5 years to roll out the service (with specified reliability, latency, IoT device support etc. as required) across its relevant sites. The year in which rollout starts varies according to the perceived need for 5G solutions and any logistical issues brought out in our discussions with industry stakeholders. Evaluation case 5 covers national forecasts for two selected use cases (smart ambulance and remote video production). Here, we projected a slower take-up to reflect potential differences across the vertical in the perceived need for 5G.

B2B2C take-up is informed by previous consumer take-up of 3G and 4G, 5G take-up in 2020 and market forecasts of 5G take-up in 2025 [13]. We fit a saturation curve based on this data.

7.3 Evaluation case 1 – benefits in an airport setting

This section summarises the assumptions and results of our economic benefits analysis for use cases taking place in an airport environment which are part of the Mobility Efficient City Platform. The excursion on an AR/VR-enhanced bus is also part of the Mobility Efficient City platform, but for the economic analysis, we placed it in Evaluation case 4, which looks at applications in a city setting, due to its links to the tourism use cases also covered in Evaluation case 4.

The key sources of value are a mixture of offering additional convenience to passengers, airport efficiency and safety. Given the airport operators' already tight focus on safety and operational efficiency, many of the benefits we identified are incremental rather than transformational. However, even relatively small percentage increases in financial benefits may be welcome for airport operators if they outweigh the costs. The use cases and the sources of value that we estimate are as follows:

- Smart airport parking management.
    - Additional spending in the terminal building.
    - Premium charge for more convenient parking.
- Video-enhanced ground-based moving vehicles.
    - Reduction in average flight delays reduces the impact of delays on airport revenues.
    - Reduction in the costs associated with accidents on the airport apron.
- Emergency Evacuation.
    - Faster re-opening of airport, reduces the cost of airport downtime.

We also recognise that the 5G applications make the airport more attractive for passengers and airlines, hence we estimate the potential impact on AIA's market share as an alternative, higher level approach.

There are further potential sources of value that may influence airport operators' decisions on the use of these services. In particular, international roaming fees from consumers using 5G in the airport terminal are a potentially important and lucrative source of revenue for mobile operators. This represents an opportunity for airport operators to gain income through revenue shares or rental fees for Mobile Network Operator (MNO) cell sites in the airport.

We also consider the wider socio-economic benefits to society associated with these use cases:

- Time savings for airport users from smart parking[1].
- Reduction of costs to airlines due to a reduction in flight delays.

The evacuation use case also generates social benefits through improving safety hence reducing the risk of loss of life and injury. Currently, we do not have sufficient information to estimate this, but we note the additional upside it should bring.

7.3.1 Key assumptions and methodology

We classify the "Smart Parking" and "Video-enhanced ground-based vehicles" use cases as B2B. The airport would use 5G to support the IoT sensors that enable smart parking, whereas passengers do not necessarily need 5G to use the service. We classify emergency evacuation as B2B2C because a significant part of the service relies on ultra-reliable communications to passengers through their handsets.

There is little data available from existing trials on the possible impact of these use cases. Hence, we formed our own hypotheses of the relevant business issues – these cover revenue objectives such as increasing passenger spend in the airport terminal or efficiency objectives such as improving safety and reducing airside accidents.

We estimate the total potential revenues and cost savings using industry data on the business issues. Given the data limitations, we take a conservative approach and attribute a moderate impact of 5G to each source of value. We assume low, central, and high values of 2.5%, 5% and 7.5% respectively, except for the case of additional fees from smart parking. Here the low, central, and high values are 5%, 10% and 15% respectively. Here the central case of 10% is based on a study of the impact of smart parking in Lisbon [15].

For our alternative measure based on boosting the airport's attractiveness, the approach is much simpler. We apply an estimate of the market share impact based on benchmarks from competition analysis that a 5-10%

[1] Gatwick airport reports roughly 40% of passengers arrive by private vehicle and hence use its parking services [14]

change represents a significant market impact[2]. AIA's current share of the Greek aviation market is about 45%, so we consider that an impact of this size (i.e., reducing to 42.75-40.5%) is plausible. This impact is then applied to the airport's revenues.

Table 41 below summarises our assumptions for estimating the maximum potential or addressable market.

Table 41. Assumptions for applications in the airport setting.

Use case	Maximum impact as % of existing visitors			Basis	ARPU (€ / unit)	Basis
	Central	Low	High			
Smart parking						
Extra spending in terminal	5%	2.5%	7.5%	Assumed moderate change	2.66	Av. spending/passenger: AIA annual report [16]
Direct fee: premium	10%	5.0%	15.0%	Time savings from smart parking (Lisbon) [15]	0.56	Parking revenue/passenger: AIA annual report
Video-enhanced ground-based vehicles						
Reduced flight delays	5%	2.5%	7.5%	Assumed moderate change	122	Cost of delay per flight [17], allocated to airport
Reduced cost of apron accidents	5%	2.5%	7.5%	Assumed moderate change	324	Av. cost of airport ramp incidents: Flight Safety Foundation [18]
Emergency Evacuation						
Reduced terminal downtime	5%	2.5%	7.5%	Assumed moderate change	615,781	Impact of 12-hour shutdown on total AIA revenues
Alternative holistic approach						
Maintain market share	10%	5%	15%	Competition analysis benchmark	19.8	Total revenue/passenger, AIA annual report [16]
Social benefits						
Smart parking time saving	10%	5%	15%	Time savings from smart parking (Lisbon)	2.4	Value per passenger of time saved [15]
Airline savings: reduced flight delays	5%	2.5%	7.5%	Assumed moderate change	683	Cost of delay per flight [17] (allocated to airline)
Reduced human cost apron accidents				Assumed moderate change		

7.3.2 Results

Figure 66 below shows our results for the airport use cases. We note that emergency evacuation has the smallest direct benefit to the airport. However, the wider benefit to society from avoiding injuries and fatalities, which does not accrue to the airport, may be significant given the high value society places on human life. Similarly, the social value from reducing injuries and fatalities through the ground-based video-enhanced vehicle could be substantial. In both cases, the information on potential injuries was not available to allow such an estimation.

Our alternative estimate based on boosting the attractiveness of the airport (i.e., increasing the market share of flights and passengers as the airport is seen as offering an improved passenger experience compared to other airports due to investment in advanced wireless for passengers and airlines) has an economic benefit five times greater than the more granular approach of identifying specific, direct benefits. It is difficult to say which approach is more appropriate. Identifying specific direct benefits has the disadvantage that we may not have captured all the individual impact on efficiency and new revenue streams from the use cases. On the other hand, while we consider a market share effect to be very plausible, we found less evidence to substantiate the effect. Hence, these two approaches should be seen as outlining a range for the potential benefits, from a pessimistic lower bound to a more optimistic upper bound.

[2] The hypothetical monopolist or Small but Significant Non-transitory Increase in Prices (SSNIP) test takes 5-10% as the scale of a significant change that can indicate whether a set of services can be defined as the relevant market when assessing possible distortions of competition. If the hypothetical monopolist can sustain a price rise of 5% for a sustained period, then the services concerned do constitute a market.

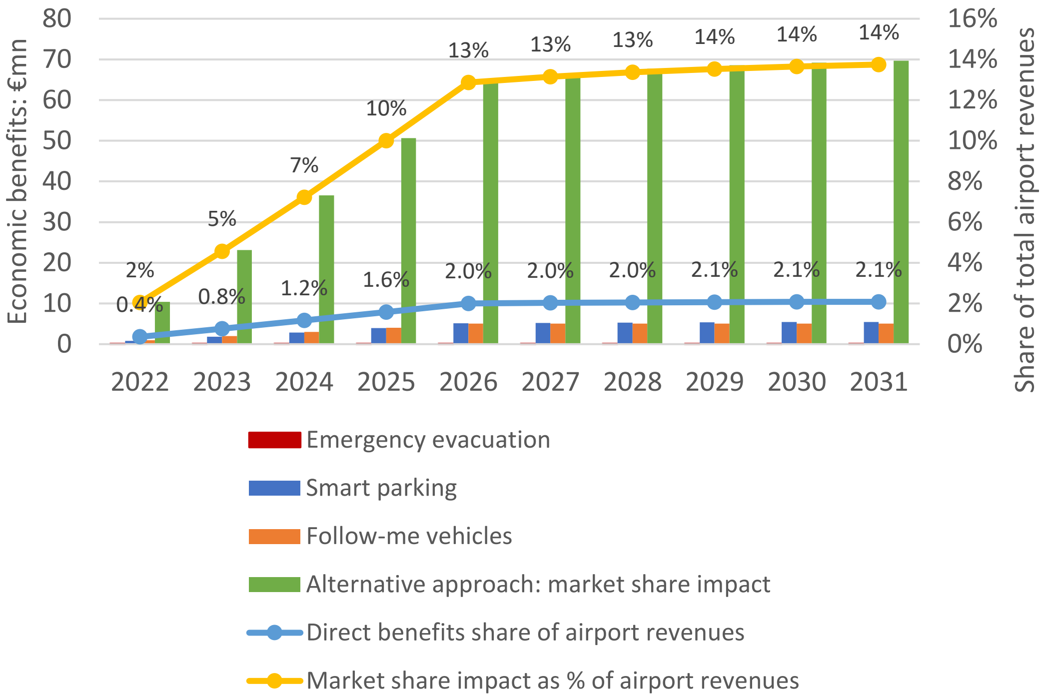


Figure 66. Economic benefits for airport use cases, Athens International Airport.

Finally, Table 42 below presents our estimates of the social benefits associated with the use cases. The social benefits fall at the lower end of the range we estimated for the private benefits, providing a moderate to significant improvement in the overall business case, depending on the level of optimism over the private benefits. Other potential social benefits which we have not been able to estimate, such as improvements to safety of life from smart evacuation, would also add to the total benefits as mentioned above.

Table 42. Social benefits from airport use cases (€ millions).

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Time savings for smart parking users	0.6	1.2	1.9	2.5	2.6	2.6	2.7	2.7	2.8	2.8
Reduced costs of delays for airlines	1.9	3.9	5.8	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Total social benefits	**2.0**	**4.2**	**6.4**	**8.7**	**11.0**	**11.2**	**11.3**	**11.4**	**11.5**	**11.6**

7.4 Evaluation case 2 – benefits in a museum setting

This section summarises the key assumptions and results for the use cases on immersive experiences in a museum setting which form part of the Touristic City platform. The other use cases in the Touristic city platform – augmented tourism and broadcasting – are covered in Evaluation cases 4 and 5 (benefits in the city and national settings). This is because they provide services across wider locations, outdoors and indoors, as opposed to enclosed indoor sites in the case of museums.

