PUBLIC-PRIVATE PARTNERSHIP

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

Deliverable D2.1
Use cases, deployment and techno-economic requirements - high level description

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Editor(s):	Yossi Altevet (LIV) Jose Enrique Gonzalez (ATOS)
Author(s):	Giuseppe La Torre (TIM) Alessandro Porta (TIM) Alessandro Trogolo (TIM) Ian Hay (ORA) Vlasis Barousis (NOK-GR) George Mitropoulos (NOK-GR) Njin-Zu Chen (PRE) Robert Jochemsen (PRE) Fons de Lange (PRE) Pascal Allain (PFC) Luca Vignaroli (RAI) Chrisoula Falagaris (AIA) Evangelia Giasla (AIA) Nikolaos Papagiannopoulos (AIA) Elena Deambrogio (TOR) Francesca La Greca (TOR) Anna Follo (FTM)

	Nelly Besnard (CHU) Tarik Cherfaoui (CHU) Erwan Donal (CHU) Jean-Yves Gauvrit (CHU) Pavlos Koulouris (EA) Sofoklis Sotiriou (EA) Maria Kampa (KEMEA) Vasilis Kasouras (KEMEA) Georgios Kokkinis (KEMEA) Anastasios Salis (KEMEA) Francesco D'Andria (ATOS) Paraskevas Bourgos (WINGS) Panagiotis Demestichas (WINGS) Ioannis Dimitriadis (WINGS) Eleni Giannopoulou (WINGS) Amalia Ntemou (WINGS) Stefania Stavropoulou (WINGS) Vera Stavroulaki (WINGS) Guillaume Campion (AMA) Philippe Moravie (AMA) Guillaume Vivier (SEQ) Yossi Altevet (LIV) Panayiotis Verrios (ACTA) Antonis Gerogiou (ACTA) Emmanuel Cordonnier (BCOM) Marco Gramaglia (UC3M) Manuel Fuentes (UPV) David Gómez-Barquero (UPV) Lorenzo Natale (IIT) Marco Randazzo (IIT) Vadim Tikhanoff (IIT)
Reviewer(s):	Giancarlo Sacco (ERI-IT)

	Eleni Rigani (NOK-GR) Jose Enrique González (ATOS) Simon Fletcher (RW)
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List of Acronyms and Abbreviations

Term	Description
3D	3 Dimensional
4G	4th Generation mobile wireless communication system
5G	5th Generation mobile wireless communication system
5GPPP	5G Infrastructure Public Private Partnership
5GS	5G System
ADO	Airport Duty Officer
AIA	Athens International Airport
AMIS	Airside Monitoring Inspection Specialist
AOC	Airport Operations Center
API	Application Programming Interface
APU	Auxiliary Power Unit
AR	Augmented Reality
ARAS	Augmented Reality Assisted Surgery
ASOC	Airport Services Operations Center
ATE	Augmented Tourism Experience
A/V	Audio-visual
B2B	Business to business
BC	Before Christ
CCS	Cultural and Creative Sector
CH	Cultural Heritage
CHT	Cultural Heritage Tourism
CI	Creative Industry
CO	Carbon Monoxide
DASH	Dynamic Adaptive Streaming over HTTP
DICOM	Digital Imaging Communications in Medicine
DL	Down Link
DVI	Digital Video Interface
E2E	End to End
EA	Ellinogermaniki Agogi
ECG	Electro CardioGram
ED	Emergency Department
eMBB	enhanced Mobile Broadband
EMS	Emergency Medical Services
EU	European Union
GAM	Modern Art Gallery
GB	Gigabyte
Gbps	Gigabits per second
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GHz	Gigahertz
gNB-RAN	5G NodeB-Radio Access Network
GPS	Global Positioning System
HD	High Definition
HDR	High Dynamic Range
HE	Horizon Europe
HEVC	High-Efficiency Video Coding
HLS	HTTP Live Streaming
HPHT	High-Power High-Tower
HTTP	Hyper Text Transfer Protocol
IIT	Istituto Italiano di Tecnologia
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
IT	Information Technology
KPI	Key Performance Indicator
KVaP	KPI Validation Platform
LED	Light Emitting Diode
LTE	Long Term Evolution
M&E	Media and Entertainment
Mbps	Megabits per second
MEC	Multi-access Edge Computing
mMTC	Massive Machine Type Communication
MNO	Mobile Network Operator
MPEG	Moving Picture Experts Group
MR	Mixed Reality
MTC	Machine Type Communication
NB-IoT	Narrow Band IoT
NO_2	Nitrogen Dioxide
NR	New Radio

O_3	Ozone
OR	Operating Room
P1	Parking Facility 1
PM	Particulate Matter
PTM	Point-to-Multipoint
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RGB	Red Green Blue
RGBD	RGB Depth
RTV	Real Time Video
SDI	Serial Digital Interface
SDS	Security Duty Supervisor
SMPTE	Society of Motion Picture and Television Engineers
SO_2	Sulphur Dioxide
SOP	Standard Operating Procedures
STARLIT	**S**mar**t** living pl**a**tform powered by A**r**t**I**ficial **i**ntelligence & robus**t** iot connectivity
STB	Satellite Terminal Building
TCP	Transmission Control Protocol
TV	Television
UC	Use Case
UDP	User Datagram Protocol
UHD	Ultra High Definition
UI	User Interface
UL	Up Link
URLLC	Ultra-Reliable Low Latency Communication
UWB	UltraWideBand
vEPC	virtual Evolved Packet Core
VR	Virtual Reality
WCAG	Web Content Accessibility Guidelines
WOR	Wireless Operating Room
WP	Work Package
XR	eXtended Reality

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Abstract

One of the key features of the 5th Generation mobile wireless communication system (5G) networks is the ability to efficiently support a multitude of services that have different network requirements. 5G networks allow network operators to simultaneously run services that have different vertical requirements on the same network by allowing flexible allocation of resources and tailoring the network capabilities to the vertical service requirements. As a key feature of the 5G network, validating that the network can indeed provide tailored capabilities to different vertical services simultaneously is imperative.

Most of the efforts to evaluate 5G networks conducted so far by public and private sectors were focused on individual vertical use cases, therefore, the need for evaluating the 5G networks performance on multiple vertical use cases became prominent. 5G-TOURS aims to fill this gap by demonstrating the ability of 5G to support multiple vertical use cases concurrently on the same infrastructure.

The use cases addressed by 5G-TOURS revolve around the life in a city. The focus of these use cases is on improving the quality of life of the citizens as well as the experience of the tourists visiting the city, ultimately making the city more attractive to visit, more efficient in terms of mobility, and safer for everybody. During the project, 5G-TOURS will deploy thirteen use cases of interest for tourists and citizens around the themes of the touristic city, the safe city and the mobility-efficient city, and trial them in a real environment involving all the relevant players of the ecosystem and providing an operational service to the relevant vertical customer in each use case. This document describes these use cases, their objectives and the benefit they devise to provide to the various stakeholders. The document also provides both technical as well as economic analysis (preliminary) and will be used by the relevant Work Package (WP) teams of the 5G-TOURS project as a baseline for their analysis.

Executive Summary

5G-TOURS will deploy full end-to-end trials to bring 5G to real users in a large number of representative scenarios.

This document reports on the set of identified use cases and the initial requirements coming from vertical industries that are considered relevant to the project. It also analyses key project performance indicators and how they relate to the ones identified by 5G Infrastructure Public Private Partnership (5G-PPP). The use cases addressed by the project are grouped around three main themes: (i) the touristic city, (ii) the safe city, and (iii) the mobility-efficient city. While each trial site revolves around one of the themes (Turin is the touristic city, Rennes is the safe city and Athens is the mobility-efficient city), several use cases incorporate aspects from the different themes – e.g., an ambulance involves both safety and mobility, and a bus with on-board entertainment involves tourism, media and mobility.

The document provides a description of the specific use cases addressed within each theme. For each of the use cases, we provide: (i) a detailed description of the envisioned functionality, (ii) a definition of the service objectives as well as preliminary business and economic analysis, (iii) the set of general and preliminary technical requirements imposed by the use case, (iv) the environmental and societal benefits, and (v) the operational aspects required for realizing the use case (e.g. location).

The following use cases, grouped by their theme, are covered in this document:

1. The touristic city
    - Use case 1 – Augmented tourism experience (ATE)
    - Use case 2 – Telepresence
    - Use case 3 – Robot-assisted museum guide
    - Use case 4 – High quality video services distribution
    - Use case 5 – Remote and distributed video production
2. The safe city
    - Use case 6 – Remote health monitoring and emergency situation notification
    - Use case 7 – Teleguidance for diagnostics and intervention support
    - Use case 8 – Wireless operating room (WOR)
    - Use case 9 – Optimal ambulance routing
3. The mobility-efficient city
    - Use case 10 – Smart airport parking management
    - Use case 11 – Video-enhanced ground-based moving vehicles
    - Use case 12 – Emergency airport evacuation
    - Use case 13 – Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus

The approach to the development of this document has been to provide the owners of each use case with a standard framework for describing the various aspects of their use case. The diversity of the stakeholders, the users and the technologies of each of the use cases provided a case study for building a new eco-system around a new concept. Evidently, this has resulted in a different emphasis in terms of the merits of technology and business value propositions across the use cases. This initial view provides an ideal platform for subsequent refinement and analysis into the business and technology evolution aspects as the project progresses.

The work performed in this WP provides continuous information to the three WPs specialized on the three test sites (4,5, and 6) and WP3 on the network architecture. Further details on the implementation plans will thus be available in the next round of deliverables due on M5.

1 Introduction

5G specifications define the next generation of mobile networks, introducing a variety of new core capabilities such as new frequency bands, new radio access technologies, virtualized network functions and coordination from the mobile radio to the core networks. Such advanced technology provides high data rates with low latency across a wide coverage area, massive machine type communication and ultra-high reliability enabling unlimited mobile broadband experience. However, the true value of 5G lies in the fact that the infrastructure is flexible, modular and fully programmable allowing fast deployment of services while providing network functionalities that are tailored to the services' unique requirements. These capabilities of the 5G network empower a transition from a "horizontal" service delivery model, where services were defined independently from their consumers, towards a "vertical" delivery model, where the provided services are tailored to specific industry sectors and verticals. This transition from "horizontal" service delivery to a "vertical" one constitutes a paradigm shift that opens the door to innovative applications across a variety of markets such as connected cities, smart agriculture, smart manufacturing, connected healthcare, VR, and autonomous vehicles.

To unlock the full potential of this paradigm shift, the 5G networks provide, by design, the ability to simultaneously run services that have different vertical requirements on the same network. Unfortunately, as of today, such a capability is not fully addressed by the public and private sectors that are trialling and validating 5G networks capabilities.

5G-TOURS aims to fill this gap by (i) allow the various 5G Key Performance Indicators (KPIs) to be validated in a holistic manner, and (ii) demonstrate the feasibility of allocating multiple industry verticals concurrently on the same network, by leveraging end-to-end network slicing technology.

The use cases addressed by 5G-TOURS revolve around the life in a city. The focus is on improving the quality of life of the citizens as well as the experience of the tourists visiting the city, ultimately making the city more attractive to visit, more efficient in terms of mobility, and safer for everybody. These use cases have been carefully designed to meet the following targets: (i) address applications and requirements that could not be met with previous cellular technologies, showing the needs and advantages of 5G, (ii) cover all the different network slice types considered in 5G, namely enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communication (URLLC) and massive Machine Type Communications (mMTC), highlighting the versatility of 5G to cover different demands, (iii) bring different application domains with diverse needs into the same site, showing the ability of 5G to address different and possibly contradictory requirements under the same infrastructure, and, (iv) represent a large variety of stakeholders to illustrate the potential impact of 5G on our society.

We remark that the sectors addressed by the 5G-TOURS use cases are a fundamental pillar of the EU economy, as they account for about 30% of Europe's Gross Domestic Product (GDP), and represent more than 50% of the business that will be generated around vertical industries in 5G. Therefore, the aim of 5G-TOURS is also to showcase how a remarkable share of the European GDP could be supported and improved by the 5G technology.

2 Purpose

The document provides general description and initial analysis of the use cases addressed by 5G-TOURS collected by the various verticals participating in the 5G-TOURS project. The main purpose is to provide enough information for the other 5G-TOURS WPs such as the network architecture and deployment (i.e. WP 3) and system integration and evaluation (i.e. WP 7) to initiate their analysis based on the defined use cases. In addition, the initial analysis should be used as a platform for subsequent refinement and analysis into the business and technology evolution aspects as the project progresses. 5G-TOURS define thirteen (13) specific Use Cases (UC), evenly spread into the three reference sites.

The document is structured to provide consistent information for all the use cases, therefore, for each of the use cases, the document details the following:

1. Contextual information such as domain overview, description, target vertical and service objective of the use case.
2. An initial qualitative view of the potential benefits of the use case from various perspectives such as business and economic, and environmental and societal.
3. Requirement set, both general requirements as well as preliminary technical requirements are specified. Since the technical analysis of the use cases are not completed at the moment, the technical requirements are given in sufficient detail to define the scope of the use cases whilst avoiding over constraining the later design.
4. Establish the basis for an operational plan including site location and trial description.

It is important to note that the approach for writing this document was to provide the owners of each use case with a standard framework for describing of various aspects of their use case. While the scheme of each use case description is identical, the emphasis on the various aspects of each use case is different.

3 High-level definition of the use cases

As mentioned above, the use cases addressed by 5G-TOURS revolve around the life in a city. The focus is on improving the quality of life of the citizens as well as the experience of the tourists visiting the city, ultimately making the city more attractive to visit, more efficient in terms of mobility, and safer for everybody.

To achieve this vision of 5G-driven quality of life improvements for tourists and citizens, the use cases addressed by 5G-TOURS are grouped around three main themes that represent different aspects of the city (see Figure 1 below):

1. **The touristic city** (use cases 1 – 5): Visitors to museums and outdoor attractions use 5G-enabled applications to enhance their experience while visiting the city. These include VR/AR applications to complement the traditional physical visit with additional content, including interactive tactile communications. The experience of the visitors is also enhanced with robot-assisted services, telepresence to allow for remote visits, as well as live events enabled by mobile communications such as multi-party concerts and content distribution. The touristic city use cases are focused on media broadcasting and will be demonstrated in Turin (Italy).
2. **The safe city** (use cases 6 – 9): 5G technology greatly improves the safety in the city by providing means to better assist health-related care in all the phases of an incident, ranging from the health monitoring for prevention and early detection, to diagnosis and intervention at the ambulance, and surgery at the wireless operation room in the hospital. The use cases will be demonstrated in Rennes (France).
3. **The mobility-efficient city** (use cases 10 – 13): Mobility to reach and move inside the city is made more efficient and comfortable. This involves smart cities, gathering information about the city and using it to improve navigation systems as well as parking. Traveling is also made more enjoyable by providing AR/VR services to passengers, and airports become logistically more efficient by relying on 5G for their operation. The mobility efficient city brings 5G to users in motion as well as to transport-related service providers. The use cases will be demonstrated in Athens (Greece).

Figure 1: 5G-TOURS themes – Touristic city, Safe city and Mobility-efficient city

We remark that all the foreseen UCs make extensive use of the three different kind of services provided by 5G (i.e., enhanced Mobile Broadband, Ultra Reliable and Low Latency communications, and massive Machine Type communications), demonstrating both the needs for improved performance (with respect to the legacy technology, as 4th Generation mobile wireless communication system (4G)) and the architectural flexibility as these diverse services will be supported by the same infrastructure in each city.

The following sections describe each of the themes and the corresponding use cases in more details.

3.1 Touristic city use case

Cultural Heritage (CH), as "legacy of physical artefacts and intangible attributes of a group or society that is inherited from past generations." [1], consists of tangible culture assets (such as buildings, monuments, landscapes, books, works of art and artefacts), intangible culture assets (such as folklore, traditions, language, and knowledge), and natural heritage (including culturally significant landscapes, and biodiversity) from the past.

The CH community has embraced a "digital revolution" since the early nineties and nowadays many CH assets have been digitized and are available through online catalogues, multi-user interactive presentations, digital art [2], online 3 Dimensional (3D) virtual exhibitions, online virtual tours, etc.

Cultural Heritage Tourism (CHT) is a branch of a "tourism oriented towards the cultural heritage of the location where tourism is occurring" [3]. This kind of tourism has grown considerably during the last few decades and forecasts indicate an ever-faster growth in the upcoming years.

Furthermore, Information Technology (IT) specialists from the Creative Industry (CI) work on providing novel approaches to digitalize CH assets together with interactive technologies such as VR and AR technologies[1] to offer a new and attractive way to engage users and make learning and consuming CH assets easier and more fun.

The touristic city realizes 5G technology benefits to residents of the city and tourists that could be on a day trip into the city or an extended stay in or around the city. This node supports a set of use cases that are designed to improve the touristic experience in the city by providing visitors with (i) added value services within the visited touristic attractions, and (ii) media applications to complement their visit. In particular, some of the use cases addressed under this theme are centered on a museum, providing AR/VR applications as well as a robot that serves a guide and allows for remote visits. Additional use cases address media production and distribution, providing users with digital content to complement their visit and producing live events that can further improve their users' experience.

The general approach that guides the development of the touristic city experience is based on the following core principles: (i) immersive, (ii) technology for all (inclusivity), (iii) multimodality in the fruition, giving the possibility to the final user to take advantage of eXtended Reality (xR) experiences through different devices, adapting to diverse situations (e.g. mobile phones, tablets, visors, etc.).
The aim is to enhance accessibility of Turin's heritage showing the historical and cultural aspects of the city through the discovery of the hints and places.

All this is linked by an overall storytelling for City Branding which can be summarized in a City of History and Culture, a strong Industrial past, now devoted to be a place to innovate.

The Turin node is made up of different Use Cases (UCs):

- Use case 1 - Augmented tourism experience.
- Use case 2 - Telepresence.
- Use case 3 - Robot-assisted museum guide and monitoring.
- Use case 4 - High quality video services distribution.
- Use case 5 - Remote and distributed video production.

[1] Reality (XR) as the umbrella term that includes Virtual (VR), Augmented (AR), and Mixed Reality (MR)

3.1.1 Use case 1 - Augmented tourism experience

3.1.1.1 Domain overview

5G is a crucial technology for improving end-user quality of experience (QoE) enabling new approaches for content distribution sharing and interaction through AR/VR technologies empowering ultra-low latency interaction with high bandwidth transition. The exploitation of such interactive technology is enabled by reliable (5G) network connectivity to provide faster and more uniform data rates as well as lower latency.

In the context of the 5G-TOURS project an ATE software solution will be developed and validated. This will integrate innovative interactive technologies such as AR/VR with 5G to create new and enhanced end user experiences, being reactive to user requirements as well as environmental and platform-specific aspects.

3.1.1.2 Target customer

The target customers for ATE solutions are city museums, municipalities or any touristic service provider that would like to provide end users - either tourists or local residences of all ages - an enhanced, interactive experience.

3.1.1.3 Use case description

The objective of this use case is to enrich the Turin’s tourism experience using technologies like immersive media content and intelligent video analysis that augment the human interaction with 3D art pieces.

The use case can be divided into the following sub-use cases:

UC1.a: In the very heart of Turin.

UC1.a is composed of a virtual guide service that delivers a hyper-personalized and interactive experience to city visitors, accompanying them in the discovery of the tourist sites of the city, with particular reference to the museums but also to tourist attractions such as: squares, monuments and streets.

In the scope of museums, a couple of services will be implemented to improve visiting experience, exploiting innovative interaction solutions.

The virtual guide service relies on XR technologies and aims to be context-aware and adaptive to the characteristics (culture, language, etc.) of the visitor. Such adaptation allows personalized interaction with the visitors, in order to understand their indications, gestures and commands.

The software will provide basic information such as details on the piece of art the visitor is looking at; or, if the statue is broken the users will be able see how it used to look like when it was new.

Art pieces will be seen through XR so they will be represented as 3D models, allowing tourists to interact with them: rotate 3D models, enlarge them, explore properties (if it is a door, it can be opened or closed), change colours, etc.

Additionally, the virtual guide service will provide further information about the creation of the art piece, the creator, other works of the same artist, artistic movement details, etc. By utilizing physical web beacons installed in the museum, the virtual guide service will be location-aware and will provide contextualized information about point of interests close to visitors. The museum can also take advantage of the information about crowding and time spent by visitors in the rooms to better manage artworks arrangement.

The overall use case does not only take into consideration indoor touristic places, such as museums, but it also aims at providing the same tourist experience even in outdoor spaces, such as squares, monuments and streets.

In this sense, the use case envisages the development of a series of Smart City Services to support users in their "Cultural walk experience", helping them to discover the most relevant places and artworks of the city. The objective is to help tourists to discover most interesting places according to their preferences. To this aim, users will be profiled according to their physical context (e.g. indoor or outdoor position) and logical context (their preferences) so as to be able to guarantee them the most tailor-made visit.

A dedicated mobile application will be provided to users to interact with Smart City services, allowing them to obtain tourist information (audio guides, multimedia contents) and at the same time getting information about logistics (transport, opening times and crowding of places) and environment (weather conditions, pollution, solar radiation and so on).

Smart City services will be based on different types of information, which may be either Open-Data (provided by the Municipality), or information obtained from sensors that will be deployed in the area covered by the trial.

In summary the UC1.a includes the following features. Users will be able to:

- consume, through XR interaction customized and adapted media contents.
- interact (zoom, rotate, exploit, etc.) with 3D objects (art artefacts) during the visit.
- access multimodal (immersive) media contents such as: customized audio guides, written guides or detailed description of art artefacts that are observed during the visit in the user preferred language.
- interact with virtual avatars to offer personalized itineraries based on user preferences and how crowded rooms in the museum are.
- temporarily save multimedia contents offered by the museum to be consumed after the visit or to be shared with family or friends, while ensuring that any digital rights requirements related to the content are met.
- Consult environment and pollution information and get suggestions about touristic walking routes selected based on the best air quality.
- Exploit information regarding the crowding of touristic places (e.g. museum rooms, squares, ...) in order to allow the tourist to better plan his visit experience.

An example of such virtual visit to the museum is depicted in **Error! Reference source not found.**.

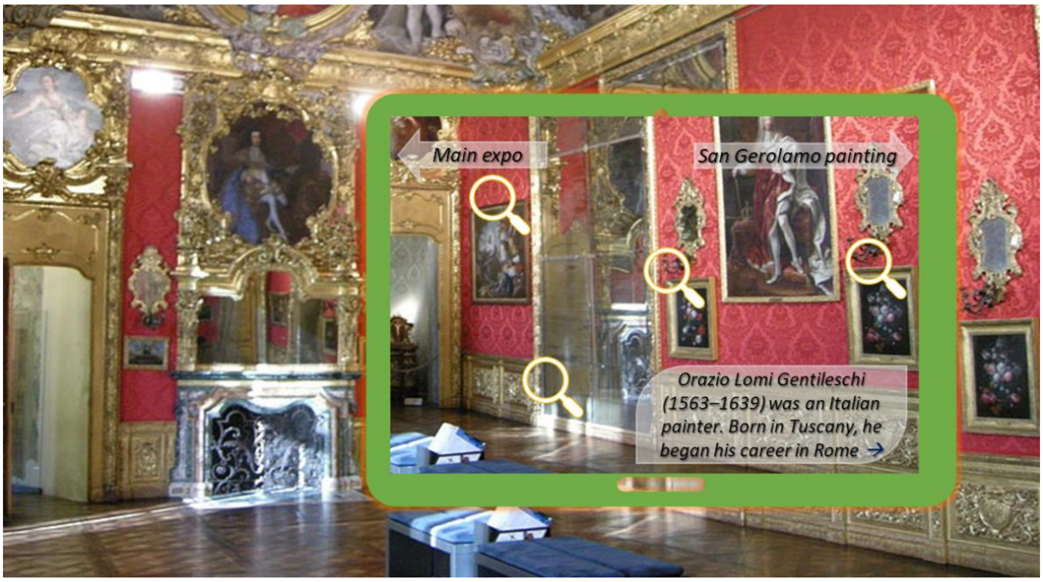

Figure 2: Palazzo Madama Torino, piano nobile.

UC1.b: GAM – Gamification, let's play artist.

This UC1.b will implement an immersive and interactive learning solution with AR games. The UC will rely on gaming and gamification technology to maximize the end-user's engagement and participation as well as provide an enhancement of the learning experience.

Therefore, the solution includes game-based learning and gamification features that are accessed by interactive technologies such as AR or VR. In depth the solution will provide the following features:

- A multiplayer interactive game about a virtual canvas that geo-locally distributed visitors can collaboratively paint, inspired by the museum's art pieces, creating an integrated huge piece of art made by lots of visitors. The canvas game) will be tested by users physically located in Educational Lab [4] and Galleria d'Arte Moderna e Contemporanea di Torino [5].

- A "mystery at the museum" game where visitors search for clues which are placed around the museum with different tests related to the pieces of art, encouraging visitors to learn about them to advance in the game.
- A minigame starts in front of an art piece, asking the visitors questions adapted to their age and giving different educational brief content depending on the answer.
- The solution enables the creation of a piece of art based on the ones that are currently at the museum, using a canvas with the background of a painting or a virtual block of stone for sculpting.

Error! Reference source not found. shows a view on the gamification techniques envisioned by this UC.

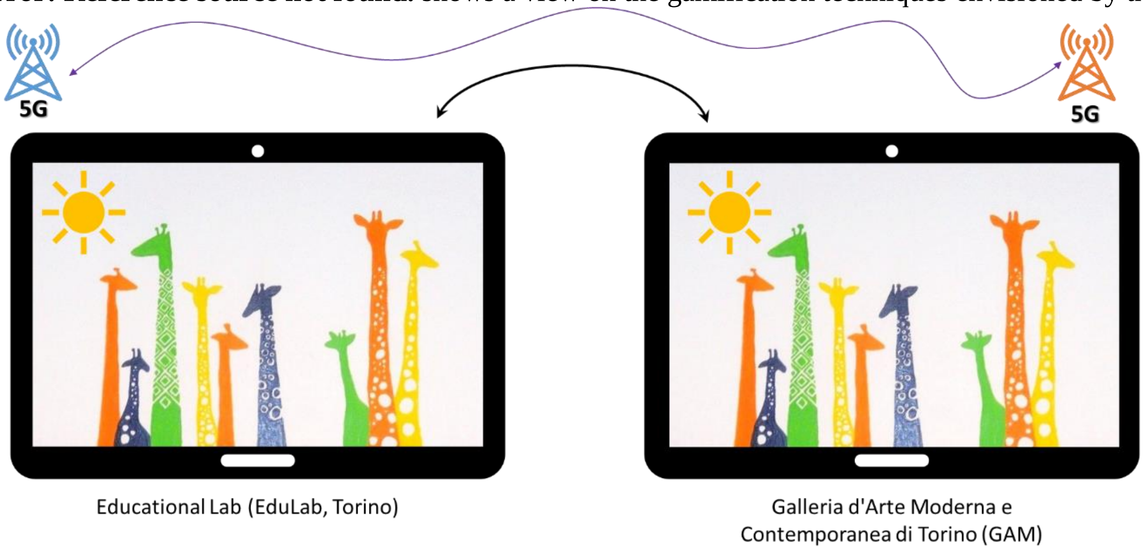

Figure 3: Collaborative distributed Canvas app

3.1.1.4 Innovation potential

5G technologies will enable the creation of new media-focused services and technologies powering new business models. 5G connectivity will provide clear benefits in terms of bandwidth and latency, whilst edge computing will enable the creation of a more efficient deployment closer to the end user.

Thus, 5G enables the management and close control of data transfer at a very high speed based on computer resources very close to the user. This offers the opportunity to unlock new immersive interactive experiences opening an entirely new way for consumers to interact with media contents; Realistic immersion combined with high quality VR will increase levels of user engagement and satisfaction.

3.1.1.5 Service level objectives

Through the implementation of the aforementioned UCs relying on XR technologies, museums, art galleries, historic buildings, etc will be able to provide visitors with contents that can adapt to their own experience and needs. This will allow the museums to accommodate more visitors with very diverse expectations in the same moment, without having to rely on the implementation of different tours.

The expected measurable characteristics (objectives) the project wants to achieve are:

- Increase in the number of visitors and foreign tourists during the trial period.
- More adequate distribution of visitors during the opening hours. If visitors can benefit from a guide suiting their specific needs at all time, they will not have to stick to the schedule of guided tours, thus avoiding the clutters and the discomfort that a visit in a large group may generate.
- Being able to organize the contents related to the museum in a way that suits their specific needs, visitors will more likely spend more time for their visit. Sensors and beacons installed for the trial will provide valuable information on the duration and highlights of the visit.
- Offer thematic tour itineraries that take into account the actual interests of visitors and the real-time crowding of the rooms in order to guarantee a comfortable visit experience.

3.1.1.6 Business and economic implications

The industry trends of globalisation and convergence of sectors through digital technology adoption underpins the economic context. The interdependence between the Creative and CH sectors provide the focus for the development of new platforms for services and products, many of which are created in collaborations.

The Cultural and Creative Sectors (CCS) are some of Europe's most dynamic ones; they are estimated to generate about 4.2 % of total EU GDP [6]. According to the figures published by Eurostat in June 2015 [7], employment in the CCS at EU level increased from 2.5 % in 2008 to 2.9 % in 2014, compared to total EU employment. Despite the financial crisis in 2008, the proportion of cultural employment in total employment has increased, suggesting not only a certain resilience of the sector, but additional job creation within it. From the "towards more efficient financial ecosystems innovative instruments to facilitate for the cultural and creative sectors (ccs)" report released by the EU [8] there is evidence confirming that the cultural and creative industries are highly attractive for young people and absorb them easily: on average, the CCS employed more 15-29-year-olds than any other economic sector (19.1 % of total employment in CCS versus 18.6 % in the rest of the economy). The use case implementation will demonstrate the benefits of the convergence of CCS in reinforcing a competitive advantage in the global European market by designing and developing novel inclusive, creative and engaging narrative approaches to share and reuse tangible and intangible data.

Besides that, the 5G TOURS ATE solution will deliver a new and engaging touristic platform for delivering and re-using digital cultural 3D assets, also with an attention and devotion to citizen with special needs and impaired users. Stories, accumulated data and the framework created for documenting digital outcomes will foster preservation and allow further engagement and data re-use in the CI domain, in education programs and other communities of use.

3.1.1.7 Social and environmental benefits

The anticipated business benefits from the use of the solution are expected to be wide ranging.

Benefits are expected to apply both to existing Touristic, Cultural and Creative industries as well as CH actors. Indeed, there will be new business opportunities for content providers, the tourism sector providing high-quality experiences also for education sector and general public.

Ground-breaking interactive technologies, such as AR/VR, combined with a fast and reliable connectivity have really transformed the traditional way of consuming Touristic/Cultural experiences by augmenting traditional visits to museums, expositions, cities, with completely new form of media contents such as interactive and immersive contents, holograms, 3D models of artistic artefacts, etc. In fact, such technologies have received considerable popularity across the world in the touristic/cultural as well as the educational field.

On the other hand, the move from individual CH institutions trying to preserve, reuse and enhance their own cultural assets to a large-scale environment where multi-source and multi-modal data are shared in a common space enriched and ready to be re-used to create fully-contextualized stories creates a direct social and environmental impact on the general public. The specific ways in which adopters of the solution will benefit are listed below.

The analysis includes the perspective of CH institutions, Creative industries and content providers, tourism and education sector and finally the general public. The benefits fall into several types: increase business opportunities, reduce costs, reduce time to market, improve scalability, improve reliability and security, social benefit etc. One of the objectives of the use case is to establish a market and sustainable business models. The solution approach integrates several high-potential innovation seeds into a modern vision of future interactive systems. Storytelling, as communication modality about CH content, is ready to accommodate personalization, which is key to ensure the reach to larger audiences supporting the adaptation of the content to the different audience characteristics.

Moreover, storytelling is supported by the solution idea of Digital Residency, which evocates a shared and multi-community digital context that is likely to be visited by people with different cultural backgrounds and with a shared interest in cultural and artistic stories. The platform will allow to be easily extended by adding more dynamism in the interaction workflow (i.e. visitors real-time feedback or augmentation of stories with personal experiences) thus opening up a whole spectrum of opportunities for third-party companies, or professionals, to extend and specialize the platform functionalities, for instance, to fully support the integration of touristic information in the story, or to support user-engagement via augmented interactivity.

3.1.1.8 General requirements

This section outlines the functional requirements of the ATE solution. The requirements have been organized in a manner that facilitates overall review.

- ***Sensors & Actuators***
  - Short-range signalling devices such as beacons, which will be placed inside museum rooms to allow indoor localization of visitors through their smartphone.
  - At least two "Earthquake Sensing Station" for each floor of the museum, in order to monitor structural oscillations and emit early warning in case of an earthquake. Each sensing station will be equipped with proper sensors (accelerometer or velocimeter) and a radio module for data transmission.
  - A least two "Air Quality Sensing Stations" deployed in the external area considered by the trial. Each sensing station will be equipped with environment sensors (temperature, humidity, solar radiation), gas sensors (Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Sulphur Dioxide (SO_2)) and dust sensors (Particulate Matter (PM)1, PM2.5, PM10), and a radio module for data transmission.

- ***Accessibility***: The proposed ATE solution will be fully accessible. It will address a series of accessibility requirements founded on the four high-level principles presented in Web Content Accessibility Guidelines (WCAG) 2.1 [9], [10], [11] as follows:
  - Perceivable – Information and User Interface (UI) components must be presentable to users in ways they can perceive.
  - Operable - UI components and navigation must be operable.
  - Understandable - Information and the operation of UI must be understandable.
  - Robust - Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.
  - The solution will be supported by a mobile app where its configuration can be made by non-experts (as well as its capability to be updated by modules that provide additional features).
  - Support accessibility through UI design.

- ***Internet of Things (IoT) Platform***
  - The data measured and sent by the sensors will be collected at an IoT platform that will make them accessible to external applications through Application Programming Interfaces (APIs). At the platform level, data analysis algorithms can also be defined to obtain correlations between apparently heterogeneous data and to define trigger-action rules (involving also third-party services), according to the well-known paradigm of If-This-Then-That.

- ***Content storage, analysis and delivery***
  - System needs to be able to (temporarily) store media files and annotations. Those contents may be stored on the cloud or on the user device. In the latter case the user should (at least) have 1 Gigabyte (GB) of free disk.
  - Management of (live) media contents.
  - Encoding functionalities (that include the capability to make on-the-fly encoding/decoding for live transmission) and adaptive streaming capabilities (e.g., dynamic adaptive streaming over Hyper Text Transfer Protocol (HTTP)). Standards such as HTTP Live Streaming (HLS) or Moving Picture Experts Group (MPEG) - Dynamic Adaptive Streaming over HTTP (DASH) may be used to ensure video streaming adaptability to play video encoded with the H.264 or High-Efficiency Video Coding (HEVC)/H.265 codecs.