We estimate economic benefits for the museums in the commune of Turin taken together rather than for a single museum which gives us a broader perspective than considering just one museum. The use cases we consider, and the corresponding sources of value are as follows:

- Touristic City – Telepresence.
  - Direct charge for immersive remote access to museum collections.
- Touristic City – XR immersive museum experience.
  - Increase in visitors because the immersive experience makes the visit more attractive.
  - Direct charge to the user.
- Touristic City – Robot-assisted museum guide and monitoring.
  - Direct charge for guiding service.
  - Museum security after closing hours.

The museum sector is one of the more promising verticals for XR for two reasons. There is already significant familiarity with immersive experiences across the sector. A growing number of museums [2] have introduced XR experiences for selected exhibitions including, the Louvre [19] and the Rijksmuseum [20]. Furthermore, Covid-19 has accelerated digitalisation, virtual 360° viewer apps and streamed curated tours as museums have sought to reach out to the public while they were closed for health reasons.

Finally, increasing reach and access for underrepresented groups, which is an objective for many museums, is another benefit of these services. We have not been able to measure its scale though it is of value to society.

7.4.1 Key assumptions and methodology

We follow the same general approach as described in section 7.2.1. We assume that the museum purchases the 5G connectivity for the immersive museum experience and robot guide. Hence these have a B2B 5G take-up profile. The telepresence remote museum visit is a B2B2C service, so we use the consumer 5G take-up profile.

Table 43 below summarises our assumptions for the maximum potential efficiency savings or addressable market. For each benefit stream we have a low, central, and high scenario.

Table 43. Assumptions for museum and culture applications.

Use case	Maximum impact as % of existing visitors			Basis
	Central	Low	High	
Telepresence: remote museum visits	10%	5%	15%	Evidence is limited, Design Museum's online tour take-up of 8% [21] informs central scenario
Immersive museum experience (XR): increase in visits	10%	5%	15%	Bath tourism trial [22]: public is more likely to visit (but not quantified). Assume effect is same scale as telepresence
Immersive museum experience (XR): sales to existing visitors	20%	10%	30%	High scenario[3]: computer game users are proxy for max. take-up - 40% [23] but 30% of this relates to the XR app and 10% to robot guide reducing this category to 20%
Robot guide: sales to existing visitors	13%	7%	20%	High scenario: different segment to XR app, e.g., older & disabled visitors: 10% are game-literate (as above) 10% are not
Robot guide: security cost savings	25%	12.5%	37.5%	5G efficiency gains predicted generally for industry (apply to cost savings) [24]

Trials of immersive experiences for museums and heritage sites show that there is demand for such services, but not the extent of that demand. However, there is some pertinent evidence from initiatives museums have taken during the Covid-19 pandemic such as curated online tours. This suggests there is demand for remote museum visits (notwithstanding the context of the pandemic) and informs our estimate of potential demand. For example, the Design Museum saw 8%+ take-up of a recent online curated tour compared to normal expected visitors as noted in the table. This is also used as a proxy for the impact of the XR museum experience on increasing visitor numbers.

The potential for immersive experiences to increase the visitor numbers is underscored by 5G trials. For example, a city of Bath tourism trial [22], found that over 90% of visitors surveyed would be likely to visit the Roman Baths more often because of immersive applications.

For sales to existing visitors of the immersive experiences and robot-guide, we use the proportion of the population that has used a video game (40%) [23] as a proxy for the addressable market for the two sources of value combined, i.e., 30% and 10% of existing visitors respectively. As the robot guide also targets separate categories of visitors to the immersive experience, e.g., older, and disabled visitors by providing extra assistance in navigating the museum, we assume this increases the robot guide addressable market to 20%. We consider these the maximum outcomes, so we apply them to the high scenario and adjust the other scenarios accordingly.

Table 44 below sets out our assumptions for the average revenue per museum visitor.

[3] We set a fixed ratio between the low, central, and high cases of 1:2:3. For this source of value, our evidence on the potential impact of the application relates to the high case, hence the other two cases are adjusted according to this ratio.

Table 44. Revenue assumptions for museum and culture applications.

Use case	Average revenue per visitor (€)	Basis
Telepresence: remote museum visits	8.5	Curated online tour prices: e.g., UK National Gallery [25]
Immersive museum experience (XR): increase in visits	13.0	Average ticket revenue per visitor[4] plus assumed immersive experience price (€7)
Immersive museum experience (XR): sales to existing visitors	7.0	In between audio-guide prices [26] and online tours
Robot guide: sales to existing visitors	7.0	In between audio-guide prices and online tours
Robot guide: security cost savings	0.61	Number of security guards per visitor[5] (assume 50% are night-time) x typical museum security salary [27]+ employer's social security (30%)

7.4.2 Results

Figure 67 sets out the economic benefit results for immersive museum applications and places them in the context of the total ticket revenues for museums in Turin. We estimated total ticket revenues by scaling up ticket revenues (including memberships) for the leading museums (Museo Egizio, Museo del Cinema and Fondazione Torino Musei).

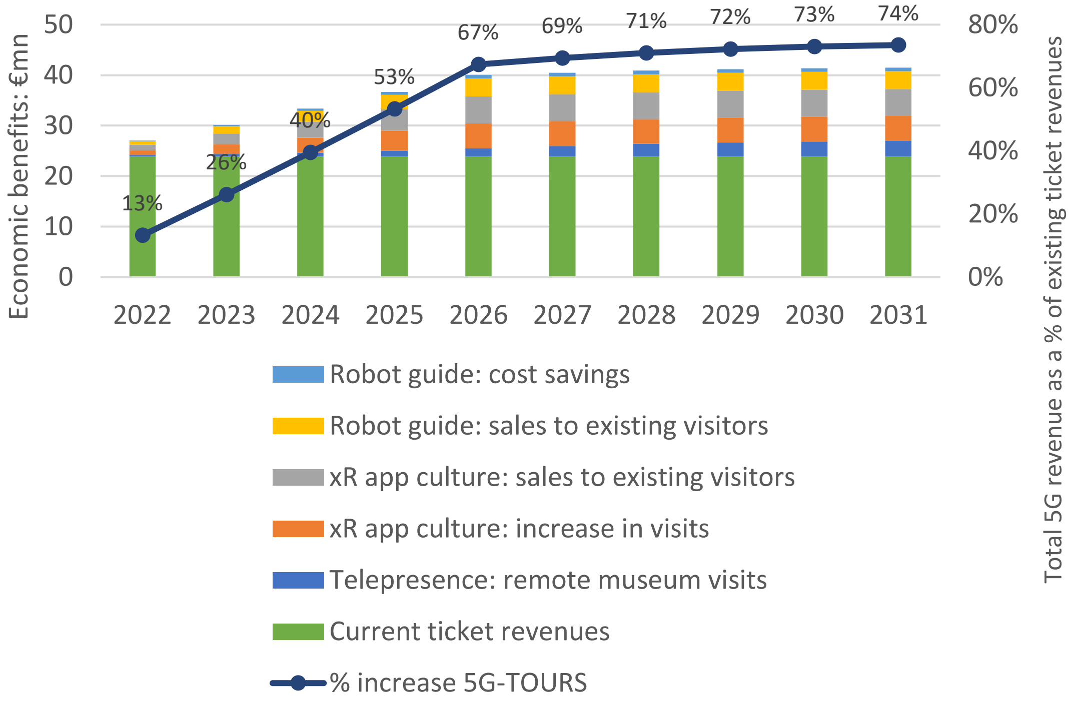


Figure 67. Estimated benefits for museum and culture use cases, Turin.

The graph shows that, in total, the 5G-TOURS augmented museum experiences could have a significant financial impact – 74% higher revenue at the end of the modelling period in 2031 compared to revenues from existing ticket revenues (central scenario). This is considerably more than audio-guides and guided tour revenues which, for example, currently equal 4-5% of ticket revenues for the Fondazione Torino Musei. This relies on our predictions for 5G take-up across museums and consumers being fulfilled and museums being able to reach all the addressable market.

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[4] Average of Museo Egizio, Museo del Cinema and the Fondazione Torino Musei [28]. This is lower than the headline ticket price because of discounts for members, students, etc.

[5] We take the number of security guards from two representative museums: Metropolitan Museum, New York (474) and the British Museum (300) [29] to estimate the number of guards per visitor

Sales of the XR immersive experience to existing visitors and its impact on visitor numbers (either new or more frequent visitors) are the largest potential revenue streams, followed by the robot guide and remote museum visits. The potential savings in security costs from the robot guide are much smaller in comparison – €700,000 by 2031 – but not negligible.

7.5 Evaluation case 3 – benefits in a hospital setting

This section summarises the approach and results for our assessment of the economic benefits of one specific healthcare use case in a hospital setting, the wireless operating theatre. The results for the other healthcare use cases, remote healthcare and smart ambulance are covered in Evaluation cases 4 and 5 which look at healthcare in a city/national rather than a hospital setting.

The sources of value we assessed are grounded in the quadruple aims of health [30], particularly patient experience/better outcomes, population health, reducing costs and team well-being. Those accruing to the hospital are as follows:

- Cost savings from reduced surgical complications (also promoting team well-being by expert back-up through telepresence)
- Cost savings from a reduction in 30-day emergency readmissions post-surgery
- Greater efficiency through faster operating theatre set-up
- Cost savings and improved training and education through telepresence.

In addition to the sources of private value to the hospital, wider social benefits arise from the potentially considerable impact on patient quality of life from: reduced surgical complications; and a reduction in post-operative readmissions to hospital.

An alternative approach is to investigate sources of value in treating individual medical conditions. Such a level of detailed investigation was not possible within the scope of this project, but it could be a viable avenue for future research.

The hospital is the purchaser of 5G connectivity in this use case, therefore a B2B take-up profile is applied. We note the challenges of deploying such solutions given the conservative approach to introducing new technology that the need for safety in the health sector engenders, the need for staff training, data management issues and coordination with other providers.

7.5.1 Key assumptions and methodology

Table 45. Assumptions for wireless operating theatre applications.