- ***Services and UIs***
  - Context-aware to interaction-based recommendations.
  - Capability to set and update profiling information.
  - Support of AR/VR interaction.
  - The user interaction must be device agnostic.

3.1.1.9 Preliminary technical requirements

Communication - Connectivity

- Low-Latency is one of the most important requirements to support XR Interaction. i.e. XR to provide pleasant immersive experience requires stringent latency requirements typically with values < 15ms of round-trip time including the rendering in the cloud.
- Fast Data Rate: immersive interaction requires data rates of about 200 Megabits per second (Mbps) for a VR system.
- Supports multiple wireless ad-hoc connections like WIFI, Bluetooth, telephone network such as 5G.
- The user should not have to configure connectivity channels.
- It is required Narrow Band IoT (NB-IoT) coverage in the areas considered by the trial (indoor and outdoor).

The following table summarizes the technical requirements of the ATE use case:

Metric	Required value
Latency	≤ 15ms Ent-to-end (E2E)
Reliability	99.999%
Density	~tens per 1km^2
Mobility	N/A
Coverage	0.5 km^2
Slice/service deployment time	≤ 90 minutes
Data rate per user/device – Down Link (DL)	200 Mbps per device
Data rate per user/device – Up Link (UL)	≥ 20 Mbps
Security	“Carrier grade”
Location accuracy	≤ 1m

Table 1: Preliminary network requirements – use case 1

3.1.1.10 Location and site facility

The trial location of the various sub use cases (UC1.a, UC1.b and UC1.c) will be as follows:

- The UC1.a “Immersive and interactive virtual tour” will be implemented in Palazzo Madama and Edulab, Turin.
- The UC1.b “3D Immersive and Interactive Learning with AR Games” will be implemented in the Gallery of Modern and Contemporary Art of Turin and Edulab, Turin.
- The UC1.c “Interactive Cultural walk experience” in the Palazzo Madama, Modern Art Gallery (GAM), Museo Pietro Micca, Turin.

3.1.1.11 Trial Overview

A virtual guide service will be provided to deliver a personalized experience to the museum’s visitors.
The first steps of the trial will concern the selection of the areas/items/materials that will become the backbone contents of the app/device the guide will be installed upon: it will provide information such as details of the piece of art the visitor is looking at or better to tell the history of the place the visitor is in across ages. Once the storytelling has been set by museum curators/educators, they will be shared with the technological partner to define the architecture of the guide and produce the 3D models/video or whatever content will be considered useful. The third part of the trial will involve a focus group with a selected target to fine-tune visitors’ experience

with the virtual guide. An IoT infrastructure will also be deployed to support the implementation of smart city services that will allow visitors to benefit from a multitude of information and facilities provided by the city, enriching their visit experience.

3.1.1.12 Stakeholders

The Stakeholders involved in the Augment Tourism Experience use cases are:

- End Users (general user) of all ages.
- Museums and Municipalities will act as product owners. So, they will offer the service to the public.
- Content Providers: Museums, Municipalities, Broadcasters or specialized companies that provide media contents will be exploited by the solution so consumed by General Users. It may be:
  - 3D Models of art artefacts.
  - Video and Audio contents (in different formats: immersive, linear, 3D, etc).
  - 3D holograms, avatars, etc.
- Solution Providers. Software companies are going to implement the "Augment Tourism Experience" software solution.
- Hardware Providers:
  - XR Hardware Providers such as: handsets, smart glasses, haptic gloves, 3D scanner, etc.
  - Cloud Providers.
- Network Providers and operators. Tech companies are going to provide 5G Connectivity and technology to properly deliver the service to the end user.

3.1.1.13 Security requirements

The solution developed in the context of the aforementioned use cases will not address security requirements since the consortium did not consider them as a key part of the solution. On the other hand, during the implementation of the trials in order to assess and validate the outcomes of the action, the project undertakes to:

- Minimise the collection, storage and processing of personal data and use anonymisation techniques to remove the ability to identify individuals where possible.
- Pseudonymise data sets identifying overall and generic factors associated with populist movements.
- Not engage in commercial exploitation of any personal within the lifetime of or after the project.
- Use advanced technical measures necessary to minimise any risks to privacy (see below), integrated into any 5G-TOURS baseline technologies which address issues of security and privacy following the principle of Privacy by Design (General Data Protection Regulation (GDPR), Recital 78; Art. 25):
  - Use of secure data storage, encrypted transfer, controlled and auditable access for different classes of data distributed over the same channel.
  - Obscuring/removing user identities at source wherever possible.
- Obscuring any associated data if possible, depending on application needs to prevent user tracking. Obscuring location through indirect/delayed routing to prevent individual localisation as much as possible and limit user tracking through correlation of depersonalised data based on its location. Seek to embed legal best practice in the technology developed and employed by the project considering relevant regulation and best practice.

Specific deliverables of the project are planned in order to ensure project compliance with the ethics requirements and to supervise and monitor their application in the trials involving final users

3.1.2 Use case 2 - Telepresence

3.1.2.1 Domain overview

Telepresence refers to technologies that allow a user to appear to be present, feel like he/she is present or have some effect in a space the person does not physically inhabit. Telepresence can include video teleconferencing tools, where a picture and audio streams are conveyed to a remote location, as well as more involved robotics installations that can help a user to accomplish tasks from a remote location.

3.1.2.2 Target customer

All museums should be engaged as target customers for local or remote telepresence solutions. Moreover, telepresence can target other type of customers, municipalities and organizers of all type of events (cultural, musical, etc).

3.1.2.3 Use case description

In general, this use case will enable the possibility to visit a museum from a remote location through telepresence robots, having the ability to move around the museum spaces like the people would do if they were physically present there. In addition, remote surveillance and monitoring of the museum would be also possible. It is worth to be highlighted that, depending on the robot that will be used and the specific sub-use case addressed (see below), a skilled operator that knows the system and is able to control the robot remotely may be required.

The use case can be divided into the following sub-use cases:

UC2.a: Palazzo Madama exclusive exhibitions for all.
In this sub-use case, a single visitor or a group of visitors in a remote location (e.g. different buildings, urban area, region or even country, will be able to visit the Palazzo Madama museum, moving inside the spaces and experience them as if would be physically present there. Visitors will be able to look at the museum spaces and artworks through a monitor or other more immersive equipment (such as a curved videowall) mounted in the remote room, having explanations provided by a guide or a teacher there present, or even by a touristic guide at the museum or in another location. The same concept can also be extended to other cases such as disabled people not able to physically access some parts of the museum; in this case a kiosk can be placed in a reachable location and used as the "entrance" to such locations. Furthermore, this technology allows to offer cultural experience in other public/open spaces to improve the experience of its users (e.g. into airports, train stations, hospitals, etc.) and in some cases to attract tourists from other places.

UC2.b: Play and visit modern art from Museum to School.
The objective here is to offer enhanced educational activities to students at school, to be integrated in their school programmes. Whit respect to the previous sub-use case, the remote visit of the GAM will be enhanced by thematic tutorials and games that would improve the visit experience with additional contents, requiring also the interaction of the end users. As an example, specific learning activities could be organized in dedicated educational modules offered to several schools in Turin and deployed in the "Art, Cinema and Theatre" laboratory within the Edulab. In such a context, while visiting the GAM through the telepresence robot, the students can be involved in a "treasure hunt" game in which they should reach the different stages by solving enigmas or pursuing artefacts and paintings using the telepresence robot.

UC2.c: Surveillance of the museum.
This sub-use case addresses remote surveillance of the museum by an external operator enabling the possibility to supervise different locations during the night time without the need to reach them physically, thus improving the efficiency and security of the surveillance guards. Furthermore, in the opening hours of the museum (day-time), the robot will be able to monitor the presence of people in areas that are forbidden to the public and deliver a warning if a violation of the rules takes place.
The surveillance activity can be also enriched by informing the remote operator regarding eventual critical events that may happen in the museums such as fire or structural failures. To such extent, un underlying IoT platform will be used to convey the information gathered from oscillation and fire sensors that will be placed inside the museum

3.1.2.4 Innovation potential

Many of the disadvantages of the telepresence robots come from the time lag in communicating remotely or the awkwardness of the person conversing through or with the machine. Moreover, continuity of the connection of the telepresence robot with the remote user(s) and/or operator will be guaranteed with high reliability. The current communication technologies such as Long Term Evolution (LTE), for long ranges or Wi-Fi for short ranges or indoor connectivity cannot meet such requirement. In addition to that, to provide the best experience to the users, the video/image should be delivered at the highest possible quality, thus requiring a very large radio connection bandwidth. All these requirements will be met through the use of 5G connections, that can guarantee high bandwidth and low reliable latency transmission through the instantiation of specific eMBB and URLLC network slices.

3.1.2.5 Service level objectives

Telepresence will allow to open to a wider public, that cannot be on the museum premises, the opportunity to access not only the museum physical space and its collections, but also to attend niche events with curators or other professional discussing temporary exhibition or highlights in the collection of the museum. This can lead to a broader diffusion of exhibition-related content that will be accessible online also after the telepresence. Among the expected objectives, the main ones are the possibility to increase the number of curators led tours, which right know are given only to the press on the opening day, and the facilitation of the surveillance tasks, with a beneficial support given to the guards by the mobile robots. Indeed, robot surveillance will improve security and reduce associated cost, helping in getting information on different locations in one central control room thus decreasing the number of patrolling tours by the night guards. Additional information can be also provided about critical events such that may happen at the museum.

3.1.2.6 Business and economic implications

The solutions comprised as part of this use case can contribute to expand the cultural offer through the virtual visit of remote places, not accessible, closed to the public. This will enable access to the area of historical buildings that are too dangerous or difficult to reach for security reasons (for example the attic of Palazzo Madama).

These solutions will allow to increase the public for selected "exclusive" exhibitions. Integrating the school programs will reach a young audience today away from this type of cultural attractions, minimizing costs for families.

In the same way, this solution will find applications in monitoring storage areas and deposits, that are not easy to access, but needs constant vigilance.

3.1.2.7 Social and environmental benefits

Telepresence robots have the potential to extend access to historically excluded audiences like for instance disable people, social disadvantaged people (e.g. substituting or complementing school field trips), people outside the country (in a way to attract tourists/users), provide enhanced education activities at school (without moving from its own classroom) as well as offering niche experiences to a wider audience to all (potentially) and for a longer time. Considering the penetration level of this kind of services based on telepresence robots, it would also be possible to reduce the CO2 emissions due to people moving around less using flights and or cars to reach the places of interest and also providing savings in terms of costs and spent time. The use of telepresence robotic solutions for remote surveillance will also improve the security inside the museum, reducing risks damages and thefts.

3.1.2.8 General requirements

This section summarizes the general requirements in terms of needed equipment for the Telepresence use case. This use case will use the Double Robotics DOUBLE robot and the R1 robot (Figure 4). The two platforms have similar characteristics for the use case. The Double Robotics DOUBLE robot is an affordable platform which facilitates commercial exploitation of the proposed solution. The R1 robot has additional mobility on the torso and the head, which simplify transferring the movement of the user on the robot, making the interaction with the environment more natural.

Figure 4: Double Robotics DOUBLE 2 (left) and R1 (right) robots.

Equipment:

For the UC2.a, UC2.b and UC2.c (daytime):

- Telepresence robot: is a remote controlled, two-wheeled videoconferencing robot that give remote users a physical presence in remote locations. It is planned to use Double Robotics DOUBLE 2 robots (Figure 4) equipped with camera kit and Apple iPad Pro controller or, depending on the availability on the market, the Double Robotics DOUBLE 3 robots
- Control Station: Remote room from where the telepresence robot in controlled, equipped with laptop, joypad and wide screen for remote control and view.

For the UC2.c:

- Istituto Italiani di Tecnologia (IIT) R1 robot:
  - R1 robot (the robot is already equipped with stereo camera, depth sensors and lidars).
  - Control station equipped with laptop, joypad and wide screen for users remote vision.
  - UWB (UltraWideBand) localization beacons to improve robot localization inside the museum (if needed).

3.1.2.9 Preliminary technical requirements

Connectivity

A mobile connection should be available in each room of the museum the robot is required to operate. A bandwidth of a least 10Mbit/s (UL) is required for successful high-quality video transmission from the robot cameras to the control room. Additional upstream bandwidth (5-10Mbit/s) might be required for additional robot sensors (robot joints data, audio stream, depth sensor and laser range finder data, etc.).
A bandwidth of at least 10Mbit/s (DL) is required to teleoperate the robot from the control room. A latency of ~10ms (or less) is recommended for safe robot teleoperation and control.
Internet connectivity for cloud computing (e.g. to connect to software for natural language processing).

The following table summarizes the technical requirements of the Telepresence use case:

Metric	Required value
Latency	≤ 10 ms (end to end)
Reliability	99.9999%
Coverage	The museum in the city of Turin in which the robot will operate (initially Palazzo Madama and GAM)
Data rate per user/device	A bandwidth of 15-20Mbit/s upstream and 10Mbit/s downstream

Table 2: Preliminary network requirements – use case 2

3.1.2.10 Location and site facility

The trial location will be as follows:

- **Museums/Educational facilities**:
    - Palazzo Madama - a large historic building that now houses the collections of the Museo Civico d'Arte Antica, Turin's municipal museum of ancient art – located in Piazza Castello, in the center of Turin.
    - GAM - Torino Civic Gallery of Modern and Contemporary Art – located in Via Magenta – linked with remote cultural and educational experiences to be delivered at Turin Educational Lab – a dedicated spaces for innovative learning methodologies just inaugurated into a school (Drovetti School – Via Bardonecchia).
    - other Museums to be identified during the planning phase, such as Museo Pietro Micca located in Via Guicciardini 7/, which is a Museum dedicated to the days of the Spanish Succession War (when Turin was besieged for four months by the French army) and Borgo Medievale located in the Valentino Park, which is an open air Museum, which reproduces 15th century buildings found on the Piedmont and Aosta Valley territory).

3.1.2.11 Trial Overview

As soon as the exhibition plan for the next years will be finalised, the first part of the trial will focus on which temporary exhibition and/or aspect of the collection is selected to organize the telepresence sessions. Then a list of possible curators/educators to guide the tours will be selected, accordingly targeted audience groups will be paired, and the telepresence sessions will be planned. When the museum is closed to the public, the robot may navigate the museum autonomously or with teleoperation, to allow remote surveillance.

3.1.2.12 Stakeholders

The main stakeholders for this UC are the following:

- Schools.
- Museums and museum operators.
- Municipalities.
- Event organizers.
- Private software applications for robotics developers.
- Private surveillance services providers.
- Network Providers and operators that are going to provide 5G Connectivity and technology to deliver the service to the end user.
- Hardware providers (e.g. robot manufacturers).

Other possible stakeholders:

- Healthcare sector, public and private which may benefit from deployment of service robots for remote assistance.
- Airports, Train stations and related entertainment service companies/providers.

3.1.2.13 Security requirements

Remote video captured by the robot may contain images and sounds from the museum visitors and employees, so network security is fundamental to meet privacy requirements of this personal data. The system will not record any image, and appropriate measurements will be taken to secure the transport channel. To meet privacy requirements, as an initial solution, an information panel informing the visitors about video broadcasted towards a remote location, will be placed in the appropriate areas. More detailed analysis on the security requirements will be performed during the next stages of the project [12].

3.1.3 Use case 3 - Robot-assisted museum guide

3.1.3.1 Domain overview

Service robots are designed to help humans in everyday tasks, operating without or with partial human intervention. Examples of applications are museums, shopping malls, hospitals or the domestic environment. It is expected that such systems will become increasingly more autonomous, and as a consequence, will require consistently more computing power. Pervasive, reliable and high bandwidth radio connectivity is fundamental to support the development of a market for service robots. The main challenge of this use case is to validate the technology developed in 5G-TOURS in the context of the control loop of an autonomous system, in which low latency and reliability are fundamental features.

3.1.3.2 Target customer

This use case directly targets museums, but the technology developed will be easily adopted in other applications, like the reception of a hospital, a shopping mall or public places like an airport.

3.1.3.3 Use case description

The goal of this use case is to leverage robotic technology to provide an enhanced museum visit experience. In this case, a robot is deployed inside the museum and has a map of the environment enriched with the location of the main attractions. Visitors interact with the robot, asking information on what they can see and where. The robot can physically guide the visitors to the required attraction. Additional robot intelligence that requires a high amount of computational resources is necessary for this task, which further motivates the use of computing power external to the robot such as a computing cluster, as well as low latency and high bandwidth communication for proper operation. To perform these tasks information such as the sound from the microphones, Red Green Blue (RGB) & depth images from the RGB Depth (RGBD) cameras and laser scans will need to be reliably transmitted over the 5G network. Software for building a map of the environment will also need to be developed, as well as the functionality to autonomously navigate it. The dialog system that allows the robot to interact with the visitors using natural language processing will also need to be developed. Figure 5 depicts the use case description.

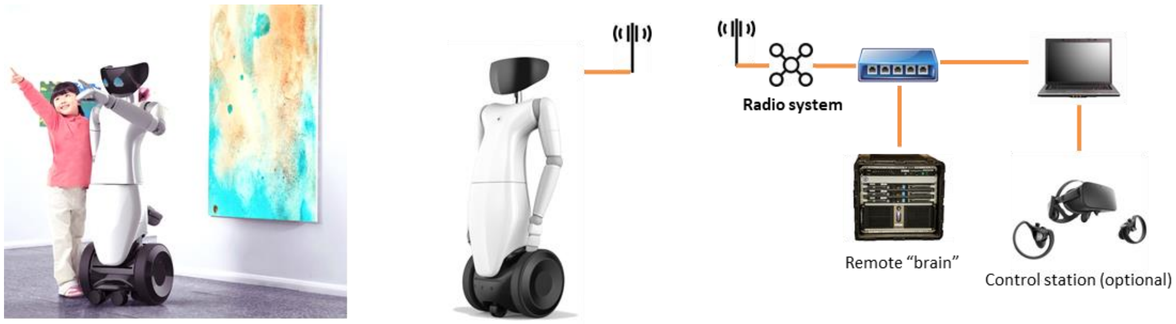

Figure 5: The Robotic guide use case (left). A schematic representation of the robot control system (right).

3.1.3.4 Innovation potential

The museum guide application requires running software for navigation, perception and natural language processing, in a sensing-action control loop. These software components need access to the whole sensory system of the robot, in real-time with low latency. Because computing power on board the robot is very limited due to the available space, payload and battery power, it is fundamental that the software can run on a remote-control station, which is reachable as the robot moves within the museum. Current technologies (4G LTE and WiFi) do not provide the necessary bandwidth, latency and reliability, especially if we want to go beyond simple prototypes and envisage commercial exploitation of the robotic technology. Additional, required features are the possibility to guarantee a certain Quality of Service (QoS) irrespective of the number of devices connected in the museum, low bandwidth for selected channels (for example motor commands and sensory signals need lower latency than images for monitoring the robot), security to guarantee confidentiality of the information acquired by the robot.

Clearly the innovation impact of this technology goes well beyond the application demonstrated in this use case, as similar requirements concerns a much larger set of applications of service robots (e.g. healthcare, domestic use, use of robots in large supermarkets, shopping malls and public spaces).

3.1.3.5 Service level objectives

The robot guide will enhance the experience of visitors to the Museum. The robot will offer basic information on internal locations, points of interest (e.g. restrooms, vest rooms, security exits, etc.,) and more sophisticated information on selected collections.

3.1.3.6 Business and economic implications

The solutions comprised as part of this use case can contribute to increase museums, historical residences and tourist attractions that are not accessible to the public or accessible for a limited period of days per year. These new solutions will make it possible to reduce the costs necessary for the opening, management and surveillance of these sites, thus expanding the cultural offer of the city.

3.1.3.7 Social and environmental benefits

The purpose of this use case is to improve the experience of visitors to the museums in Turin and cultural events taking place therein, providing a better education to school students and making museum attractions reachable to all the population segments. We expect that the robotic technology will improve the quality of the service provided to all visitors, but to be particularly attractive for children and teenagers, who are enthusiastic users of new technologies and will be eager to interact with the robot. This will help to increase visits to the museum and participation in its cultural events.
Broadly speaking, the technology developed in 5G-TOURS for the robotic use cases will contribute to the deployment of service robots in all domains of application of robotics, including healthcare.

3.1.3.8 General requirements

This use case explores the requirement of an autonomous system which is controlled by a remote-control station. In this case high bandwidth is required upstream to transmit data acquired by the robot sensory system (RGB and depth cameras, laser range finder, audio stream, robot joints data) and make it available to the set of computers that control the robot from a remote station (the robot "brain", see Figure 5Figure 5). The control station processes the data received from the robot, e.g. audio analysis for speech-to-text, natural language processing and localization of the robot on the map. It then computes the commands for the robot: speech (audio format), motor velocity for the wheels on the base or the robot limbs. The control loop should be reliable with low latency to guarantee correct operation of the robot. As different streams of data have different importance for the application, QoS control may be also investigated to assign higher priority to data streams that are involved in the control of the robot.

3.1.3.9 Preliminary technical requirements

Connectivity
A mobile connection should be available in each room of the museum the robot is required to operate. A bandwidth of a least 10Mbit/s (UL) is required for successful high-quality video transmission from the robot cameras. An additional upstream bandwidth of ~5-10Mbit/s is required for additional robot sensors, such as depth sensor and laser range finder, which are required by the robot to autonomously navigate the museum environment.
A bandwidth of at least 10Mbit/s (DL) is required to teleoperate the robot from the control room.
A latency of ~10ms (or less) is recommended for both safe robot teleoperation and navigation control.
Additionally, an Internet connectivity is required for cloud computing (e.g. to connect the robot to third-party service providers for natural language processing).

The main KPIs are summarized in **Error! Reference source not found.**:

Metric	Required value
Latency	≤ 10 ms (bidirectional mode)
Reliability	99.9999%
Coverage	The museum in the city of Turin in which the robot will operate (Palazzo Madama and GAM)
Data rate per user/device	A bandwidth of 15-20Mbit/s upstream and 10Mbit/s downstream

Table 3: Preliminary network requirements – use case 3

3.1.3.10 Location and site facility

The use case will take place in the city of Turin and will involve the museums of Palazzo Madama and GAM.

3.1.3.11 Trial Overview

The R1 Robot will be placed before the ticket desk at the entrance to the museum to provide potential visitors with information on the collection highlights, the temporary exhibition. The robot will offer to serve as a guide inside the museum if necessary. In case of lines to access the museum, the robot will also assist visitors giving them real time information about the line and prospect waiting time. A warning: this user case is strictly connected to the ongoing temporary exhibition in the museum and in general we have a reliable program a year in advance. The robot could also guide the visitors along a predefined path inside the exposition. The robot could stop in front of each attraction, provide some description of the artwork and eventually respond to some questions of the visitors. The robot could also monitor the group of visitors. For example, it could warn people not to come too close to forbidden areas or check if they are actually following him during the tour.

3.1.3.12 Stakeholders

The main stakeholders for this UC are the following:

- Residents of the city of Turin.
- Museum of Turin and museum operators.
- Private companies developing software applications for robotics.
- Private companies providing surveillance services.
- Network Providers and operators that are going to provide 5G Connectivity and technology to enable this use case

3.1.3.13 Security requirements

The mobile network has to guarantee the appropriate level of security such that an unauthorised person cannot access the system and take control of the robot movements.
As mentioned in use case 2, panels will be used to inform visitors that data acquired by the robot will include images and audio from people that are visiting the museum. These audio/video streams will be only temporarily processed and not permanently stored by the robot. Nevertheless, the network will implement all the security protocols required to guarantee the privacy of visitors and to comply with the GDPR.

3.1.4 Use case 4 - High quality video services distribution

3.1.4.1 Domain overview

The fourth use case of 5G-TOURS focuses on eMBB and in particular on the Media and Entertainment (M&E) verticals. The objective of this use case is the distribution of audio-visual (A/V) content and services to a potentially unlimited number of users. The use case is about A/V reception; therefore, the type of content that is transmitted is horizontal. The A/V content can be either high-quality video (e.g. 4K/8K) for smartphones and televisions (TVs) or immersive media for AR/VR devices.
When specific content is demanded by a large number of users, the devices will be able to automatically switch to multicast or broadcast services as appropriate. The main challenge is to deliver this information to all required users at once by using the 5G-broadcast capabilities of the 5G-TOURS architecture. In specific cases, there is a need for personalisation and, therefore, multicast users are required to provide feedback information in the UL.

3.1.4.2 Target customer

This use case targets the distribution of enhanced high-quality video services for tourists, citizens and students providing immersive functionalities to enrich their touristic and/or educational experiences. The main providers of such content are museums that would like to provide cultural and educational content or the municipality when providing touristic information about the city. The use case mainly targets distribution of A/V content within the city of Turin and inside touristic venues such as the Palazzo Madama.

3.1.4.3 Use case description

Immersivity lies in providing the user with additional content related to the surrounding environment (i.e. pictures, video or virtual content) by using smartphones, TVs or VR/AR devices. This type of services requires the availability of computing resources in the network edge in order to support such advanced processing techniques.

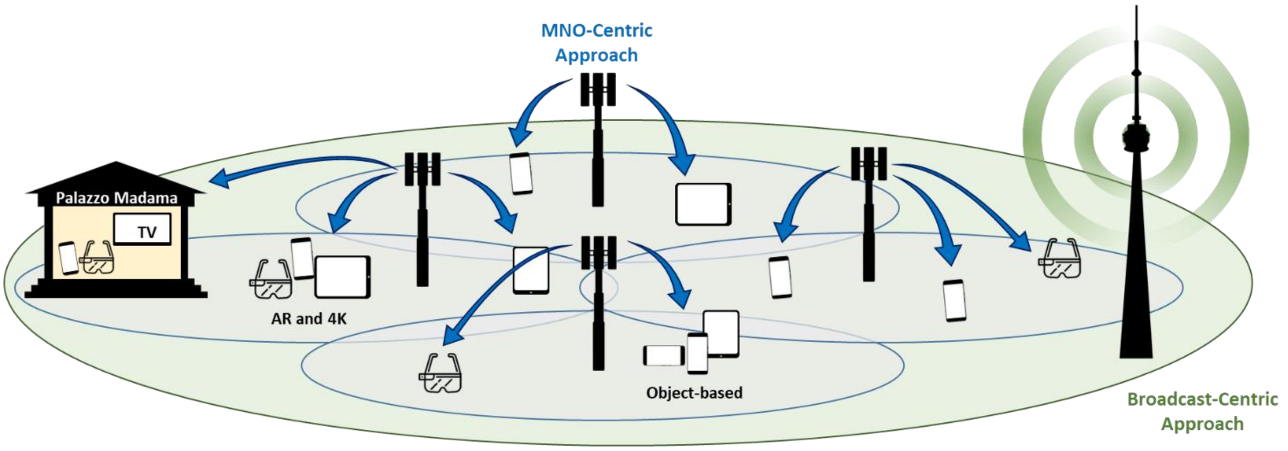

Figure 6: High quality video services distribution with both Mobile Network Operator (MNO) and broadcast-centric approaches

The above immersive experience is combined with high quality and personalized contents simultaneously distributed to a large number of users by relying on the use of advanced broadcast technologies. For instance, object-based transmissions, where the content is divided into objects (video elements, audio elements, captions, subtitles, music type, etc.), is an efficient approach for delivering such contents to users with different requirements and preferences (e.g., language, simple or complex tour, personalization, etc.). The common objects can be delivered by using multicast/broadcast, while the objects for personalized content can be delivered with a unicast service. Then, the final personalized rendering is to be done by the application in the user terminal. This use case not only encompasses the provision of object-based content, but also VR/AR or traditional linear TV content. The project will explore two possibilities for the efficient delivery of such content.

First, the consortium will consider an **MNO-centric approach**. In this case, the content is transmitted via the cellular 5G network in a mixed mode where multicast/broadcast and unicast share resources. The second option is a **broadcast-centric approach**, where a broadcaster's infrastructure with High-Power High-Tower (HPHT) topology is used to transmit receive-only content to all users simultaneously.

3.1.4.4 Innovation potential

Point-to-multipoint techniques are traditionally used to satisfy the needs of high-quality video distribution to a multitude of users. Since the use of unicast transmissions to this end would be highly inefficient, the support of broadcast and multicast is essential. Its combination with 5G networks brings a unique topic to the project.

The combination of multicast/broadcast capabilities with the transmission of immersive content also brings a unique and innovative use case to the project. The use of new immersive technologies will create new solutions that are engaging and will allow users to live experiences in the tourism world as never seen before. In other words, A/V content transmission to smartphones and AR devices will also impact the way that tourists visit cities nowadays. Additionally, these applications entail a new paradigm for the delivery of media content. In contrast to traditional TV applications, here content can reach the user anywhere, favoring the content of interest in the proximity of the user (e.g., when visiting an attraction).

3.1.4.5 Service level objectives

The main objective of the use case is the transmission of high-definition and immersive content to different devices by using point-to-multipoint technologies developed within the 5G-TOURS umbrella. The use of broadcast and multicast services to provide different types of content to many users at once will permit the museum to reach a higher number of visitors that experience the touristic content with a very reduced cost of spectrum resources.

Regarding the type of content, naturally the transmission of ultra-high definition (UHD) or immersive media will enhance the experience of visitors to the museums as compared to nowadays' visits. The main objective of this use case is to increase the number of visitors to the museum by using these technologies in a consistent manner. Immersive media will also contribute to prolong the time of visitors in the museum or the surroundings, in the case of outdoor services.

3.1.4.6 Business and economic implications

5G, along with its multicast/broadcast capabilities, is expected to impact the business model of broadcasters and media companies. The use case offers new opportunities to actors involved in the tourism sector, which can reach new mobile users with localized content (e.g., content about Palazzo Madama to the visitors of the museum), engaging users as an active part of the process (with immersive user experiences). The value provided to the users and the subsequent economic impact will be evaluated by actors involved in the use case.

3.1.4.7 Social and environmental benefits

The use of 5G will permit the enhancement of cultural experiences such as the visit to a museum. The 5G architecture developed in 5G-TOURS will increase the attractiveness to visitors and tourists, by developing AR and A/V applications that provide immersive and interactive media. In addition, these A/V content will be focused on education, not only for tourists but also for school students, to enrich the educational experience and make it more attractive.

3.1.4.8 General requirements

Immersive A/V services require edge-computing equipment for fast server processing, ensuring very reduced latencies. This is especially important to keep a good user experience when transmitting AR content. This use case also requires extremely good reliability with very-high data rates to deliver the content with consistent and extremely good quality. Another requirement is the capacity to cover a high density of users. Up to several users per square meter are expected in crowded areas such as the museum or its surroundings.

The main use case components to make this use case a reality is, on the one hand, a 5G network including both Core and Radio Access Network (RAN) with multicast/broadcast capabilities. On the other hand, 5G compatible receivers, which in turn can be AR devices (e.g. HoloLens) or smartphones. Smart TVs with connectivity are also needed in the museum.

3.1.4.9 Preliminary technical requirements

The main service level objective of this use case is to provide the same high-quality content to an extremely large number of users with high reliability. Another objective is the use of innovative A/V formats such as object-based video and AR. Finally, enhanced Broadcast solutions shall be put in place for this UC. The specific requirements are the following:

Metric	Required value
Latency	≤ 10 ms (bidirectional mode) N/A for Point-to-Multipoint (PTM) mode
Reliability	99.9999%
Mobility	250 Km/h
Coverage	Venue (museum, and surroundings) / Turin city (radio ~15 km).
Data rate per user/device	≥ 25 Mbps

Table 4: Preliminary network requirements – use case 4

3.1.4.10 Location and site facility

The trials of this use case will be done in the city of Turin. In particular, they will take place in Palazzo Madama, its surroundings and the other locations to be defined in the progress of the project, as depicted below.

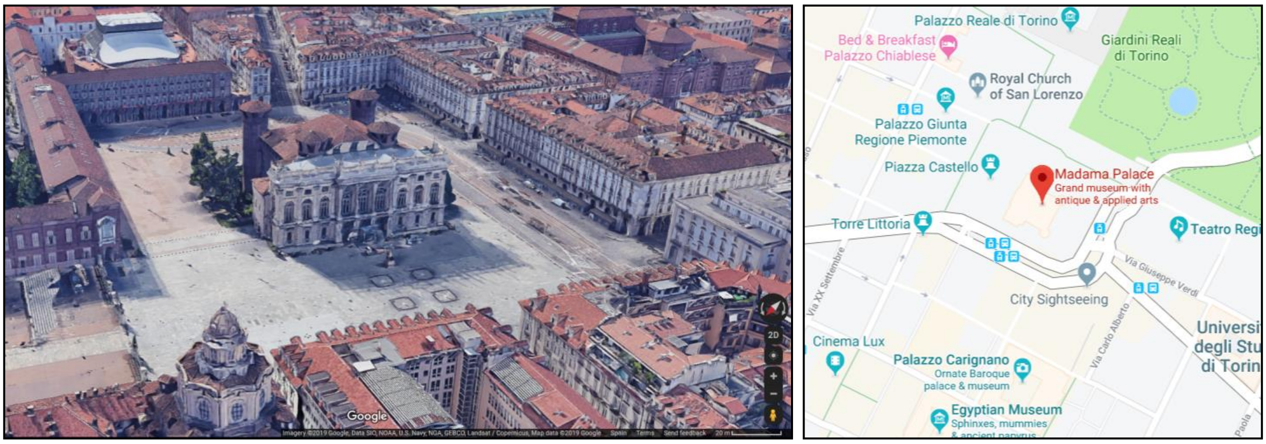

Figure 7: Location and site facility: Palazzo Madama in Turin

3.1.4.11 Trial Overview

The trials for the video distribution use case will be done by using the 5G non-standalone (NSA) infrastructure of both the network provider and the MNO. The first option is to develop an MNO-centric network with (PTM) capabilities. This network is intended to be updated to a 5G standalone (SA) core network with PTM capabilities. The second option is the use of a broadcaster's infrastructure to transmit linear TV content via enhanced TV (enTV) Rel-14 and Rel-16. Each option will have a series of trials associated in order to validate and demonstrate the technologies implemented.