Use case	Maximum efficiency gain	Basis of maximum efficiency gain assumption	5G contribution to efficiency gain			Relevant costs affected
			Central	Low	High	
Efficiency: fewer surgical complications	4%	Incidence of complications (17%) x % of complications not needing further intervention (25%) [31] [32]	25%	12.5%	37.5%	Emergency and non-elective inpatient care
Efficiency: lower 30-day emergency readmissions	14%	Rate of readmissions to emergency care NHS England [33]	25%	12.5%	37.5%	Emergency care excl. ambulance costs
Faster theatre set-up	n/a	Little evidence so we assume a small change in relevant costs	5%	2.5%	7.5%	Cost of surgery
Education and training with teleguidance	n/a	Little evidence so we assume a small change in relevant costs	5%	2.5%	7.5%	Education and training
Social benefits						
Better outcomes: lower post-operative mortality	0.6%	Post-operative death rate 3.2% [34] x (rate of readmissions + complications 19%)	25%	12.5%	37.5%	# of CHU operations x Value of human life (€1.4mn) [15]

The methodology for the healthcare use cases discussed here in Evaluation case 3 (and in cases 4 and 5), is slightly different to that for the other use cases. We estimate the maximum potential efficiency gain for each source of value. This is largely based on clinical issues/healthcare activities where the 5G applications can bring improvements such as lowering the rate of re-admissions to hospitals after operations due to better patient outcomes, which reduces emergency care costs. In Evaluation case 4, some data from trials for remote health use cases are also available.

We then apply three scenarios for the extent to which the 5G application contributes to maximum potential efficiency gain. The limited direct data that we found on trial usage of AR in industry [31] show productivity increases of 25%-30% (at Boeing and General Electric). We also took account of McKinsey studies attributing productivity impacts of 15-35% for IoT across a wide range of industries [24]. However, we note that the impact of immersive wireless technologies might be significantly greater than that of IoT. For the faster operating theatre set-up, and education and training cost savings, we assume for the maximum efficiency gain (5%) because there is less relevant direct evidence. Our assumptions are set out in Table 45 above.

7.5.2 Results

Figure 68 sets out our results for the wireless operating theatre. It shows both the private benefit to the hospital and the wider social benefits from better patient outcomes, both in absolute terms and as a percentage of the CHU Rennes budget. Although in percentage terms the benefit is relatively low, it compares favourably with current spending on IT in UK healthcare which is currently 2% [35]. The social benefit (which is itself an underestimate as it relates only to strokes) is considerably larger. We decided to focus on stroke outcomes because they are one of the most significant medical conditions – in terms of impact on the population and healthcare – where the wireless operating theatre could make a significant difference to patient outcomes. Moreover, obtaining data on the potential impact of the wireless operating theatre on patient welfare for other medical conditions, proved difficult. We note that this could be an important future step for research in conjunction with hospital providers.

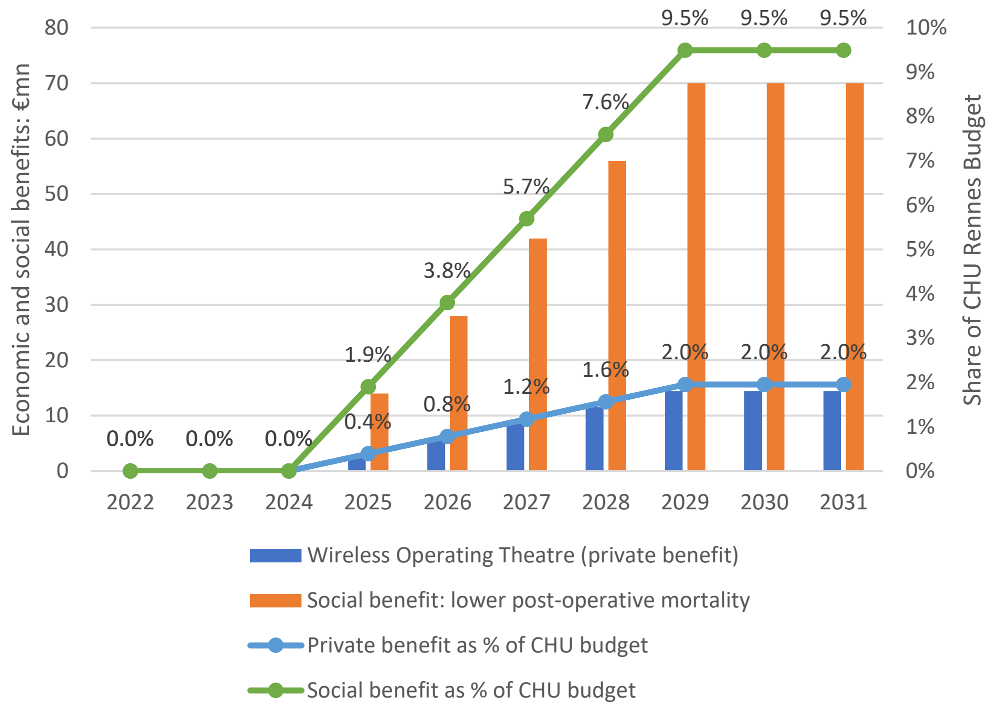

Figure 68. Socio-economic benefits for wireless operating theatre, CHU Rennes.

The results indicate that the wireless operating theatre could generate significant social value in addition to the private value to hospitals; this would accrue to government (acting on behalf of the public and the wider health system). However, societal benefits from better patient outcomes etc. are not monetizable. Moreover, the private benefits to the hospital may not be fully monetizable – for example the balance between the greater number of patients that may be treated (which increases revenue) and reduction in hours of treatment per patient (reduces billed revenue) is not clear.

As a result, it is possible that the wireless operating theatre may not be financially viable from the hospital's perspective and society could forego these substantial additional benefits even though total public and private value might easily exceed the costs. The risk is all the higher because the social benefits are large in comparison to the private benefits to the hospital. And we note that the cost includes not only the 5G service/network, but also significant work needed to update hospital equipment and facilities to support the wireless operating theatre.

To summarise, unless governments allocate and distribute specific funding to hospitals, wireless operating theatres might not be deployed despite net benefits to the economy and society.

7.6 Evaluation cases 4 and 5 – benefits across a city and nationally for tourism, health, and broadcast industries

This section summarises the economic benefit assumptions and results for the 5G-TOURS tourism, broadcasting, and healthcare use cases requiring wide area coverage across a city (as opposed to more local coverage in evaluation cases 1 to 3). In the related network cost analysis in WP8, we shall assume that these services are delivered across a common city area, though they can be provided by different organisations. These services are all covered in Evaluation case 4, focusing on city scale benefits, whereas Evaluation case 5, indicating benefits at a national level, only covers the broadcasting and healthcare use cases. Between these two evaluation cases we scale up the city level benefits to a national level based on population and households.

Table 46 below gives an overview of the use cases and the sources of value we investigate for Evaluation Cases 4 and 5.

Table 46. Overview of Evaluation Cases 4 and 5.

Use Case	Testbed Platform	Services modelled	Private benefits	Wider socio-economic benefits
Remote, distributed broadcast/video production	Touristic City	Wireless camera and video transmission enabling remote direction and editing	Cost savings (net of additional costs) in equipment, transport, and personnel	N/A
Broadcast/video content distribution	Touristic City	Wireless distribution of video content to consumers, complementary to existing broadcast services	Advertising; subscription services; and licence fee payments	Public Service Broadcasting (PSB) value associated with the video content
Augmented tourism	Touristic City	Self-guided walking city tour or equivalent, AR/VR enabled	Direct payment for immersive XR applications, Advertising on immersive XR applications	Local economy benefits as it enhances the city as an attractive tourism destination
Excursion on an AR/VR-enhanced bus	Mobility Efficient City	Enhanced coach/bus tours within the city or touristic area	Direct payment included in overall excursion fee. Advertising mixed in with content	Local economy benefits as it enhances the city as an attractive tourism destination
Remote healthcare	Safe City	Remote monitoring, surveillance, and diagnostics to help citizens manage chronic conditions[6]: in the home and across the city	Better patient outcomes: reduced General Practitioner (GP) appointments Better patient outcomes: reduced outpatient appointments Fewer missed appointments Cost savings: delaying the average time of entering residential care Greater efficiency and cost savings in domiciliary (home-based) care	Value of shorter travel time to appointments for chronic illness patients
Smart ambulance	Safe City	Teleguidance for better patient assessment and initial treatment on arrival or in transit. Smart routeing for faster ambulance journeys	Better patient outcomes: reduction in subsequent re-admission for emergency patients Cost savings/greater efficiency: reduced patient transfer times to hospital	Better outcomes: reduction in mortality from better and faster treatment Savings in CO^2 from reduced patient to hospital transport times.

We note that Evaluation Case 4 focuses solely on the commune of Turin, except for the two healthcare use cases where results are presented for both the commune of Turin and Haute-Bretagne in France, the catchment area for CHU Rennes. CHU Rennes is one of the testbed partners in 5G-TOURS for the wireless operating theatre, hence it seemed sensible to provide results for the other healthcare use cases to give additional context. We scale the results based on population to go from Haute-Bretagne to Turin.

[6] We focus on chronic illnesses such as diabetes, cardiovascular disease, and age-related problems, because this is where remote health services are likely to have the greatest impact (improving people's ability to live independently). In addition, these are the areas on which remote health trials have focused.

7.6.1 Key assumptions and methodology

We follow the same general approach as set out in section 7.2.1. i.e., estimate the maximum potential cost savings or addressable market, estimate the proportion of this maximum that the 5G application can deliver, and apply a relevant 5G take-up forecast.

7.6.1.1 Touristic City – Broadcast/video content distribution and production

We modelled video content distribution as a complement to terrestrial broadcasting and not a substitute. We expect one of the key drivers to be watching live video content on the move as opposed to the on-demand streaming video available today. Sport, concerts, theatre, and news are key drivers. A sporting event, for example, could offer a package of pre-prepared competitor information, multiple camera angles, live match analysis, and stadium information.

Broadcasters are already beginning to use remote production, particularly in the light of Covid-19, For example, BT Sport sees significant potential [36]. The "Live + Wild" project led by Candour Productions, a trial of 5G enabled remote production focusing on documentary making in "extreme" locations, under the aegis of the UK's 5G CREATE programme, also illustrates broadcasting interest in remote production [37].

Table 47. Assumptions for remote production and video content distribution applications.

Use case	Maximum impact as % of existing visitors			Basis	ARPU (€/ household)		Basis
	Central	Low	High				
Remote production	15%	7.5%	22.5%	ADL study on net cost savings from remote broadcasting [38]	n/a		n/a
Content distribution: subscription	10%	5%	15%	Maintaining reach: based on benchmark from competition analysis	69		Subscription revenues per household, UK [39]
Content distribution: advertising	10%	5%	15%	As above	128		Advertising revenues Italy [40]
Content distribution: licence fee	10%	5%	15%	As above	90		Current licence fee in Italy [41]
Social benefit: PSB	10%	5%	15%	As above	216		Econometric study on the value of PSB from UK [42]

Our assumptions for remote production and content distribution in broadcasting are presented in Table 47 along with the socio-economic benefits from expanding public service broadcasting through video content distribution. We note that the three content distribution value streams represent different market segments. All TV households should pay the licence fee in Italy. Subscription service users are a subset of TV households and pay directly for the channels included in their bundle. Advertising revenues are generated from channels where advertising is possible and are paid by companies and organisations.

The maximum impact for remote production is based on an Arthur D Little study [38] which found a 10-20% net cost saving from remote production (equipment, transport, and personnel costs). This is applied directly to our estimate of broadcast production costs in Italy.

Our assessment of the maximum impact for video content distribution is based on the view that it will help to reverse the decline in terrestrial broadcasting's reach (this fell 7.6% from 95% in 2012 to 87.4% in 2019) [43]. This assumption is also supported by economic analysis, where a 5-10% change is an indicator of a potential competitive advantage as mentioned above in Evaluation case 1.

We estimate the average revenue per household for content distribution based on the total revenues from the three market segments relating to subscriptions, advertising, and the licence fee in Italy.

7.6.1.2 Touristic City – Augmented tourism applications

By augmented tourism, we envisage services provided by providers of tourism services, using XR (most likely AR) technology to provide an enriched experience to the visitor. AR tourism apps have been available for a while on 4G, as we noted in 5G TOURS Deliverable D2.2 [2], initially adapted from existing tours and more latterly formats mixing gaming and interactive elements are beginning to emerge. 5G offers the potential to deliver a richer, more immersive experience which could bring a step change for end-users.

Table 48 summarises our key assumptions for the augmented tourism benefit streams. It includes the private and the wider socio-economic benefit from the applications. We note that the two private benefit streams for augmented tourism are mutually exclusive alternatives and should not be added. Furthermore, the assumptions on the addressable market for augmented tourism (using video-game take-up as a proxy) are consistent with the immersive museum application assumptions in Evaluation case 2.

Table 48. Assumptions for augmented tourism applications.

Use case	Maximum impact as % of existing visitors			Basis	ARPU (€ /user)	Basis
	Central	Low	High			
Direct payment: augmented tourism	27%	13%	40%	High scenario based on % of population using videogames	22.5	Assume 20% (based on Airbnb platform fee [44]) of prices for a sample of Italian city tours
Advertising funded: augmented tourism	27%	13%	40%	High scenario based on % of population using videogames	0.14	Social media CPMs[7] assuming 10 adverts/hour for a 2-hour tour [45]
Social benefit – impact on wider local economy	10%	5%	15%	Use benchmark from competition analysis (5-10%) as proxy for the significant reduction in market share avoided *	471	Average spending per international tourist in Italy [46]

* Actual evidence on the impact of XR on tourism is limited, however the VR experience at Amsterdam's Central Station lends support to the existence of such effects: Amsterdam Marketing reported an increase in tourists arriving by train of between 15% and 20% at three of the six sites involved [47].

7.6.1.3 Mobility Efficient City – Excursion on an AR/VR-enhanced bus

We modelled this service as a B2B2C offering, accessed over the passenger's own handset (though the bus could provide its own terminals) with the content provided by either a bus operator, tour company or educational provider. We believe that this use case has much in common with the augmented tourism use case discussed in section 7.6.1.2 above, in terms of the end-user value. Although the experience takes place on a bus rather than at a tourist site or walking around a city, a similar mix of storytelling, information and multimedia content can be provided to the visitor.

Table 49. Assumptions for AR/VR bus application

Use case	Maximum impact as % of existing visitors			Basis	ARPU (€/visitor)	Basis
	Central	Low	High			
Alternative 1: Direct revenue	27%	13%	40%	High scenario based on % using videogames	17	2 x price of curated online tour: e.g., National Gallery [25]
Alternative 2: Advertising revenue	27%	13%	40%	As above	0.14	Cost per thousand impressions for Facebook/Google [45]
Wider benefit to local economy	10%	5%	15%	Market share impact, competition analysis benchmark	143	Av. coach passenger spend per night (ANAV) [48] minus transport costs

Table 49 summarises the assumptions for this use case. Similarly, to augmented tourism walking tour, we identify the addressable market based on the proportion of the population having used videogames. The potential direct charge per visitor is based on charges for curated online museum tours multiplied by two because we expect the duration over the course of a day trip to be longer than the online tour. Advertising revenue is based on industry cost per thousand impressions (CPMs) for social media and 10 adverts per hour.

We apply these assumptions to the number of passengers arriving by coach in Turin. This is based on data for coach passengers arriving in Florence from ANAV (Italian National Association of Bus Passenger Transport) adjusted by the relative number of tourists overall in Turin and Florence [48].

[7] Cost per thousand impressions (or views)

The use case may also have a potential wider impact on the local economy, i.e., spending in shops, hotels, and businesses other than tourist venues. As before we take the benchmark from competition analysis as the basis for the potential increase in the city's "market share" of tourism as a result of the increased attractiveness due to AR/VR bus services.

7.6.1.4 Safe City – Remote healthcare and smart ambulance

The methodology for the two healthcare use cases is slightly different to that for the other Evaluation Case 4 use cases and more like the wireless operating theatre in Evaluation case 3. As described in more detail in Evaluation case 3, we estimate the maximum potential efficiency gain for each benefit stream and the potential of 5G to secure these efficiency gains. As before, the sources of value are also grounded in the quadruple aims of health.

Table 50. Assumptions for remote healthcare and smart ambulance applications.

Use case	Maximum efficiency gain	Basis of maximum efficiency gain assumption	5G contribution to efficiency gain			Relevant costs affected
			Central	Low	High	
Remote healthcare						
Reduced GP appointments	17%	Liverpool 5G healthcare trial (remote sensor app) [50]	25%	12.5%	37.5%	Primary care (x % for chronic illness)
Reduced outpatient admissions	40%	Liverpool 5G healthcare trial (remote sensor app) [50]	25%	12.5%	37.5%	Out-patients (x % for chronic illness)
Fewer missed appointments	7.5%	Survey on missed appointments in France [51]	25%	12.5%	37.5%	Primary care & outpatients (x % for chronic illness)
Later entry & lower costs in residential care	25%	Tunstall Home elderly care trials, UK and Spain [52] [53]	25%	12.5%	37.5%	Residential care home costs
Reduced domiciliary care costs	19%	Liverpool 5G remote medication assistance [50] & remote monitoring trial, Kent [54]	25%	12.5%	37.5%	Domiciliary care costs
Smart Ambulance						
Better outcome, reduced readmissions	14%	Rate of 30-day readmissions to emergency [33]	25%	12.5%	37.5%	Ambulance related emergency costs
Efficiency-saving: faster patient transfer	12%	Reduced travel time for Intelligent Transport Systems [55]	25%	12.5%	37.5%	Ambulance costs excl. call handling
Social Benefits						
Faster ambulance transfer: lower mortality	8%	Ambulance transfer time & mortality study [56]	25%	12.5%	37.5%	Value of human life saved
Better ambulance care: reduction in disability post stroke *	48%	90-day disability rate (slight to moderate) post stroke [57]	25%	12.5%	37.5%	QALYs[8] lost per stroke [56] x value of QALY France [49]

* Similar to benefits of Mobile Stroke Units in Berlin and US

We see considerable support in principle for these type of applications as evidenced by a significant number of 5G trials in these areas and because Covid-19 has accelerated the use and patient acceptance of existing applications (particularly remote health) using wired and 4G connections. Moreover, for smart ambulances, 5G Heart [49] has reported that 5G delivers a step change compared to 4G in the quality of medical images and video that can be shared from an ambulance to remotely sited colleagues. This could facilitate significant benefits for patient treatment and staff empowerment. The full list of assumptions is set out in Table 50.

7.6.2 Results for Evaluation case 4

7.6.2.1 Touristic City – Broadcast/video content distribution and remote production

Figure 69 below presents our results for the broadcasting use cases which suggest that the direct benefits are significant. By 2031, the direct benefits could be equivalent to c. 10% of broadcasting revenues (scaled to the

[8] Quality Adjusted Life Years (QALYs) are a measure of the impact of a medical procedure on the number and quality of additional years for the patient. QALYs can aim to give a standardised measure of health impact across different interventions.

population of Turin). Remote production will also bring forward new creative opportunities, enriching the services offered to viewers over traditional broadcast and 5G networks. This is difficult to quantify but the value of future innovations could be significant. Furthermore, there may be synergies in using 5G to support remote production and video content distribution at venues such as sports stadia where wireless cameras add considerable value and spectators may value access to video content – replays, different camera angles – in addition to the events unfolding on the field of play.