3.1.4.12 Stakeholders

The main stakeholders of this use case are:

- The network provider and the operator, which will provide the 5G network infrastructure for the trials and ensure that the necessary spectrum is available when the trials take place.
- Broadcasters to deliver point-to-multipoint services through a broadcast network.
- Manufacturers, by providing 5G devices to perform the trials. Examples of these devices are smartphones or AR googles.

- The consortium to ensure that the broadcast middleware is correctly implemented in such devices.
- The municipality to facilitate the entrance to all players involved into the museum for performing the trials.
- Tourists and students that will enrich their experiences by using 5G technologies in real time.

3.1.4.13 Security requirements

As specified in use case 1, the solution developed in the context of this use case will not address security requirements since the consortium not consider them as a key part of the solution. However, partners involved in the use case will ensure that the network security guarantees correct handling of any type of confidential content. In addition, the project will minimise the collection, storage and processing of personal data where possible.

3.1.5 Use case 5 - Remote and distributed video production

3.1.5.1 Domain overview

The video production process for creating a program may involve developing a script, creating a budget, hiring creative talent, designing a set, and rehearsing lines before filming takes place.
The multiple camera method is used for shooting inside or outside a studio. A number of cameras are focused on the action taking place on the set, and scenes are shot in sequence. Each camera operator works from a list of camera positions and framing requirements for the full scene. Together the cameras cover all required view angles.
Using headsets to communicate with the camera crew, the director asks for camera adjustments during the filming of the scene and indicates to the technical director which cameras to use at each moment. The technical director ensures the selected shot is recorded. The result is a fully edited, complete show, needing only sound effects, music, optical effects, and titles to be complete.
The main challenge of the use case is to exploit the 5G-TOURS network features for remote video production, in which the director is located far from the set where the action is taking place, and also in the case of covering live events.

3.1.5.2 Target customer

With 5G technologies, MNOs will offer new services for remote distribute production in city areas allowing customers as broadcasters and media companies to use new tools to produce TV content. Therefore, the main target customer for the use case are media companies that are engaged in content creation. The personnel involved in the production of a TV program include creative talent such as actors, directors, writers, and producers as well as technical crew members such as camera operators, electrical technicians, and sound technicians. This use case is related to media companies.

3.1.5.3 Use case description

The objective of this use case is to analyze how 5G networks could support various scenarios where high-quality video (e.g., in 4K, High Definition (HD)/High Dynamic Range (HDR) or Video 360°) is created and transmitted. Video contents could be delivered from cameras located in places where an event is taking place to a TV studio in the broadcasting center or to a remote studio facility on the event location itself. Such video contents could be used both for immediate live broadcasting of the event or recorded to be further edited and used in TV programs to be broadcasted later on.
In case the video production is distributed, 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 challenge in this scenario is the end-to-end delay between the local and the remote site, which must be kept very low and constant. Furthermore, each AV flow at the remote site can be only mildly compressed before transmission to preserve sufficient headroom for editing and distribution coding, so the content size needs to be large. On the other end, the number of required remote flows is planned in advance and kept fixed during the program production. The final program can then be distributed to the users live or at a later time, as depicted in Figure 8.

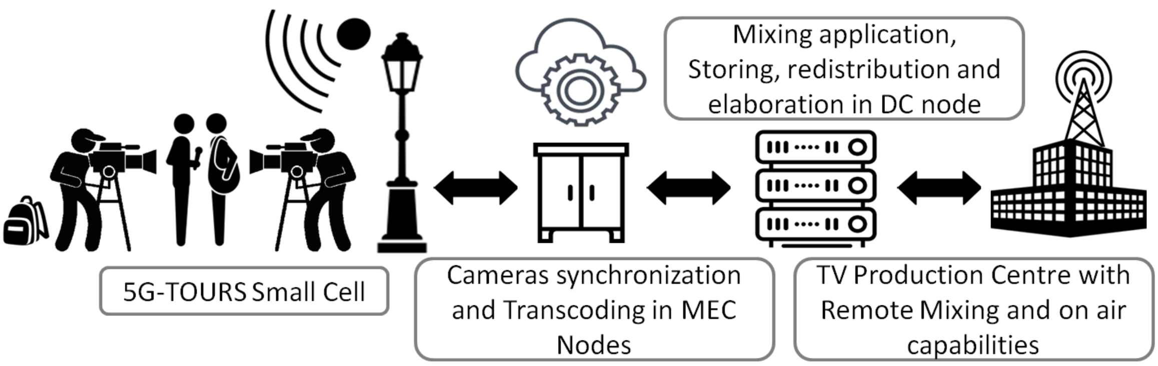

Figure 8: Example of a remote production environment

An example of this use case implementation is an **itinerant orchestra**. Here, the event is a concert performed by an orchestra with some musicians located in the main concert hall and some other itinerant musicians walking in the streets while approaching the concert hall. Each itinerant musician is followed by a cameraman shooting their performance and providing cues to stay in synch with the main orchestra performance. The high-quality AV signal (HD, 4K, Video 360°) is streamed via the 5G network to the main editing facility where it is properly processed and mixed with both the rest of itinerant musicians and the orchestra located in the concert hall. The spectators in the concert hall will see the itinerant musicians on a Light Emitting Diode (LED) wall and listen to their performance via an amplification system, mixed to the local orchestra, until they enter the concert hall and join the orchestra. The overall performance will be recorded for future broadcast distribution (see Figure 9).

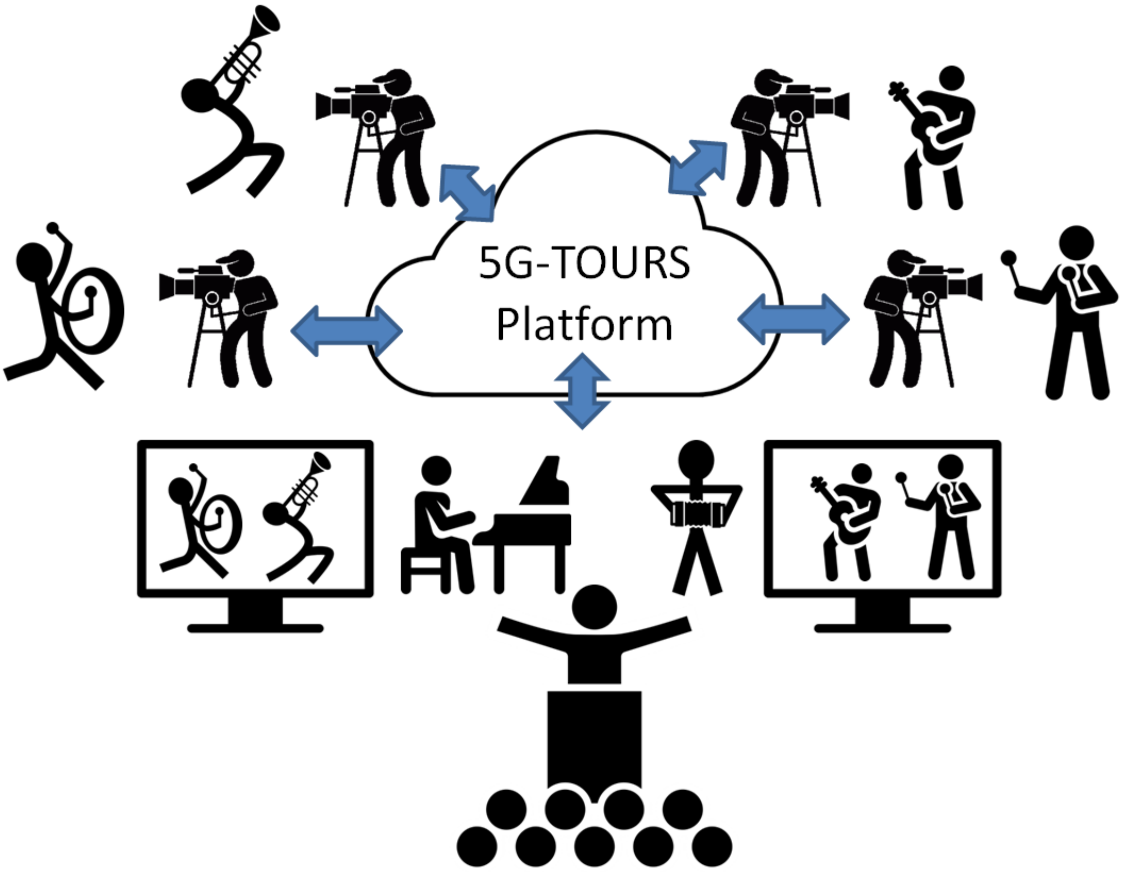

Figure 9: The itinerant orchestra work flow

3.1.5.4 Innovation potential

The use of remote production over 5G networks for TV content can revolutionize the typical work flow of broadcast and media companies. The incoming 5G networks will be a disruptive technology for the broadcasting world, for example the availability for MNO to offer services for remote distribute production in city areas, allowing broadcasters and media companies to rethink the way to produce TV content, saving money and optimizing efforts of employees. In this environment this benefit will be massively involved to give to director and authors new tools to realize high quality new TV product.

The use case is extremely challenging, it needs very low and stable delays, an ultra-reliable capability and a very large bandwidth capacity in order to reach a good final result. One of the biggest challenges in this use case is to synchronize the audio coming from the different sources and make sure that all musicians are playing in sync with each other.

3.1.5.5 Service level objectives

The main objective of the use case is to exploit the 5G TOURS network features for remote video production, in which the director is located far from the set where the action taking place working in seamless way, and also in the case of covering live events.
The main service level objectives of this use case are:

- improving video quality of live connections (real-time transmission).
- enabling the mobile unit to utilize more bandwidth (provisioning a specific slice with a guaranteed QoS).
- enabling the use of edge computing processing capabilities for production of video contents at the edge of the network.
- supporting the work flow typically used by broadcasters and media companies.
- providing low delays and data flows synchronization.

3.1.5.6 Business and economic implications

The main target stockholder for the use case is media companies that are significantly involved in content creation. The personnel involved in the production of a TV program include creative talent such as actors, directors, writers, and producers as well as technical crew members such as camera operators, electrical technicians, and sound technicians, then the work flow of content production is very complex.
This use case aims to verify that the exploitation of new network technologies will increase the productivity of content improving the whole work flow for the TV production.
At the same time new services and new TV formats could be created from the joining between new technologies and creative people.
In any case, this use case, is an example in how 5G technologies will enable the new business-to-business (B2B) market between media verticals and network and service operators.

3.1.5.7 Social and environmental benefits

The purpose of the use case is to contribute to the increase in value creation and value capture surrounding cultural events taking place within the territory of the cities involved in the experimentation. In particular, it aims to broaden the media coverage of events by helping to deliver content to tourists present or transit through the city. In addition, live 360 ° shooting of events, distributed through a specific App on smartphones, will give tourists and locals a full immersion experience in the place thanks to the VR viewers. This aspect will help to improve local, national and international tourism with social and economic utility for cities.

3.1.5.8 General requirements

The itinerant orchestra use case data flow is constituted of two consecutive parts. The first part includes transmission of high-quality video from multiple locations to a local/remote studio. This implies the involvement of a video production team (cameramen, local producer, director and staff) and all equipment in order to connect the TV production teams with the 5G network to reach the mixing room whereas the second part includes video production and live video transmission to a number of wall LED screens as well as to spectators’ devices.
The use case in general needs very low and stable delays, an ultra-reliable capability and a very large bandwidth capacity.

3.1.5.9 Preliminary technical requirements

The use case needs very low and stable delays, an ultra-reliable capability and a very large bandwidth capacity. We can summarize indicative relevant 5G KPIs as follow:

Metric	Required value
Latency	≤ 10ms (bidirectional mode), taking into account to use audio streams to synchronize all content
Reliability	99.9999%
Coverage	Turin city - where remote musicians are moving The auditorium where the event take place
Data rate per user/device	≥ 25 Mbps (for each video)

Metric	Required value
	Note - it depends by the coding of videos, to avoid additional delay from the video coding phase some very low delay coding mode is needed.

Table 5: Preliminary network requirements – use case 5

3.1.5.10 Location and site facility

The trial site will be the city of Turin, the exact locations are to be defined according to the network infrastructure. In general, we have to cover areas where remote musicians are moving and the auditorium where the event take place (e.g. the auditorium Rai "Arturo Toscanini").

Figure 10: The auditorium Rai "Arturo Toscanini"

3.1.5.11 Trial Overview

Currently almost all TV content producers are using what in popular language is called a “backpack unit” for video transmission in remote areas. The backpack unit bonds multiple 4G connection together to transmit the video signal back to the TV studios for further processing. This use case will demonstrate how the 5G-TOURS architecture will improve the available bandwidth of live connections (real-time transmission) and will enable low delays leveraging on features of 5G network. The 5G-TOURS system will enable the increase of bandwidth used for live connections, providing specific slices with a guaranteed QoS. Furthermore, 5G-TOURS architecture could exploit the capabilities of 5G network enabling video processing at the network edge instead of studios, reducing high production costs of multi-camera events covering.
In particular, for the itinerant orchestra we plan to build an environment in an incremental way. The first step is to arrange the entire technical infrastructure which enables the second step in which (a few in number) testing musicians will be involved to test the whole system. Then, the last step, will be the organization of an event with the involvement of a real orchestra.

3.1.5.12 Stakeholders

The described use case has a strong impact in the 5G ecosystem in terms of involved actors. it is possible to identify the following stakeholders:

- Hardware (Equipment) manufacturers / vendors: providing the necessary equipment in the 5G-TOURS architecture in order to cover all requirement to run the use case on different parts, ICT related, networking equipment and end user devices.
- Software Developers: Developing services and applications that can benefit the potential and capabilities of the 5G-TOURS architecture fulfilling the requirements of media company users.

- Infrastructure owners: hosting the computing, storage and networking infrastructure needed to run the use case.
- Network Operators (ICT infrastructure providers): exploiting the physical resources of the network.
- Content/Service Providers: in particular broadcasters and media companies, taking advantage from the 5G-TOURS architecture in order to create new and innovative content and services.
- End Users: enjoying new services and new devices that, exploiting 5G features, will be offered from all different actors involved in the telecommunication ecosystem, also taking into account that the end user can become a content producer for new services.

3.1.5.13 Security requirements

This use case will not use any sensitive users' information, therefore no GDPR compliant policy is needed. Furthermore, it considers all specific needs in term of security, privacy and copyright aspects, to protect the author's Intellectual Property Rights (IPR). Therefore, in order to prevent IP spoofing, packet sniffing, and network man-in-the-middle attacks, this use case requires a proper isolation from others network tenants and possible malicious users.

3.2 Safe city use case

The Safe City aims to demonstrate how multiple vertical industries can simultaneously use the same 5G architecture and services to deliver advanced use cases to citizens. In order to facilitate this the project is setup around three key themes across specific cities of which Rennes has been selected to demonstrate the use case family designed to provide a safe journey for tourists and local citizens alike. These use cases are as follows:

- Use case 6 - Remote health monitoring and emergency situation notification
  - Using wearables and devices to enable remote monitoring using a variety of datasets and quick, reliable notification of nearby ambulance or medical staff.
- Use case 7 - Teleguidance for diagnostics and intervention support
  - Enabling new interaction possibilities between hospital-based experts and first responders using AR, enhanced vision and remote access to complex medical equipment.
- Use case 8 - WOR
  - Delivering a new paradigm for operating theatre usage including Augmented Assisted Surgery, synchronous multiple video sources and enhanced surgeon feedback for Image Guided surgeries.
- Use case 9 - Optimal ambulance routing
  - Combining AI and multiple data sources with the patient condition to define the optimal routing of ambulances to ensure most efficient and safest routes are taken.

Rennes is an active metropolis at the heart of a very high-level economic, digital and academic ecosystem. Capital of the Brittany region and only 90 minutes from Paris it also has very favourable demographic dynamics (450 600 inhabitants, + 1.2% per year). Ranking third among French metropolis for its GDP and second in terms of attractiveness for students, it is also regularly acclaimed as one of the cities of France where life is good with a commitment to strong economic development, respectful of the environment and promoting a harmonious social life.

The scenarios covered by the use cases consist of two patients who are both doing a touristic tour in Brittany, thereby paying a visit to Rennes.

- During this visit, one person is involved in an accident suffering from **respiratory distress related to a pneumothorax** and **reduced heart function** due to **pericardial effusion.**

- The other person who is staying at the hotel is suffering from **breathlessness, related to aortic valve stenosis.**

In emergency care, teleguidance is especially important in case a patient is critically ill and will not survive transportation to the hospital, while it is difficult to diagnose the causes of this condition and not clear what to do. 5G technologies will be used to enable novel enhancements to traditional care techniques such as enabling live AR with advanced computer vision and 360 cameras providing richer contextual information enabling better quality of care during treatment. Other possibilities include the ability for experts in the hospital to remotely access and even control the settings of equipment being used on scene by ambulance doctors.

In addition to the enhancement of care at the scene; 5G capabilities will also be utilised in the safe and efficient transport of patients using a variety of data sources whilst ensuring prioritised communications throughout the incidents.

3.2.1 Use case 6 - Remote health monitoring and emergency situation notification

3.2.1.1 Domain overview

Remote health monitoring is becoming more and more popular attracting the interest of patients and healthcare professionals. Patients receive proper diagnosis and treatment at an early stage and their medical situation can be evaluated by multiple doctors reducing the wait and travel time. On the other hand, physicians have the opportunity to access to the patients' health and medical parameters in real-time. Emergency situation notifications are an essential part of remote health monitoring. The fully integrated communications system supported by 5G will be able to deliver automatic escalation of alerts giving the opportunity to the travellers (or citizens in general) to feel safer.