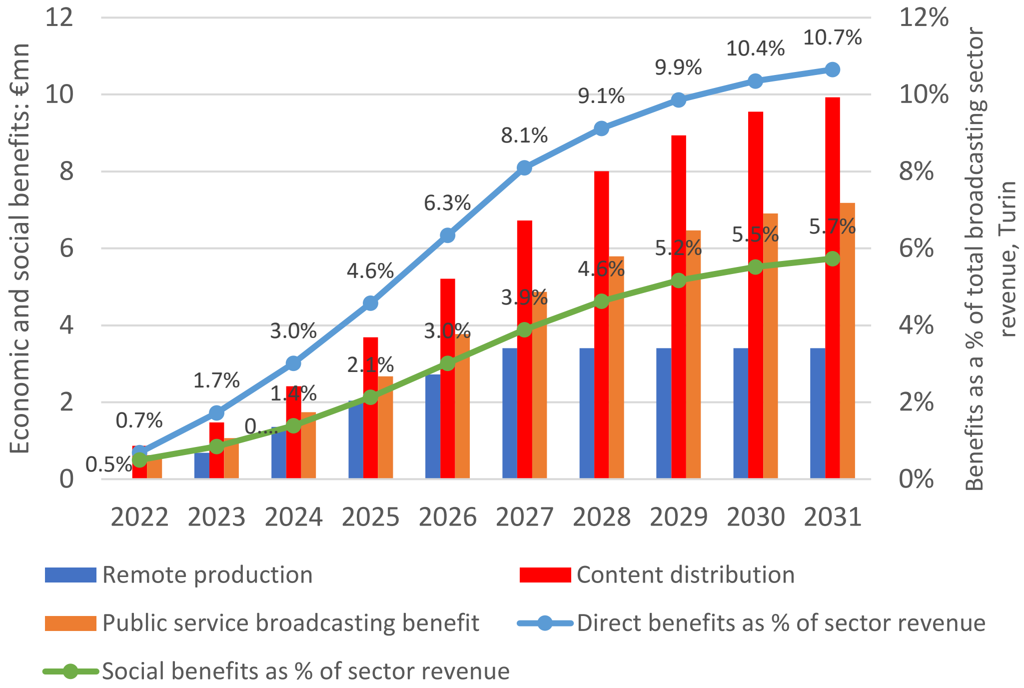

Figure 69. Economic benefits for broadcasting applications, Turin.

The social benefits associated with video content distribution provide an important additional benefit, though unlike many other use cases, they are smaller than the direct benefits we estimated. Hence, there is a much stronger case in broadcasting that the private sector can deliver the necessary investment unaided (than in tourism for example) since the private benefits outweigh the public benefits. Furthermore, media and entertainment services are a natural target for wireless service providers due to the digital nature of the product and the proximity of the consumer market to telecoms services.

7.6.2.2 Touristic City – Augmented tourism walking tour

Figure 70 below presents our results for augmented tourism to support walking tours of the city of Turin. The direct benefits to tourism operators are significant, though the potential wider impact on the local economy is several times greater.

We note that, in direct revenue terms, advertising funded services bring in little revenue and directly charging the end-user appears to be a better route to market for tourism businesses. However, from the city's perspective, it should receive the spin-off impact on local tourism regardless of whether tourism operators take the advertising or direct charging approach.

Given the potential size of the spin-off benefits to the wider city, there may be a debate to be had as to how to fund schemes that might accelerate the roll out of wireless infrastructure to support such tourism related applications. Tour operators alone are likely to be too small individually to provide the investment needed to stimulate infrastructure roll out for these more immersive applications.

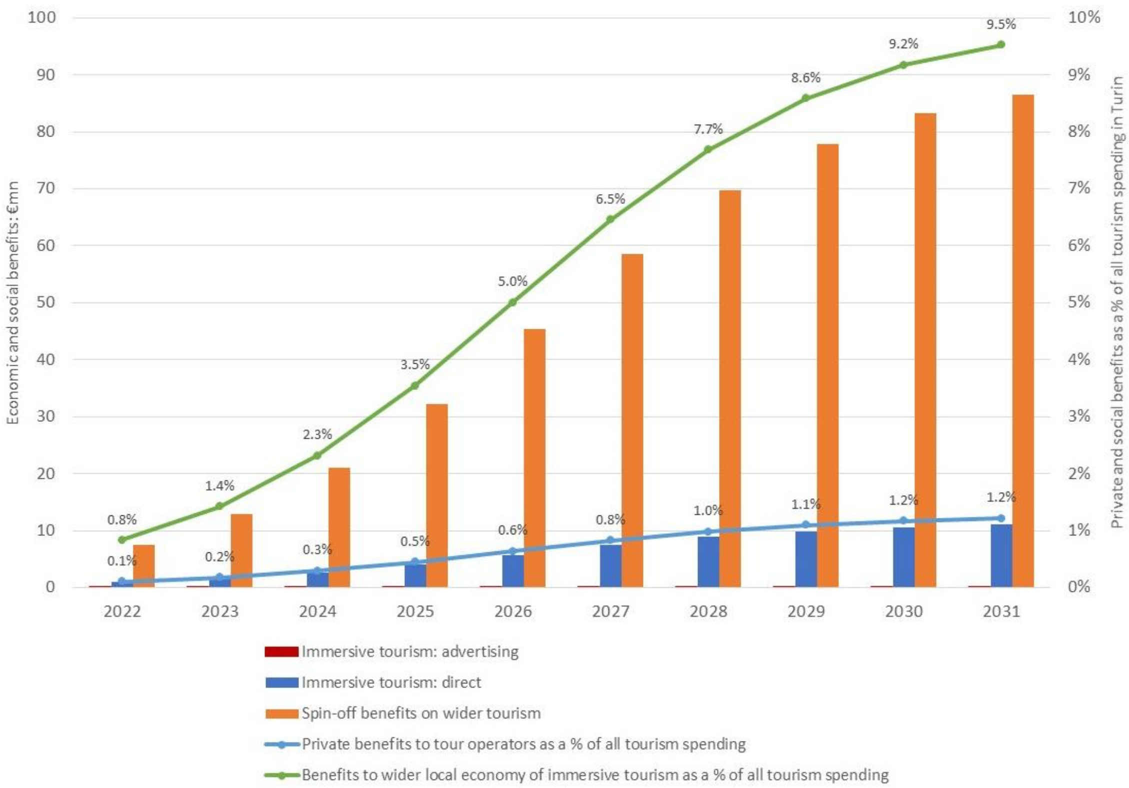

Figure 70. Economic benefits for augmented tourism, Turin.

7.6.2.3 Mobility Efficient City – Excursion on an AR/VR-enhanced bus

Figure 71 below presents the results of our benefit assessment for the AR/VR-enhanced bus use case. Direct charging appears to be a much more considerable source of benefit than an advertising funded service, similar to the augmented tourism city walking tour use case. However, the advertising funded service could still generate significant wider economic benefits to the city if the AR/VR service became important in maintaining Turin's attractiveness as a tourist destination.

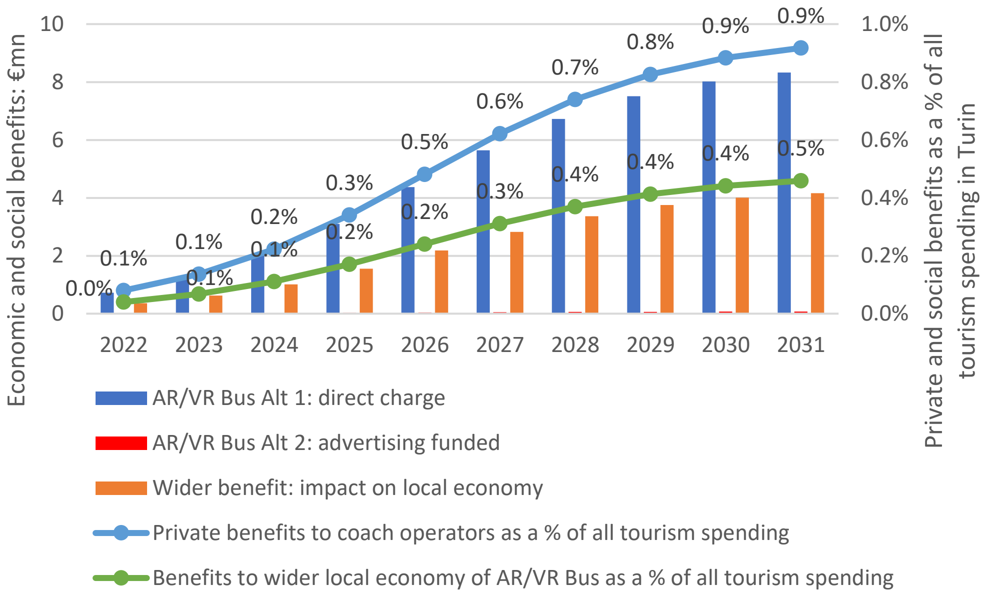

Figure 71. Economic benefits for AR/VR bus applications, Turin.

The potential private benefits to coach tour operators are readily monetizable and double the wider economic benefits to local businesses in Turin. Hence, we would expect coach tour operators to take the lead in paying for services once the network capabilities were in place. However, given the large number of coach tour operators that may serve Turin, a question mark remains over how the initial network investment would be stimulated since it would be unrealistic for several hundred coach operators to coordinate on this.

On the other hand, the wider benefits to the local economy are still significant. Therefore, the city of Turin could be justified in using public funding to encourage the development of infrastructure to provide the capacity enhanced bus services would need if it made the business case more viable.

7.6.2.4 Safe City – Remote healthcare and smart ambulance

Table 51. Estimated benefits for remote healthcare and smart ambulance (€ mn), Rennes.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Reduced GP appointments	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8
Reduced outpatient admissions	0.5	0.8	1.3	2.1	2.9	3.7	4.5	5.0	5.3	5.5
Fewer missed appointments	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.3	1.3	1.4
Later entry to residential care/ lower costs	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.7	0.8	0.8
Reduced domiciliary care costs	0.2	0.4	0.6	0.9	1.3	1.6	1.9	2.2	2.3	2.4
Remote Healthcare - Total	**1.0**	**1.6**	**2.7**	**4.1**	**5.7**	**7.4**	**8.8**	**9.9**	**10.5**	**10.9**
Reduction in 30-day emergency admissions (ambulance patients)	0.0	0.5	0.9	1.4	1.8	2.3	2.3	2.3	2.3	2.3
Smart routeing: efficiency saving	0.0	0.3	0.5	0.8	1.1	1.3	1.3	1.3	1.3	1.3
Reduction in 90-day disability	0.0	1.0	2.0	3.0	4.0	5.0	5.0	5.0	5.0	5.0
Smart Ambulance – Total	**0.0**	**1.7**	**3.5**	**5.2**	**6.9**	**8.6**	**8.6**	**8.6**	**8.6**	**8.6**
Better patient outcome: Faster ambulance transport time	0	26	53	79	105	131	131	131	131	131
Reduction in 90-day disability (QALYs lost to stroke)	0	16	33	49	65	82	82	82	82	82
Social Benefits – Total	**0**	**43**	**85**	**128**	**170**	**213**	**213**	**213**	**213**	**213**

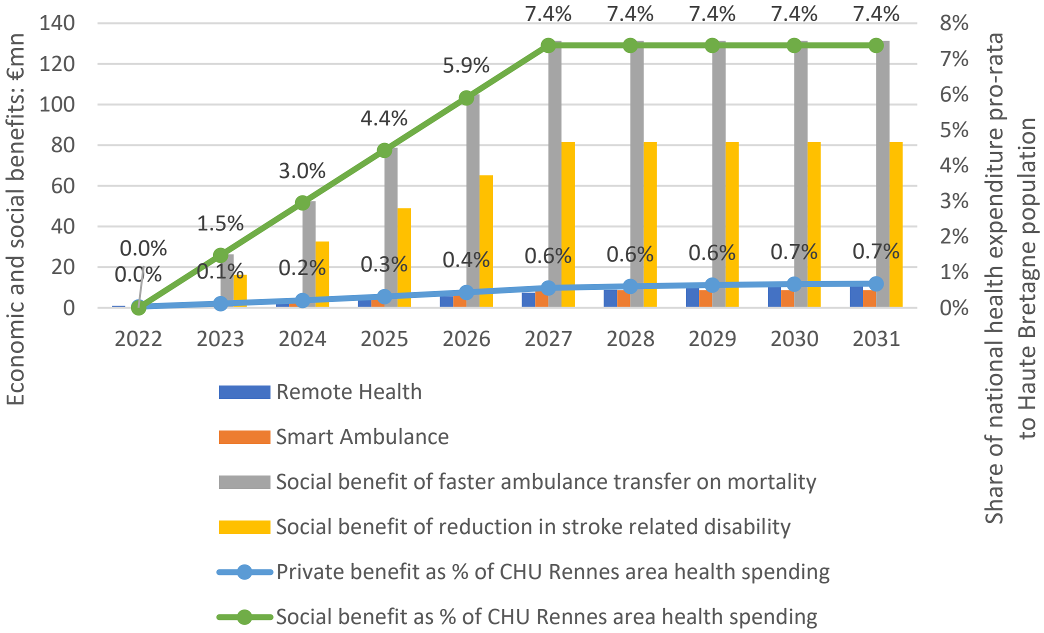

Figure 72. Socio-economic benefits for remote health and smart ambulance, Rennes.

Table 51 and Figure 72 show our results for the remote healthcare and smart ambulance use cases. These results are initially calculated for the Rennes area since CHU Rennes is a consortium partner participating in the healthcare testbed. Hence this provides a consistent healthcare set of results in conjunction with those for the wireless operating theatre. To put them in context, we present the benefits in absolute terms and as a percentage of overall health spending (scaled down from France to Rennes/Haute-Bretagne according to population). Overall health spending includes primary and secondary healthcare services, and ambulances.

However, we have also calculated results for the commune of Turin in Table 52 and Figure 73. This allows for a consistent comparison of the Evaluation case 4 results across one location, i.e., Turin. It will also enable a consistent evaluation of the business case when the economic benefits are combined with our network cost modelling in WP8.

Table 52. Estimated benefits for remote healthcare and smart ambulance (€ mn), Turin.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Reduced GP appointments	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.7
Reduced outpatient admissions	0.4	0.8	1.2	1.9	2.7	3.5	4.1	4.6	4.9	5.1
Fewer missed appointments	0.1	0.2	0.3	0.5	0.7	0.9	1.0	1.2	1.2	1.3
Later entry to residential care/ lower costs	0.2	0.4	0.6	1.0	1.4	1.8	2.1	2.3	2.5	2.6
Reduced domiciliary care costs	0.2	0.3	0.5	0.8	1.2	1.5	1.8	2.0	2.1	2.2
Remote Healthcare - Total	**1.0**	**1.8**	**2.9**	**4.4**	**6.3**	**8.1**	**9.6**	**10.7**	**11.5**	**11.9**
Reduction in 30-day emergency admissions (ambulance patients)	0.0	0.4	0.8	1.3	1.7	2.1	2.1	2.1	2.1	2.1
Smart routeing: efficiency saving	0.0	0.2	0.5	0.7	1.0	1.2	1.2	1.2	1.2	1.2
Reduction in 90-day disability	0.0	0.9	1.9	2.8	3.7	4.6	4.6	4.6	4.6	4.6
Smart Ambulance – Total	**0.0**	**1.6**	**3.2**	**4.8**	**6.4**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**
Better patient outcome: Faster ambulance transport time	0	24	48	73	97	121	121	121	121	121
Reduction in 90-day disability (QALYs lost to stroke)	0	15	30	45	60	75	75	75	75	75
Social Benefits – Total	**0**	**39**	**79**	**118**	**157**	**196**	**196**	**196**	**196**	**196**

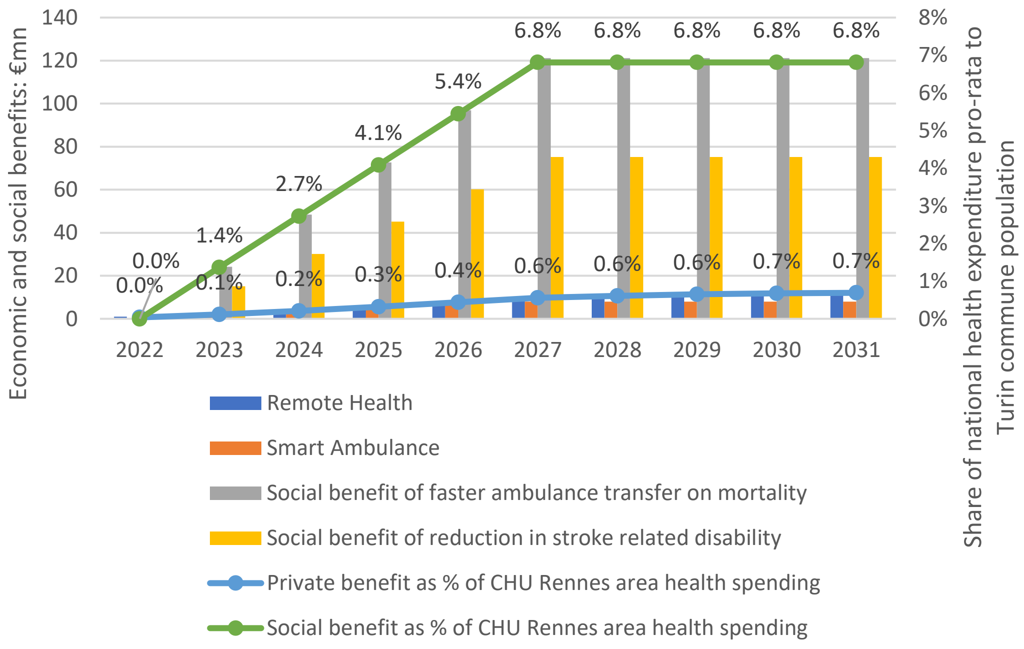

Figure 73. Socio-economic benefits for remote health and smart ambulance, Turin.

As with the wireless operating theatre results in Evaluation case 2, although the direct benefits from greater efficiency in healthcare for the elderly and chronic illness sufferers, and ambulance services are significant in absolute terms they are relatively small compared to the overall health budget. However, the benefits of better patient outcomes, which benefit society and the health system as a whole, are much larger.

7.6.3 Results for Evaluation case 5

Figure 74 and Figure 75 below show the results for remote healthcare, smart ambulance, remote video production and video content distribution at a national level for Italy. We have extrapolated the results from the city-wide analysis in Evaluation case 4 by scaling based on relative population sizes and we have applied a different 5G take-up rate for 5G for the B2B services. In both healthcare and broadcasting, we assume, take-up will be slower across these verticals nationally than for B2B2C consumers. This is because many companies may decide to be "followers" in terms of 5G adopters than pioneers as assumed in Evaluation case 4, replacement cycles for equipment that needs to be 5G enabled will vary across companies and we are not assuming a national coordination across these sectors. As a result, we have assumed that the B2B take-up nationally will follow the same evolution as for B2B2C services but delayed by 2 years.

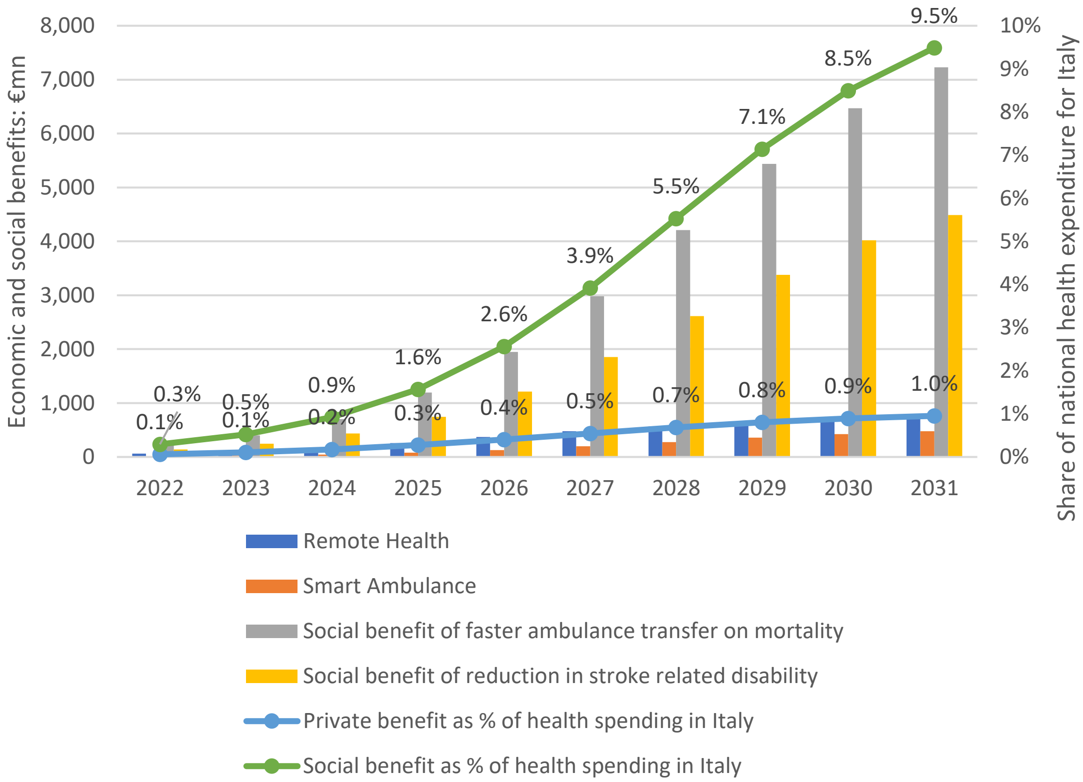

Figure 74. Socio-economic benefits for remote health and smart ambulance, Italy.