Health and social care services will benefit from 5G technology in various ways. Using high speed 5G networks in the existing infrastructures related to remote health monitoring, the velocity and the reliability of the data transportation will experience significant changes, as the 5G's abilities penetrate further than the current wireless networks. The sensors, the actuators and the communication technologies have to work in concert in order to provide services achieving comfort, high level performance and usability. Today's restrictions on the bandwidth and the quality of the services in the mobile communication systems will be significantly extended.

The accuracy and the quickness of the information are the main challenges of this use case, as well as the interoperability of the data. Additionally, dealing with real users, there are always errors or failures attributed to the human factor. Despite emerging difficulties, this use case can be addressed through well-defined emergency planning strategies. Through the aforementioned mechanisms and functionalities supported by 5G, an effective and accurate risk management can be achieved.

This use case will demonstrate how 5G can enable early detection and forecasting of emergency situations to mitigate the risks and improve the quality of life especially of patients with chronic diseases (e.g. hypertension, cardiovascular diseases, etc.).

3.2.1.2 Target customer

Patients (with chronic diseases, elderly, post-surgery, etc.), Emergency Medical Services (EMS) and hospitals will be the main vertical customers for the remote health monitoring and emergency situation notification.

3.2.1.3 Use case description

Enabling remote monitoring, especially when it comes to a person diagnosed with a disease, and consultation by their medical attendants, as well as their remote collaboration with the local medical personnel leveraging advanced technology in case of an emergency is expected to act as additional motivation for travelling. The main features offered by this use case involve (a) remote health monitoring services leveraging a variety of datasets, including, but not limited to, health signs, air quality, weather conditions, site waiting times, transportation, traffic and location, and (b) quick, reliable notifications to nearby ambulances, medical professionals and family members in case of a health incident or a health emergency prediction. The use case will leverage wearable devices tracking the tourist's vital signs and having them aggregated inside an IoT-based platform named STARLIT (**S**mar**t** living pl**a**tform powered by A**r**tIficia**l** **i**ntelligence & robus**t** IoT connectivity), where they will be processed in a combined fashion exploiting also various city sources and open APIs (providing information on aspects such as weather conditions, traffic, etc.). At this point it is envisaged that devices will be connected with the rest of the system (server at the edge or cloud platform) via a gateway. This gateway will be installed in close proximity with to the devices and will be responsible i) for connectivity, ii) for acquiring data (measurements), iii) for performing a lightweight processing of these data and finally, iv) for transmitting them to the dedicated servers, using available communication technologies and protocols. This gateway will also realize the function/intelligence for switching between different reporting modes for different devices (potentially supported on this by intelligence at the edge). It should be noted that while actual devices connected in some way will be used to showcase connectivity aspects, these will need to be combined with emulated data (given the complexity of involving actual patients) to carry out detailed evaluations and to also showcase aspects such as scalability of the use case solutions. STARLIT's outcome will be the identification or the prediction of a health-related emergency situation, which will be followed by the immediate notification of the dispatch center of the Rennes University Hospital.

3.2.1.4 Innovation potential

Improved connectivity, cloud-based storage and an array of connected devices and services, will be consolidated through 5G capabilities. With the exploitation of 5G technologies the solutions for mobile remote health monitoring and real-time assessment by physicians will become much more reliable. More specifically, 5G will facilitate fast and reliable data acquisition from various sources that will in turn enable real time remote monitoring on the go and the derivation of knowledge from observed data that will allow for personalised support of patients, offering early and reliable detection of health issues and providing real time alerts/notifications to appropriate medical staff. The overall aim is to exploit the speed and reliability that a 5G network promises to further increase the automation and peace of mind of people with certain health conditions thus improving overall quality of life, as well as potentially reducing healthcare costs.

3.2.1.5 Service level objectives

This use case aims at making subjects and health care staff feel better supported in the case of an unexpected / emergency condition, providing simple, usable, low cost and comfortable services by remote health monitoring. The main service level objectives of this use case are reliable real time remote health monitoring on the go and fast detection or even forecasting of a health issue and consequently the improvement of patients' outcomes.

3.2.1.6 Business and economic implications

The solutions comprised as part of this use case can contribute to reducing the overall health-care costs by reducing the number of times required for physical visits to the doctor or hospital and hospital (re) admission. Moreover, with the possibility of early detection and forecasting of health issues while the patient is on the go, for instance while travelling, appropriate measures can be taken for timely addressing health issues as they may occur; this again can contribute to the reduction of associated healthcare costs outside of the patients' country of origin. At the same time patients with chronic diseases or health issues can potentially increase their participation to daily life activities and in general become more active thus increasing their contributions to the overall economy (e.g. by spending money on travelling and touristic activities which they might otherwise be unable to participate to).

3.2.1.7 Social and environmental benefits

The nature of this use case is such that there are mainly social benefits. Remote health monitoring has the ability to offer patients and their care teams a set of tools that can enhance outcomes and lower costs. Adding the advantages of 5G technologies in the remote health monitoring and emergency situation aspects, the overall quality of provided care is improved and both patient and doctors feel safe as they have real-time access to information related to patients' health and they also have direct communication (doctors and patients). As already mentioned, the speed and reliability that a 5G network promises can be utilised in this use case to increase the automation and peace of mind of people with certain health conditions thus improving overall quality of life, as well as potentially reducing healthcare costs. Last but not least, the chances of survival of critical patients increase through early detection and forecasting of health issues while the patient is on the go. In terms of environmental benefits, it could be noted that fewer trips to the doctor or hospital may be required (or from the doctor to the patient) and thus a small contribution towards reducing emissions could be seen as an environmental benefit of this use case.

3.2.1.8 General requirements

Remote health monitoring requires some distinct component for the use case implementation as well as specific series of functions for their effective communication. A set of machine type communications is foreseen in the context of continuous monitoring of the user's health condition, as well as of city sensors so as to offer a combined touristic health-aware experience.

Input devices (biosensors, wearable devices, smartphones, etc.) are used for the data collection (biological measurements, vital signs or disease-specific indicators) which are transmitted and displayed near real-time to dashboards for the user and family members as well as responsible physicians, while the gathered information can also be stored in a local repository (cloud-based infrastructure) to be transmitted to the healthcare facility through different types/forms of communication. The appropriate software/AI mechanisms will automatically examine the data and if something abnormal exists, notifications/alarms will be sent to the doctors/caregivers/emergency responders and then immediate assistance will be provided to the patient. In case of an identified emergency low latency communications (URLLC type) will be required.

3.2.1.9 Preliminary technical requirements

The fully integrated 5G System (5GS) promises a high level of performance through the aforementioned functions with high reliability and low latency communication for fast notification of affected users, family members, corresponding physicians and ambulance services if/when required. As this is a health-related application, reliability and latency are crucial for the correct and efficient operation of the use case. KPIs (corresponding to KPIs defined by the 5G Infrastructure Public Private Partnership (5GPPP) [13]) are also summarized below.

Metric	Required value
Latency	<10 ms
Reliability	99.999%
Location accuracy	≤ 200 m
Mobility	Up to 100 Km/h
Coverage	Full coverage

Table 6: Preliminary network requirements – use case 6

3.2.1.10 Location and site facility

The trials for this use case will be carried out in Rennes with the Rennes University Hospital in France.

3.2.1.11 Trial Overview

While further details on the trial setup will be detailed at a later stage, it is important to mention that an important choice already made is the use of emulated users/data and/or phantoms, instead of real patients or real patient data. Using real patients and their data is considered ethically undesired in this phase.

The overall story supposes Maria, the mother of the tourist family, to have a family history of chronic cardiac pathology and as such is medically followed by an Italian medical team. We will mainly focus of cardiac signals as well as of physic activity monitoring.

Initial focus is on testing how to make this tele-monitoring concept appreciated by the hospitals and emergency services.

The bandwidth and latency aspects will be validated with a real 5G network, if possible, with some parameters to degrade the performance to simulate expected ‘non-ideal’ circumstances.

Various parameters related to health/vital signs of a traveller with a health condition are continuously collected from wearables (e.g. heart rate, blood pressure etc.) along with other data relevant to the user’s health condition (e.g. air quality, weather conditions, site waiting times, transportation, traffic and location). Real-time data are transmitted and displayed continuously to remote medical experts as well as the traveler and family members via appropriate dashboards. In the event of observed abnormalities in the vital sign values collected notifications are sent to medical experts and alarms are raised to trigger the necessary actions (e.g. if the blood pressure or the heart rate does not reflect normal levels and the patient probably suffers from cardiovascular disease, notifications to nearby ambulances, medical professionals and family member will be sent). Notifications/alarms can also be raised in case something is not yet abnormal, but the data analysis of recorded values show a predictive trend towards a potential problematic situation (e.g. increasing blood pressure which has still not reached a certain threshold may still be worrying). In this case a notification is issued to the user’s smartphone that informs the user for the possible upcoming health situation. At the same time a designated doctor/health care professional is informed about the possible abnormality of the person under supervision. In both cases (reactive and proactive) if the medical experts deem it necessary an ambulance can be dispatched immediately to the current location of the user (see also use case 9).

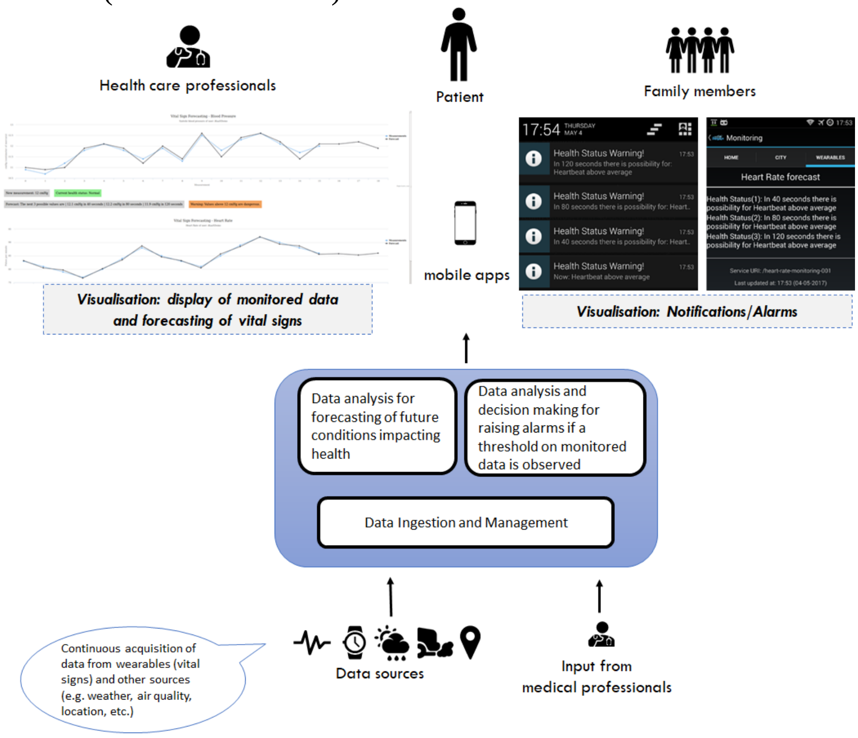

Figure 11: Remote health monitoring and emergency situation notification overview

3.2.1.12 Stakeholders

The main stakeholders for this use case are the following:

- Health care professionals and hospitals that will be facilitated in their work and will be able to provide their services more efficiently by receiving real time information on patients under their care.
- People with chronic conditions and their family members that will be able to continuously monitor vital signs (e.g. heart-rate, blood pressure, respiration rate, etc.) and will receive alarms if an irregularity is observed or if a potential future problem is forecasted.
- Data providers and IoT solution providers that can enhance their service offerings by providing information required for the forecasting of potential health issues.
- Network providers that can enhance their service offerings by providing the network infrastructure required for the remote health monitoring and emergency situation notification.
- Infrastructure owners: hosting the computing, storage and networking infrastructure needed to run the use case.

3.2.1.13 Security requirements

Taking into account that this use case includes sensitive user data, various needs in term of security and privacy need to be considered. More specifically, authentication, authorization, and accounting are required. End-to-end encryption, automatic standard-based encryption from devices to applications and encrypting data in transit should be supported. Protection is required across multiple communication protocols. Privacy rules must be implemented as stated by the GDPR. Specific deliverables of the project are planned in order to ensure project compliance with the ethics requirements and to supervise and monitor their application in the trials. It is important to note that real users will not be involved, but emulated users/data and/or phantoms.

3.2.2 Use case 7 - Teleguidance for diagnostics and intervention support

3.2.2.1 Domain overview

In case of accidents and other medical emergencies, ambulances go out to the emergency location, and perform initial diagnosis and treatment. In urgent cases, they have only minutes to resuscitate and stabilize the patient, so the whole process must be fluid. Once the patient has been stabilized, and further treatment or observation is deemed essential, the patient is transported to a suitable hospital. Preferably, the hospital is informed about the incoming patient, so they can be as prepared accordingly.

Currently, the ambulance staff work mostly autonomously, relying on training and procedures. This works well for the most common scenarios but has limitations in less common cases. Furthermore, in the purely voice-based communication to the hospital about the incoming patient, valuable information may be lost.

The ambition of this use case is to leverage teleguidance and telepresence over 5G. This makes the ambulance resemble a virtual room of the hospital. Valuable experts can start looking at, thinking about and diagnose the patients, facilitating a seamless handover of the patient at arrival to the hospital. The Emergency Department (ED) is optimally prepared to start taking care of the patients, but other departments can also be prepared. For example, reserving time at imaging facilities or Operating Rooms (ORs). Having the experts immersively present at the site of the emergency enables them to quickly assess the context and overall state of the situation. They do not need to claim time and attention from the local emergency responders to provide high-level verbal reports.

In order to realize this ambition, the key is to have a solution that can be relied upon. Healthcare is a conservative domain, and innovations are only accepted when they fit well into the workflow and are perceived to always work.

3.2.2.2 Target customer

Emergency care as a whole is addressed in this use case. This includes emergency care / specialist departments in hospitals, emergency call centres and ambulance fleet organizations.

3.2.2.3 Use case description

The 5G connected ambulance can function as the "first room of hospital", enabling on-the-spot, direct treatment of the patient under the guidance of a remote expert in order to prevent further, and potentially irreversible, deterioration of the condition of the patient. The hospital may be far away from the patient and the ambulance, so the patient may not survive. Alternatively, permanent damage may by incurred to the patient during transport. The key to such situations is to perform a first diagnosis as fast as possible, in order to determine next steps. In particular, the emergency responders need to determine the best treatment to stabilize the patient, locate the most suitable hospital and, notify it to make all necessary preparations for the patient, e.g., prepare the OR and call all necessary medical staff. Especially in cases of trauma, immediate intervention strongly impacts the outcome, e.g., for hemodynamic unstable patients, in case of suffocation, internal bleeding, complicated fractures, critical prenatal cases, etc. The available equipment within the ambulance for monitoring, examining, and guiding interventions include ultrasound, which is rapid, non-invasive, portable, versatile and low cost, patient monitors and, 4K video. In addition, instant access to medical records is important to understand the patient's condition prior to the incident, which can also be visualized on AMA's Xperteye smartglasses (interactive HD head up display for monitoring patient's vitals, medical imagery, protocol; first person point of view live camera).

Next to the improvements for the staff in the ambulance, this use case will also evaluate whether the use of AR/VR over 5G can improve the situational awareness the medical staff in the hospital has, which positively impacts the quality of the teleguidance. AR/VR technology also brings enhanced video and spatial scanning features that further improve the immersion and richness of the presented information. These again should positively impact the quality of remote guidance and telepresence.

3.2.2.4 Innovation potential

5G connectivity is essential to this mission-critical use case. Network slicing technology will be exploited to have the appropriate quality of service. Furthermore, the data rates and low latencies achievable with 5G should enable a much more natural telepresence than is currently possible.

3.2.2.5 Service level objectives

Service level objectives are differentiated into primary and secondary objectives.

Primary objective:

- Improved patient outcomes, e.g. lives saved, faster recovery.

Secondary objectives:

- Making health care staff feel better supported in difficult situations.
- Cost reduction due to better informed choices in the care path.

3.2.2.6 Business and economic implications

There are many experts in hospitals, whose expertise could be used when handling incidents. Of course, it is not feasible to send all such experts in every ambulance. 5G can bridge this gap to some extent: experts in a hospital can virtually join the ambulance at the moment their expertise is required. An intermediate solution is to have dedicated hospital staff available to support the ambulances, with this staff being trained to an intermediate level in a broad spectrum of medical disciplines. Operational efficiency with respect to scarce skills will reduce costs and create value.

3.2.2.7 Social and environmental benefits

The primary goal is to improve patient outcomes: better and faster treatment of patients in emergency situations, resulting in improved quality of life for citizens. Secondary benefits follow from this in the form of reduced cost and material usage for treatment, and better use of scarce specialists.

3.2.2.8 General requirements

The following figure illustrates the flow of the use case.