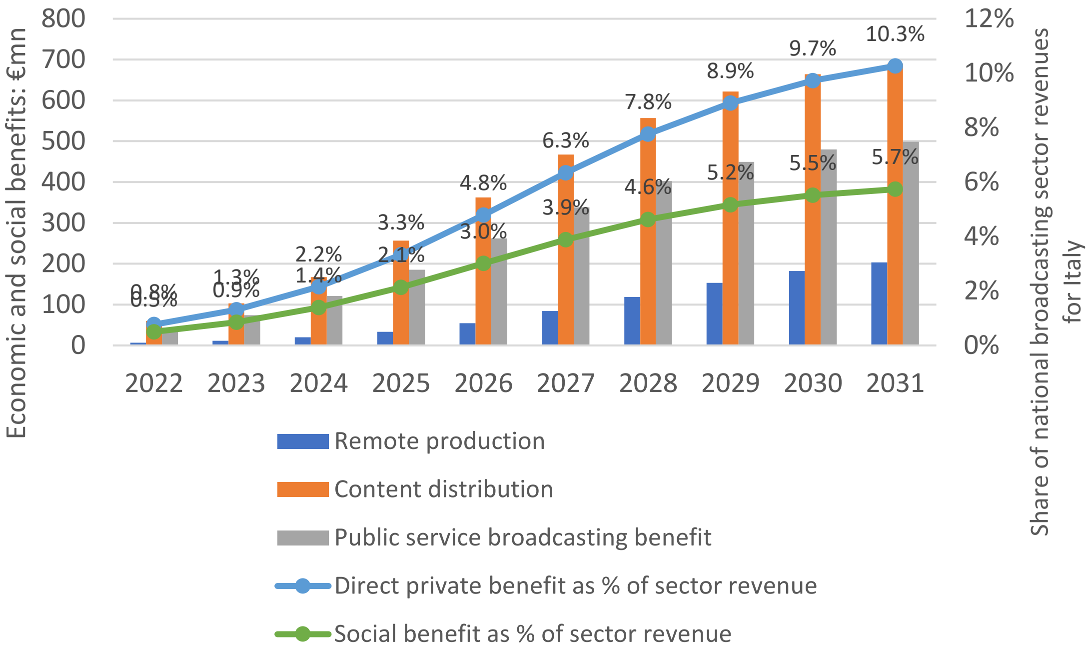

Figure 75. Economic benefits for broadcasting applications, Italy.

7.7 Key findings from benefits analysis across evaluation cases

Looking at results across each of the evaluation cases, we make the following high-level conclusions per evaluation case:

- Evaluation case 1 – Athens airport scenario
  - The private benefits to the airport could grow to 2% of existing revenues by 2030, using our more pessimistic approach to benefits modelling in this scenario.
  - In an industry where revenues are already highly regulated, this level of benefit could well be enough to interest airports in investing in improved connectivity in and around their facilities.
  - Keeping pace with other airports on connectivity and passenger experience might also be a further motivation to avoid loss of market share.
- Evaluation case 2 – Turin museums
  - The direct benefits to museums from offering immersive experiences could be significant.
  - Revenues from immersive experiences, such as the use cases suggested by 5G-TOURS, could add as much as 74% to existing museum revenues from ticket sales.
  - This additional revenue comes partially from existing visitors but also from encouraging a wider demographic to avail of such venues.
- Evaluation case 3 – Rennes hospital
  - Unlike the previous two evaluation cases, the calculated social benefit of the wireless operating theatre is 5 times higher than the direct cost savings that the hospital would likely benefit from.
  - It is uncertain whether direct cost savings to individual hospitals of improved connectivity would be realized by the hospital in practice or would rather result in a reduced budget or increased volume of patients being treated.
  - For this evaluation case, it is less clear that individual hospitals would have the resources and motivation of direct benefits to invest in advanced connectivity that the previous two vertical groups of an airport or museum might have.
  - This suggests that finance for improved connectivity in hospitals may need to be funded more centrally to ensure that the larger social benefits of such use cases are realized.
- Evaluation case 4 – City of Turin
  - This shows that investment in wireless infrastructure in a city will bring significant socio-economic benefits to businesses and citizens in the area.

  - Supporting improved connectivity and more immersive experiences could help a city to differentiate itself from other tourist destinations. Any protection of existing market share or even increase in market share will bring indirect benefits to the city which will greatly outweigh the direct benefits in terms of revenues for charging for such experiences.
  - Cities stand to gain indirect social benefits in the order of 9.5% of existing spend on healthcare by 2031 if they invest in supporting remote health and smart ambulance services in their region.
  - Potentially local authorities investing in wireless infrastructure in their area will be able to benefit from economy of scale effects of reusing the same infrastructure to deliver a range of services such as the more immersive touristic services and connected health services identified above.
- Evaluation case 5 – Italy
  - Much larger social benefits are expected from nationwide connected healthcare services than private benefits. This suggests that centralized public sector investment may be required to stimulate the rollout of infrastructure to support such services at a nationwide level.
  - In contrast, the direct benefits associated with providing broadcast related connectivity services are calculated to be much greater than the social benefits. This suggests that investment in infrastructure supporting services of this nature is more likely to come direct from the broadcast and entertainment industry than from more centralized public funding.

The evaluation cases analyzed show that it is not always obvious where the investment in advanced wireless infrastructure should come from for any given use case or scenario. Instead, an analysis of the direct benefits against the wider socio-economic benefits is required to understand where the strongest motivation and willingness to invest in infrastructure and connectivity solutions is likely to come from. These observations will be built upon in WP8 in the analysis of business model options for the above set of evaluation cases.

8 Conclusions

This document defined a standard framework for the description of the diversity of use cases being addressed by the 5G-TOURS project. For each of the thirteen different use cases being implemented, it provided:

- final description of its functionality, result of the continuous refinement of the use case during the first 30 months of the project lifetime;
- updated sequence diagram(s) enriching such descriptions via the definition of the flow of events and interactions of the key actors with the 5G-TOURS infrastructure;
- final user and network requirements and corresponding analysis;
- GSMA network slice types, a more standardized way for verticals to provide their technical requirements to network operators.

A total of 22 radar charts have been created and included in this deliverable for the analysis of the network requirements. One of the main conclusions that we can make from their analysis is that most of the UCs require a 5G network in order to deliver the prescribed service in a satisfactory way, with the most demanded 5G capabilities being Reliability and Network Slicing. In some cases, the requirements provided even stretch some of the 5G capabilities in terms of Reliability, Capacity and Location Accuracy. An evaluation of these requirements is currently being performed in WP7; the results will be documented in the next deliverable of this WP.

Regarding the network service / slice types, the three core slice categories, URLLC, mMTC, and eMBB, are required according to the analysts' views. The highest demand is for URLLC (9 UCs), followed by eMBB (8 UCs) and mMTC (4 UCs).

The use cases also derived some system requirements that helped the project identify how the 5G-EVE platform, over which the 5G-TOURS use cases are being deployed, had to be improved in order to support the demand of the project´s use cases. AI Enhanced orchestration and Broadcast support are just some examples of the extended functionality being developed as part of WP3 because of those system requirements.

The deployment of the 5G-TOURS UCs over the 5G-EVE infrastructure also required from the consortium to understand this project´s E2E operational model, roles and the use of its blueprints. The dependencies with 5G-EVE, the interactions and the deployment implications were also analysed in this deliverable.

The 5G-EVE E2E facility is composed of different interconnected sites, and this is also reflected in the 5G-TOURS deployments. The 5G-TOURS uses cases, grouped in three themes, are being implemented in three of these sites, each theme in a different trial site: 1) Turin, the touristic city; 2) Rennes, the safe city; and 3) Athens; the mobility-efficient city. This document also described the main functionalities and peculiarities of each of these three sites with respect to the other two and analysed their deployment implications.

Finally, the economic drivers for the commercial deployment of 5G-TOURS use cases are analysed. This deliverable introduced the framework for understanding the economic and commercial potential of the use cases being implemented by the project, as well as evaluation cases used for assessing benefits and commercial exploitation. Then the approach and results for our assessment of the economic benefits of different specific settings were presented, including the key findings from benefits analysis across evaluation cases. The results showed that it is not always evident where the investment in 5G infrastructure should come from and that an analysis of the direct benefits against the wider socio-economic benefits is required to understand where the strongest motivation and willingness to invest could come from. WP8 will extend this analysis via the elaboration of business models for the set of evaluation cases introduced in this deliverable.