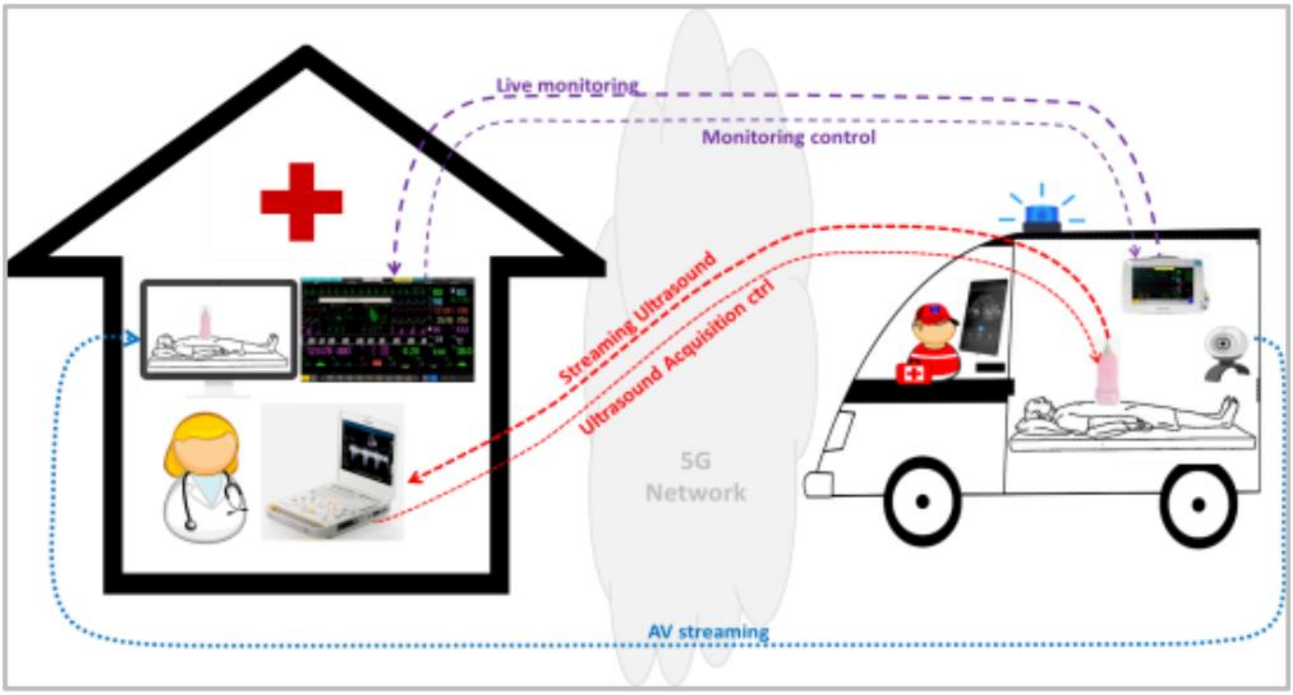

Figure 12: Teleguidance for diagnostics and intervention support - use case context

In this use case, the ambulance staff gets tele-guidance from an expert in the hospital. This expert should base his guidance on live video from cameras in the ambulance and the camera in the smart glasses, as well as ultrasound image data. The expert should also be able to control the ultrasound acquisition parameters of the ultrasound equipment in the ambulance directly. The received ultrasound images must be interpreted directly

by the expert in the hospital or must be fed into clinical decision support algorithms to help the expert. Inside the ambulance, the staff must get the guidance through smart glasses. Additionally, the staff should also be able to retrieve information from the medical file of the patient through the smart glasses.
Inside the hospital, the expert will have the option to use regular displays to keep overview or use AR/VR technology to immerse himself in the situation in the ambulance. The immersion aids in making the context and situation understandable without the need for local staff to manage information provisioning for the remote expert. In the ideal case, this creates a virtual team, consisting of the emergency responders and the hospital expert. They should enable the experience of an uninterrupted workflow and dialog within the team.

3.2.2.9 Preliminary technical requirements

The previous requirements lead to the following communication-centric technical requirements:

- High dependability: the solution should work everywhere and always in the safe city.
  - Bandwidth and latencies should be always sufficient for clinical use.
  - Even in very crowded situations, e.g. with priority over all non-essential 5G traffic.
  - It should not depend on where the ambulance is parked.
- The network capacity should be available with very little advance notice (<1 minute).
  - Keeping the bandwidth continuously reserved is a waste of resources and unnecessarily expensive, so an 'instant' slicing based solution is probably desired. This impose a stringent requirement on the service creation time.
- This use case focusses on a single ambulance.
  - In more advanced scenarios, e.g. a major emergency, a hundred ambulances may be involved, although probably not all of them will use tele-guidance.
- While the tele-guidance is expected to happen in a stationary situation, it is desired that most functionality is still available during transport of the patient to the hospital.
- Data streams:
  - Three camera video streams from the ambulance to the hospital. Per camera:
    - HD / 4K.
    - ~ 45Mbps.
    - ~ 50ms latency end-to-end including compression.
    - Two static cameras, one smart glasses.
  - Ultrasound data streams towards the hospital:
    - ~720p resolution.
    - ~ 5Mbps (compressed) / 30Mbps (uncompressed).
    - ~ 50ms latency end-to-end.
  - Guidance AR video stream towards the ambulance, for display on smart glasses:
    - ~720p.
    - 5Mbps (compressed).
    - ~ 25ms latency end-to-end.
  - Smart glasses position + orientation data stream towards the hospital.
    - Needed to generate AR video stream.
    - < 100 kbps.
    - ~25ms latency end-to-end.
- Location accuracy is not a critical parameter.

Discussion:

- Latency is especially relevant for AR/VR applications where movement of the smart glasses or Ultrasound probe should be reflected as fast as possible in the augmented video. Ideally this would be 10-20ms end-to-end round-trip. 50ms round trip would provide a less seamless experience but could probably be made to work acceptably. Tolerable latency also depends on the task the data is being used for. Sometimes latency can be compensated for with bandwidth, e.g. streaming foveation codecs for 360° video, but not always, e.g. feedback loop on device positioning and image forming.
- Even more important than low latency is low jitter and synchronization. Humans can work with some latency, but consistency in latency (low jitter) and synchronization (same latency) between multiple video streams are essential.

- Reliability (in terms of packet loss) is not easy to specify as a number. Much depends on the robustness of the application-level software and the network protocols chosen. For example, Web Real-Time Communications (WebRTC) video-collaboration software can either use User Datagram Protocol (UDP) or Transmission Control Protocol/Internet Protocol (TCP/IP), with different tradeoffs on user experience.

3.2.2.10 Location and site facility

The trial will be located at the Rennes University Hospital and the premises of B<>COM.

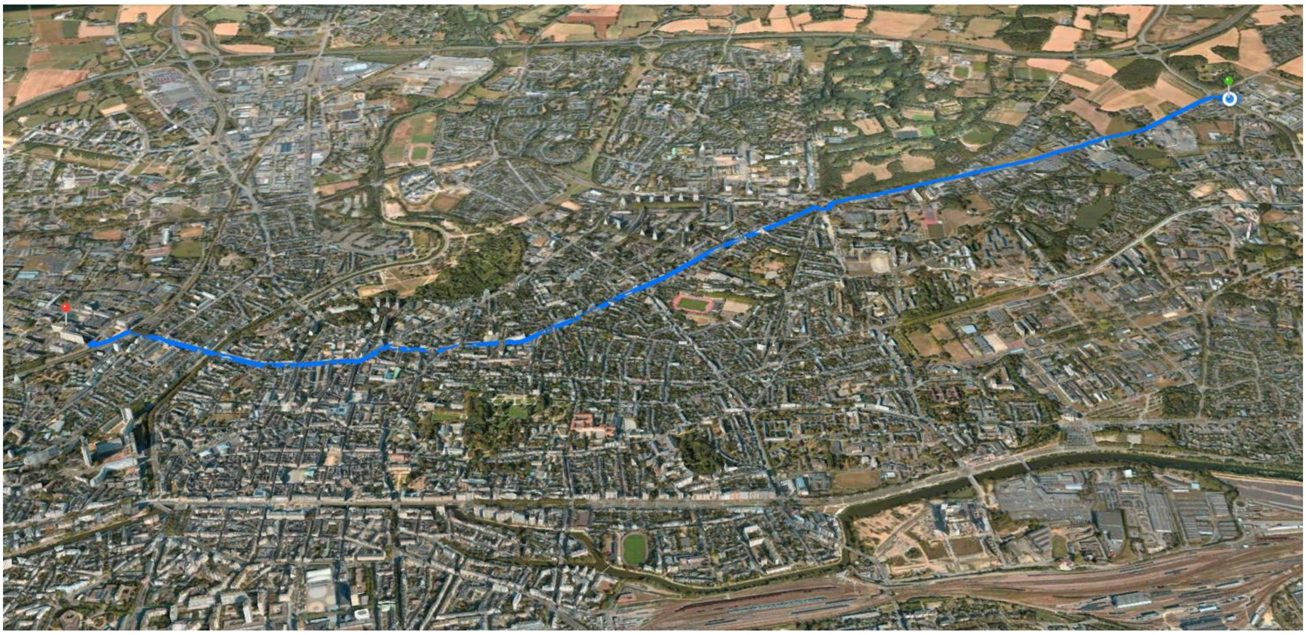

Figure 13: Teleguidance for diagnostics and intervention support - use case trial location.

3.2.2.11 Trial Overview

While further details on the trial setup will be detailed at a later stage, an important choice already made is the use of phantoms (like a crash-test dummy), instead of real patients or real patient data. Using real patients and their data is considered ethically undesired in this phase.
Initial focus is on testing how to make this tele-guidance concept appreciated by the hospitals and emergency services.
The bandwidth and latency aspects will be validated with a real 5G network, if possible, with some parameters to degrade the performance to simulate expected 'non-ideal' circumstances.
Dependability analysis can for now be done based on paper, e.g. based on detailed 5G coverage maps, and other service statistics.

3.2.2.12 Stakeholders

The main stakeholders are the following:

- Hospitals, including their IT departments.
- Emergency services.
- Ambulance staff.
- Medical specialists / experts.
- Medical device manufacturers.
- Generic 5G partners.
    - Technology providers, network operators, service providers.

3.2.2.13 Security requirements

While security will be an essential part of a final product / solution, for now there are no 5G and use-case specific security requirements. The trial will also be done purely with dummy and phantom based patient data, allowing the team to focus on the aspects where 5G makes a real difference.

3.2.3 Use case 8 - Wireless operating room

3.2.3.1 Domain overview

In this use case, we specifically focus on critical medical applications, which is a generic term covering medical devices and applications involved in the delivery of care for patient's survival. In this context 5G can help healthcare providers that face revenue pressures both to adopt new and more efficient care delivery models and to shift to outpatient services in order to reduce administrative and supply costs.
Image guided surgeries, claiming for less invasive procedures, become the main stream. Combination of multiple imaging modalities (e.g., endoscopy and X-Ray) implies hybrid rooms requiring interoperability among vendors, enabling a video monitor to display images coming from various equipment. Emerging AR applications, merging different sources in a coherent view, improve surgeon gesture but imply accurate time synchronization between videos and associated metadata (e.g., 3D position of sensors). In addition, imaging equipment are smaller, enabling to use them without prior planning. Finally, access to remote expertise is increasing in the context of practice involving more frequently collaboration between multiple specialists around the patient. Wireless communication as well as slicing, to be compatible with high bandwidth and low latency, makes 5G a very good candidate to contribute to the re-engineering of the OR.

3.2.3.2 Target customer

Hospitals will be the customer of WORs.

All hospitals should be engaged as target customers for wireless operating theaters solutions. Moreover, some of this wireless medical equipment can be used for other activities, including intensive monitoring in the resuscitation rooms or in the emergency services.
Public hospitals such as CHUs are concerned but also private clinics

3.2.3.3 Use case description

5G will be deployed in a real OR comprising several pieces of equipment for interventional procedures and ultrasound guided gestures, as well as videos produced by digital cameras, as documented in the TherA-Image platform [14] and depicted in Figure 14. A surgery enhanced with 5G connectivity improves the effectiveness of the OR, especially in cases of an unplanned procedure that needs to be performed during the operation. The quality, reliability and low latency provided by 5G makes it possible to support advanced medical applications such as Augmented Reality Assisted Surgery (ARAS) and Cobotic-aided surgery. In the same network infrastructure, various types of communications can be supported (e.g., ARAS, tele-mentoring using smart glasses, real-time broadcast of surgery for educational purposes, etc.) with a proper management of slices, providing the necessary degree of isolation and reliability to guarantee the quality of the critical slices ensuring the patient's safety. In case the patient is a tourist, the WOR room allows the home doctor of the patient to provide remote assistance.

Figure 14: TherA-Image platform at Rennes University Hospital

3.2.3.4 Innovation potential

OR theatre involves multiple communications going from pedal command to 4K video through Electro CardioGram (ECG) signals, all of them using different communication support. Rapid increase of communication channels makes it impossible to continue to keep various communication infrastructures (RS422, video coaxial, Wi-Fi, etc.) without mitigating the patient safety due to increased complexity. In the next 10 years, all communications will employ IP, on a necessarily consistent infrastructure still using different supports for its optimization and security. Slicing is required in WOR in order to support parallel communications with different level of technical requirements and priorities. Wireless communications will bring flexibility and largely simplify management of cables inside the OR, that is always very challenging for safe person circulation and equipment sterilisation issues.

3.2.3.5 Service level objectives

The service level requirements will be:

- enabling wireless video communication inside OR for better flexibility.
- maintaining a low end-to-end latency from surgeon gesture to secondary display or AR application.
- maintaining a very good time synchronization between video source to obtain an acceptable accuracy in AR application.
- enabling connection of additional video source without stopping the other ones.
- managing the priority between communication channels to ensure the patient safety.
- supporting high level of security since patient safety and privacy are concerned.

3.2.3.6 Business and economic implications

5G based OR will improve efficiency of surgical procedures:

- Patient benefit:
    - ARAS solution will allow surgeons to augment their real-world perception during the procedure with additional digital information, therefore helping them to execute more accurate gestures. URLLC and eMBB will be enablers, that will result in better and quicker treatments with reduced hospitalization duration.
    - Thanks to wireless communication and dynamic network reconfiguration, it will be possible to introduce new medical imaging equipment during a procedure, enabling an optimal response

to situation that were not predicted (complications…), therefore there will be less cases of re-intervention.
    - Consistency of communication technologies inside the OR and outside the OR and hospitals will simplify remote expertise improving quality of interventions especially on very specialized and uncommon procedures, thus reducing patients travels and improving equal access to quality care.
- Reduction of adverse events (occurrence estimation: 8 ‰ chirurgical procedures in a 2009 study in France [15]:
    - By facilitating better communication of video and associated information among multiple monitors inside OR, implying relevant orchestration and slicing, adverse events due to non-respect of procedures, miscommunication between participants and stress will be reduced, decreasing the cost of re-interventions and legal proceedings for physicians and healthcare providers.
    - The high level of security management in 5G will improve patient safety and privacy, minimizing risks with financial impact on healthcare providers.
- Reduction of costs:
    - By providing a common architecture which can offer a consistent communication platform relying on various supports (Ethernet, Wi-Fi, LTE, New Radio (NR), etc.) as well as virtualization, 5G will drastically reduce the cost of each OR which will share equipment with other ones within a surgery department, while maintaining the high quality of medical practice.
      We anticipate a reduction in the duration of use of the room for a procedure, from the installation of the equipment and the patient, to the cleaning before the next intervention. Such an optimization of the use of the OR will help to support more patients per day. Thus, the waiting time for a programmed intervention will be reduced and the emergency management of the unscheduled interventions will also be facilitated.

The tests of the project will be carried out on phantoms not on real patients. Once the feasibility and security aspects have been validated, medico-economic studies will be conducted to validate these benefits in retrospective and prospective cohorts. These studies will be the subject of response to other calls (could be some of the Horizon Europe (HE) program). This remark applies to UC 7 also.

3.2.3.7 Social and environmental benefits

By improving clinical efficiency of surgery procedures, the 5G-based ORs will have significant impact on population health. In particular: removing video cables will largely simplify the workflow by easing the connection of new devices; enabling to prioritize the communications inside the OR makes it possible to add additional features like tele-mentoring or streaming for education without mitigating the quality of the intervention; harmonizing the communication inside the OR with WAN communications while maintaining a high level of security will open possibility of remote control on surgical procedure.
By minimizing number of equipment inside OR, it will contribute to reduce the environmental impact, including the one related to equipment cleaning and sterilization.

3.2.3.8 General requirements

The use case requires a hybrid OR equipped with multiple monitors, able to support additional equipment (HD camera, ultrasounds, etc.). It has to be extensible with additional communication solutions (antenna, gateway, terminals, etc.). It has to be compliant with both constraints of clinical procedures (in order to check compliance of 5G infrastructure with medical practice) and technological research (on scheduled vacations), as well as regulation and acceptability constraints (medical device regulation, GDPR, radio waves tolerance, etc.).