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References

[1] 5G-TOURS, 2019. *D2.1 "Use cases, deployment and techno-economic requirements-high level description"*

[2] 5G-TOURS, 2020. *D2.2 Touristic city, safe city, and mobility-efficient city use cases – final version*

[3] 5G-TOURS, 2020. *D7.2 First Integrated 5G-TOURS Ecosystem*

[4] 5GPPP, 2021. 5G PPP phase II KPIs

[5] ETSI ENI ISG PoC Report. PoC#9 Final Report: ENI(21)000010_POC_9_Final_Report.pdf (etsi.org)

[6] 5G-EVE, 2021. D2.3 "Final 5G-EVE end to end facility description"

[7] 5G-EVE, 2018, *D3.1 "Interworking Capability Definition and Gap Analysis Document"*

[8] GSMA, "Generic Network Slice Template", Version 5.0, 01 June 2021

[9] 5G PPP Test, Measurement and KPIs Validation (TMV) Working Group, https://5g-ppp.eu/5g-ppp-work-groups/

[10] 5G-TOURS, 2020. D4.2 "First Touristic City use case results"

[11] 5G-TOURS, 2021. D3.3 "Technologies, architecture and deployment advanced progress"

[12] Stefan Neumeier, Philipp Wintersberger, Anna Katharina Frison, et. al. Conference Paper: "Teleoperation: The Holy Grail to Solve Problems of Automated Driving? Sure, but Latency Matters". At 11th International Conference, September 2019. Available at https://www.researchgate.net/publication/335941077_Teleoperation_The_Holy_Grail_to_Solve_Problems_of_Automated_Driving_Sure_but_Latency_Matters

[13] GSMA, The Mobile Economy, 2020: available at https://www.gsma.com/mobileeconomy/wp-content/uploads/2020/03/GSMA_MobileEconomy2020_Global.pdf

[14] "Gatwick Airport Interim Car Parking Strategy", April 2017. Available at: https://www.gatwickairport.com/globalassets/company/sustainability/reports/2017/gatwick-airport-interim-car-parking-strategy-2017.pdf

[15] UK Department for Transport, TAG Data Book 2020: available at https://www.gov.uk/government/publications/tag-data-book

[16] Athens International Airport, https://www.aia.gr/company-and-business/the-company/facts-and-figures

[17] Website, accessed 2021: https://www.allthingsontimeperformance.com/flight-delays-in-numbers-not-only-painful-for-passengers/

[18] Flight Safety Foundation: available at https://flightsafety.org/asw-article/covering-the-ground/

[19] Musée du Louvre: accessed 2021, https://www.louvre.fr/en/what-s-on/life-at-the-museum/the-mona-lisa-in-virtual-reality-in-your-own-home

[20] Rijksmuseum: accessed 2021, https://www.rijksmuseum.nl/en/whats-on/app

[21] The Art Newspaper: Article accessed 2021, https://www.theartnewspaper.com/feature/can-museums-really-make-digital-visits-pay

[22] BBC Research and Development White Paper, "Mobile Augmented Reality using 5G: A trial at the Roman Baths in the 5G Smart Tourism project", 2019: available at https://www.bbc.co.uk/rd/publications/mobile-augmented-reality-5g-roman-baths-smart-tourism

[23] Ofcom, "Online Nation", 2020: available at https://www.ofcom.org.uk/research-and-data/internet-and-on-demand-research/online-nation

[24] McKinsey and Company, "The Future of Automated Ports", 2018: available at https://www.mckinsey.com/industries/travel-transport-and-logistics/ourinsights/the-future-of-automated-ports

[25] National Gallery: accessed 2021 https://www.nationalgallery.org.uk/about-us/press-and-media/press-releases/new-online-curator-s-tour-of-artemisia-launched

[26] Louvre: accessed 2021 https://www.louvre.fr/l-audioguide-du-musee

[27] Website: accessed 2021, https://www.money.it/Vigilante-museo-cosa-fa-e-quanto-guadagna

[28] Museo Egizio, Fondazione Torino Musei and Museo del Cinema: available at https://api.museoegizio.it/wp-content/uploads/2020/07/Schema-nota-2019.pdf, and https://www.fondazionetorinomusei.it/sites/default/files/allegati/Bilancio%20Previsionale%202020-2021-2022.pdf and https://www.museocinema.it/sites/default/files/downloads/trasparenza/bilancio_consuntivo_2019_1_conto_economico_sintetico.pdf

[29] British Museum and website: accessed 20102, https://www.britishmuseum.org/about-us/jobs/vacancies-visitor-and-security-services-department and https://hyperallergic.com/433312/museum-guards-new-york-salaries-working-conditions/

[30] Sikka, R, Morath, J M, Leape, L, "The Quadruple Aim: care, health, cost and meaning in work", 2015: available at https://qualitysafety.bmj.com/content/24/10/608

[31] Tevis, S and Kennedy G, "Postoperative complications and implications on patient-centered outcomes", Journal of Surgical Research, 2013: available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3637983/

[32] Hobson, York-Mui, Hadjipavlou, Stevens, "An Introduction to Post-Operative Complications", 2014: available at https://www.ucl.ac.uk/anaesthesia/sites/anaesthesia/files/Intro_to_postop_Complications.pdf

[33] NHS England, "Emergency readmissions within 30 days of discharge from hospital", 2021: available at https://digital.nhs.uk/data-and-information/publications/statistical/ccg-outcomes-indicator-set/october-2020/domain-3-helping-people-to-recover-from-episodes-of-ill-health-or-following-injury-ccg/3-2-emergency-readmissions-within-30-days-of-discharge-from-hospital

[34] Pearse, R M et al., "Mortality after surgery in Europe: a 7-day cohort study", Lancet, 2012: available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3493988/

[35] National Audit Office, "Digital Transformation in the NHS", 2019: available at https://www.nao.org.uk/wp-content/uploads/2019/05/Digital-transformation-in-the-NHS.pdf

[36] Article: accessed 2021 https://mobileeurope.co.uk/me-videos/15242-5g-performing-at-the-edge-2020-day-1-case-study-transforming-broadcasting-5g-remote-production

[37] Live + Wild: accessed 2021 at https://www.liveandwild.com

[38] Arthur D Little, "Broadcasters' 5G evolvement within a hybrid environment", 2020: available at https://www.adlittle.com/en/BroadcastIn5G

[39] Ofcom, "Media Nations", 2020: available at https://www.ofcom.org.uk/research-and-data/tv-radio-and-on-demand/media-nations-reports/media-nations-2020

[40] PwC, "Key highlights Entertainment & Media Outlook in Italy 2015 – 2019": available at https://www.pwc.com/it/it/publications/assets/docs/em-outlook-highlights.pdf

[41] Agenzia delle Entrate: accessed 2021 https://www.agenziaentrate.gov.it/portale/Aree+tematiche/Canone+TV/

[42] Holden Pearmain, "Assessing the value of public service programming on ITV1, Channel 4 and Five", 2008: available at https://www.ofcom.org.uk/__data/assets/pdf_file/0020/40457/annex6.pdf

[43] Censis, "16o Rapporto Censis sulla comunicazione", 2020: available at https://www.censis.it/comunicazione/16%C2%B0-rapporto-censis-sulla-comunicazione/le-diete-mediatiche-degli-italiani-nel-2019

[44] Airbnb: accessed 2021, https://www.airbnb.co.uk/help/article/1857/what-are-airbnb-service-fees

[45] Articles: accessed 2021 https://blog.adstage.io/youtube-benchmarks-cpc-cpm-and-ctr-0 and https://ignitevisibility.com/lower-facebook-cpm-maximize-return/

[46] OECD, “Tourism Trends and Policies 2020”: accessed 2020 https://www.oecd-ilibrary.org/sites/3d4192c2-en/index.html?itemId=/content/component/3d4192c2-en

[47] Reported in 5G-MoNArch D6.3 https://5g-monarch.eu/wp-content/uploads/2019/07/5G-MoNArch_761445_D6.3_Verification_and_validation_final_report_v1.0.pdf

[48] ANAV “Primo rapporto sul mercato del noleggio autobus con conducente e il trasporto turistico”, 2018: available at https://www.anav.it/wp-content/uploads/2018/01/rapporto-noleggio-gennaio-2018.pdf

[49] 5G HEART, Telenor, RedZinc, "5G Heart Experiences with wearable video in pilots with Oslo Ambulance Service and AmbulanceZorg Groningen", 2020: available at https://5gheart.org/5g-heart-webinar-series-webinar-1-healthcare-vertical-trials-videos-and-presentation-files/

[50] Liverpool 5G Health and Social Care Testbed available at https://liverpool5g.org.uk/wp-content/uploads/2020/05/Liverpool-5G-Heath-and-Social-Care-Testbed-Benefits-Outcomes-Impact.pdf

[51] Survey by Odoxa for La Mutuelle Nationale des Hospitaliers, 2019: article accessed 2021 https://sante.lefigaro.fr/article/rendez-vous-non-honores-medecins-chassent-lapins-desesperement/

[52] Tunstall, "The transformational potential of telecare", 2020: available at https://www.tunstall.co.uk/siteassets/uk/white-papers/telecare-transformation-report---more-independence-for-older-people-at-home.pdf

[53] Collingridge Moore, D et al., BMJ Open "Length of stay in long-term care facilities: a comparison of residents in six European countries. Results of the PACE cross-sectional study", 2020: available at https://bmjopen.bmj.com/content/bmjopen/10/3/e033881.full.pdf

[54] Dartford and Gravesham NHS Trust, Wearable remote monitoring trial in Kent: accessed 2021 https://www.digitalhealth.net/2019/11/remote-monitoring-saves-nurses-time/

[55] Article accessed 2021 https://www.intelligenttransport.com/transport-articles/72221/moscow-public-transport-network/

[56] Gauss, T et al., "Association of prehospital time to in-hospital trauma mortality in a physician-staffed emergency medicine system", 2019: available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6764001/

[57] Erbinger et al., “Association between dispatch of mobile stroke units and functional outcomes among patients with acute ischemic stroke in Berlin”, Journal of the American Medical Association, 2021: available at https://pubmed.ncbi.nlm.nih.gov/33528537/

[58] Téhard, B et al., "Value of a QALY for France: A New Approach to Propose Acceptable Reference Values", 2020: available at https://www.sciencedirect.com/science/article/pii/S1098301520301881

[59] Abraham, M and Annunziata, M, “Augmented Reality Is Already Improving Worker Perfor-mance”, Harvard Business Review, March 2017: available at https://hbr.org/2017/03/augmented-reality-is-already-improving-worker-performance

[60] 5G-MoNArch, Deliverable D6.3, 2019: available at https://5g-monarch.eu/wp-content/uploads/2019/07/5G-MoNArch_761445_D6.3_Verification_and_validation_final_report_v1.0.pdf

[61] Luengo-Fernandez, R, Gray, A M, Bull, L, Welch, S, Cuthbertson, F, Rothwell, P M, "Quality of life after TIA and stroke: ten-year results of the Oxford Vascular Study ", Neurology, 2013. Available at https://pubmed.ncbi.nlm.nih.gov/24107865/

[62] Hobson, York-Mui, Hadjipavlou, Stevens, "An Introduction to Post-Operative Complications", 2014: available at https://www.ucl.ac.uk/anaesthesia/sites/anaesthesia/files/Intro_to_postop_Complications.pdf

Appendix A – User requirements definition

Table 53. 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 54. 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 55. 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 56. 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 57. 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

For the user requirements presented above, there is a metric and value that the end user should define or select. 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 in order 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< 1year, 1 year<Medium<9 Year, High > 10 years

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

Appendix B – Network requirements definition

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 58 below for different levels of availability).

Table 58. 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

*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.