3.2.3.9 Preliminary technical requirements

The Thera-Image OR at the CHU will be extended to support wireless 5G equipment, as depicted in Figure 15:

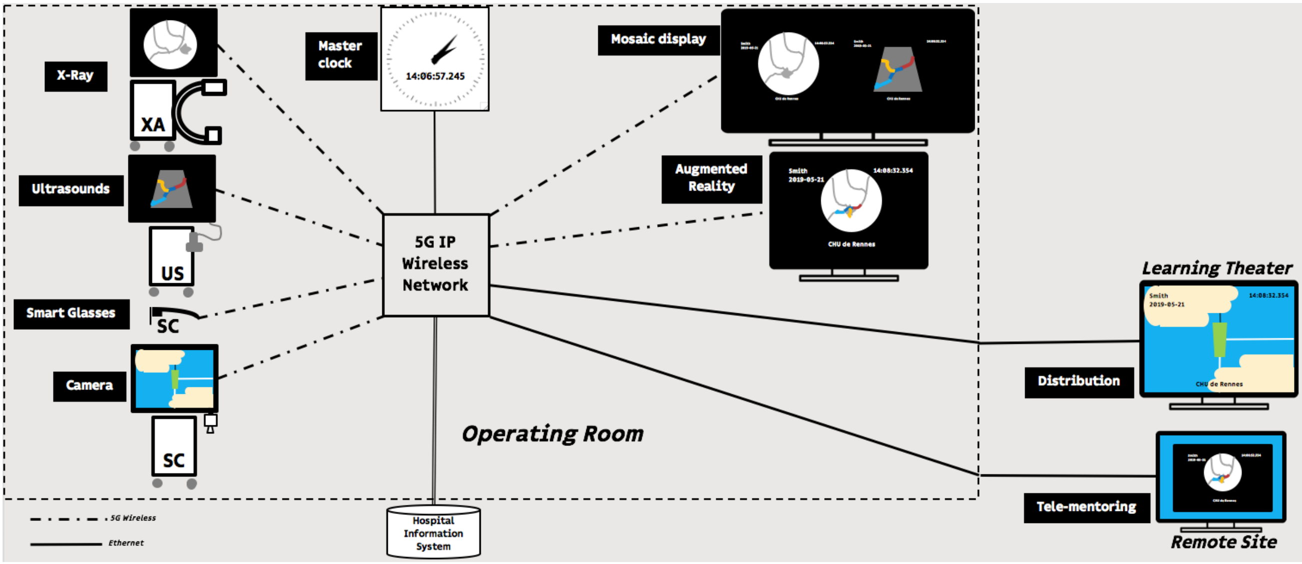

Figure 15: General overview of wireless operating room use case

Multiple video connections will be modified to be conveyed over IP while respecting the Digital Imaging Communications in Medicine (DICOM)-Real Time video (RTV) [16] standard (relying on Society of Motion Picture and Television Engineers (SMPTE) ST 2110-20 for the video [17]), replacing the Digital Video Interface (DVI)/Serial Digital Interface (SDI) cables and video switch:

- X-Ray (20Mbps to 100Mbps).
- Ultrasounds (60Mbps to 800Mbps).
- Smart glasses (30Mbps to 700 Mbps).

Several devices will be added in the OR:

- External camera (150Mbps to 3 Gigabits per second (Gbps)).
- Mosaic display (150Mbps to 3Gbps).

And, finally, an AR application will enable to combine multiple video flows:

- AR Application (150Mbps to 3Gbps).

Metric	Required value
Latency	≤ 5ms for synchronization between videos and associated metadata (AR), ≤ 15ms for video transmission (local network contribution at the overall latency)
Reliability	99.999% (to be discussed)
Density	N/A
Mobility	N/A
Coverage	100 m^2
Slice/service deployment time	≤ 90 minutes (≤ 1 minute for planned slice)
Data rate per user/device – DL	≥ 150 Mbps (compressed fullHD 3 Gbps video)
Data rate per user/device – UL	≥ 150 Mbps (compressed fullHD 3 Gbps video)
Security	“Carrier grade”
Location accuracy	N/A

Table 7: Preliminary network requirements – use case 8

3.2.3.10 Location and site facility

Then main location will be Thera-Image OR in Rennes University Hospital, with potential connection with a remote participant in Turin.

3.2.3.11 Trial overview

The demonstrations and trials will be performed as interventional procedures by real users (physicians, nurses, etc.) on models. Two sources of live images will be displayed on a mosaic monitor on the one hand, combined in an AR application on the other hand. In addition, complementary video communications will be established for smart glasses display and/or video streaming for education, those communications having lower priority. The demonstrations will compare the same AR applications using wired connections vs. 5G based wireless connection. The demonstrations will show the proper respect of the priority management since lower network performance will impact the complementary communications first.

3.2.3.12 Stakeholders

The main stakeholders for this use case are the following:

- Health care professionals and Hospitals that will be facilitated in their work by having access to a more flexible OR enabling use of not-planned equipment as well as mobile devices (smart-glasses, wireless monitors, etc.) and easier collaboration with external colleagues (tele-mentoring, etc.).
- Patients (simulated by phantoms during the trials) who will beneficiate from better surgical procedures.
- Medical equipment manufacturers that will increase use cases for their products and identify additional value-added extension (AR, tele-mentoring, etc.).
- Network providers that can enhance their service offerings by providing the network infrastructure required for the WOR.
- Infrastructure owners: hosting the computing, storage and networking infrastructure needed to run the use case.

3.2.3.13 Security requirements

The security will be put at the minimal level to enable use of network systems. Use of phantoms only instead of actual patients makes it possible. However, in the real life, security topics will be major in such OR use case.

3.2.4 Use case 9 - Optimal ambulance routing

3.2.4.1 Domain overview

Ambulances arriving on time on site where patients are located as well as reaching the appropriate ED is a critical issue for public and private EMSs. As stated in a report by the United Kingdom (UK) National Health Service (NHS) "Delays in handover of patients from ambulance services to EDs result in: increased risk to patients on site due to delays in diagnosis and treatment and increased risk in the community because fewer ambulances are available to respond" [18]. Reduction of the time required for an ambulance to reach a patient and the ED can be critical for the survival of patients, especially those suffering from cardio-vascular diseases [19],[20].

While optimal ambulance positioning and routing have been addressed extensively from a decision-making perspective and more theoretical aspect, the emergence of technologies such as 5G actually enable the fast and on-the-go acquisition of data from various sources that can affect the route and travel time of an ambulance for optimal ambulance routing. More specifically, 5G will facilitate fast and reliable acquisition of data on changing factors of an urban or sub-urban environment such as traffic flow, changing road graph, population mobility, and hospital capabilities and availability to be exploited by AI powered decision making for dynamic optimal ambulance routing.

3.2.4.2 Target customer

The main target customers are public and private EMS, which can exploit the service of the use case for enhancing the efficiency of their operation, by ensuring that the time required to reach a patient and getting the patient to the most appropriate medical centre is minimal and via the best possible route.

3.2.4.3 Use case description

This use case essentially acts as the step following the health monitoring and emergency situation identification use case described above. In this context, 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 – potentially in public locations and streets.
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 quick as possible as well as for the ambulance to arrive at the hospital as soon as possible once the patient has been stabilized on site.
The WINGS's platform, STARLIT, is exploited so as 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. Information taken into consideration, in this respect, refers to current traffic status, real-time road closures (due to demonstrations or concerts), etc. Sensors deployed within the city but also open data APIs, such as the ones offered by the Rennes Open Data Platform [21], will be leveraged for comprehensive decision-making. Real-time route updates will be performed as new information arrives.
In the meantime, the nearest hospital – that has been selected out of a list of hospitals by the medical professionals in the ambulance – will have been notified so that the arrival of the patient is expected.

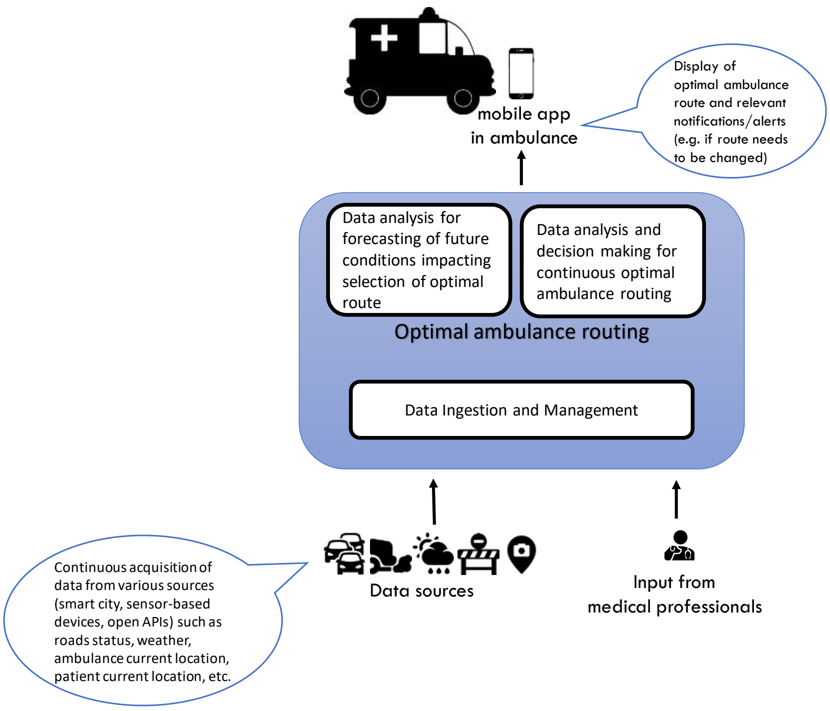

Figure 16: High-level view of optimal ambulance routing use case

3.2.4.4 Innovation potential

The key innovation stemming from this use case is the optimisation of ambulance routing. As already introduced ambulances arriving on time is a critical issue for the efficiency of EMS and can help to significantly increase the chances of patients' survival. While optimal ambulance positioning and routing have been addressed extensively from a decision-making perspective and more theoretical aspect, the realisation of the use case requires the fast and on-the-go acquisition of data from various sources that can affect the route and travel time of an ambulance. 5G will facilitate fast and reliable machine type communication for acquisition of data on changing factors of an urban or sub-urban environment such as traffic flow, changing road graph, population mobility, and hospital capabilities and availability to be exploited by AI powered decision making for dynamic optimal ambulance routing.

3.2.4.5 Service level objectives

The main service level objectives for this use case are reducing the time required for an ambulance to reach its destination and consequently increase the efficiency of EMS and improve the overall quality of care provided and the chances for survival of critical patients.

3.2.4.6 Business and economic implications

In some cases, ambulance delays may be eligible to legal claim, leading to costly legal processes for ambulance and EMS. Optimal ambulance routing can contribute to increase the efficiency of such services and therefore potentially reduce the number of patients and relatives seeking legal and/or financial retribution. Moreover, reducing ambulance delays can also contribute to faster and more efficient recovery of patients which in turn can contribute to the reduction of health care costs (e.g. fewer days required in hospital, less medical care required if patient makes full recovery).

3.2.4.7 Social and environmental benefits

This use case can significantly contribute to the improvement of the overall quality of care provided, the faster and more efficient recovery of patients and most importantly increase the chances of survival of critical patients (e.g. suffering from a stroke, cardiovascular related incidents, etc).

3.2.4.8 General requirements

The use case requires a fast and reliable network connection for real-time acquisition and communication of data from various sources (sensors, devices, APIs). The key components for this use case include: (i) various data sources which may be open APIs (e.g. DarkSky for Weather API) or other devices potentially connected via a Gateway with different connectivity options; (ii) the STARLIT platform for the collection, management and analysis of the data and the derivation of the corresponding actions, ; (iii) an ambulance dashboard for the visualisation of the continuously updated optimal ambulance routings, notifications and alerts and (iv) the dashboard for Hospital Dispatch Center showcasing the progress of the ambulance towards the emergency site as well as towards the Hospital.

3.2.4.9 Preliminary technical requirements

Indicative relevant 5G KPIs (corresponding to KPIs defined by the 5GPPP [13]) are listed in the following table.

Metric	Required value
Latency	$\leq$ 10ms
Reliability	99.999%
Mobility	Above 100Km/h
Coverage	3 km^2
Security	“Carrier grade”
Location accuracy	$\leq$500 m

Table 8: Preliminary network requirements – use case 9

3.2.4.10 Location and site facility

The trials of this use case will be done in the city of Rennes.

3.2.4.11 Trial Overview

The scenario/script for the trial corresponding to this use case will roughly evolve as follows (as part of the overall safe city use case):

- An ambulance needs to be dispatched to an emergency site.
- Optimal ambulance routing for the specific ambulance is initiated, taking into account the site location, the available routes, traffic flow, weather conditions (if applicable), city events (e.g. road closures). Relevant data is continuously retrieved to select and update the optimal route on the go.
- Once it is decided that the patient(s) should be transferred to hospital based on the assessment of the medical experts involved optimal routing is initiated to dynamically calculate the route to the most suitable hospital and ED.

For the sake of showcasing the operation of the optimal ambulance routing under various conditions (traffic, weather, appropriateness of hospital) of the trial may be emulated such as the ambulance on route, the traffic conditions, weather conditions, etc.

3.2.4.12 Stakeholders

The main stakeholders for this use case are the following:

- Hospital and ambulance/EMS that will be facilitated in their work and will be able to provide their services more efficiently.
- Patients and the general public that will receive better quality of care.
- Data providers and IoT solution providers that can enhance their service offerings by providing information required for the optimal ambulance routing.
- Network providers that can enhance their service offerings by providing the network infrastructure required for the optimal ambulance routing.
- Infrastructure owners: hosting the computing, storage and networking infrastructure needed to run the use case.

3.2.4.13 Security requirements

For the optimal ambulance routing it is not envisaged that any personal information will be exchanged. However, the connection should be secured to ensure that the data acquired to dynamically select on the optimal ambulance routing are not tampered with.

3.3 Mobility-efficient city use case

The mobility-efficient city aims at presenting a set of use cases that improve the tourism and tourism-related experiences from various perspectives. The use cases described below depict how airport processes can be improved leveraging the offering of 5G both from the side of the visitors and of the airport management. To this end, (i) smart sensor- and AI-based parking management, (ii) personalized evacuation procedure, (iii) follow-me vehicles enhanced with high-quality video streaming capabilities use cases are foreseen. iv) On top of the above, 5G-TOURS presents efficient ways of entertaining/educating travelers – in this case, students going on an excursion - on a smart bus. The Athens-node use case take place on the way to the Athens International Airport (AIA) and at the airport itself as well.

5G-TOURS will also leverage 5G technology to devise novel solutions for transportation-related applications, which rely on the capabilities of 5G to aggregate transportation-related information and communicate between different transportation agents:

- Use case 10 - Smart parking management
  - This is a solution that relies on the mMTC functionality provided by 5G. A large number of sensors installed at each individual parking position will help keep track of available and occupied spots in real time, facilitating the parking process within an airport as well as in any other controlled parking area. As a result, this will also add to the travelling efficiency of tourists through targeted parking spot suggestions.
- Use case 11 - Airport evacuation application
  - This application will monitor the location of the different users and provide them instructions for evacuation. It will rely on 5G capabilities so as to instantly notify travelers and identify the exact position of the crowds. Based on this, it will devise an evacuation plan and send individual messages to each user with personalized instructions.
- Use case 12 - Video-enhanced follow-me cars
  - Follow-me vehicles, which lead aircrafts to parking positions, monitor and oversee the activity at the Airport Airside area, and attend incidents, emergencies and critical events. In 5G-TOURS will develop a solution to equip mobile units of the airport with high definition cameras, sending multiple live feeds to the Airport Operations Centers (AOCs) and other stakeholders. This solution will leverage 5G to enable live streaming of high-resolution video feeds, thus allowing for instant situation awareness and more efficient guidance towards parking locations.
- Use case 13 - AR/VR-enhanced school bus
  - Students usually spend a lot of idle time on route, while being transferred to or from the school premises. Applications based on AR or VR can easily attract students' attention and help them focus on valuable informative sessions on the road which were not feasible before 5G. 5G-TOURS will demonstrate how 5G and these advanced technologies can work together towards turning students' idle time on a bus to constructive experiences.

3.3.1 Use case 10 - Smart airport parking management

3.3.1.1 Domain overview

The AIA area accommodates three short- and long-term parking lots for AIA visitors and travelers, altogether occupying an area of around 190km^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 favor the environment from an emission perspective.

The AIA parking customers will have a real time image of available and occupied spaces. They will be able to locate available parking spaces directly, will be guided there through the optimal route and will pay their parking fees easily online. In addition, the AIA smart parking management will contribute to the emission reduction by limiting unnecessary vehicle movements to locate a parking space.

3.3.1.2 Target customer

The airports, but also other vast parking areas owners/handlers will be the main vertical customer for the smart parking management system.

3.3.1.3 Use case description

On peak departure days for AIA, approximately 50 vehicles can become congested in Parking Facility 1 (P1, see Figure 17). It appears that upon arrival to parking within the facility, the vehicles begin to search for an adequate parking spot, ideally near the staircase and elevators. Unfortunately, a situation in which many stressful drivers search for the ideal parking spot simultaneously can evidently lead to traffic congestion and even drivers dangerously driving in the wrong directions. Whilst driving in the wrong direction, a driver trying to get a parking spot before another driver gets it first, can end up crashing into a car that drives in the correct direction. Consequently, the drivers will proceed to make the necessary arrangements to report the said accident. Both drivers in question were scheduled to depart on flights at approximately in two hours after the accident occurs and thus will inevitably miss their flights. At the same time, a driver who had been searching for a spot to no avail, eventually found a more distant spot and upon arriving at the terminal, proceeded to the check-in counters to check in his bag, only to be informed that the check-in process was closed and therefore, he was unable to fly and missed his flight.

In this direction, the AIA parking areas will be equipped with 5G-supporting parking occupancy sensors providing a real view on the parking availability status of the overall area. This will enable the real-time monitoring of available and occupied spaces, while intelligent Machine Learning-based algorithms will take advantage of this information so that travelers and AIA visitors are optimally supported throughout the parking process. To this end, travelers and AIA visitors will be provided with suggestions on actual parking spaces that are free while they enter the parking area, but also on the basis of current demand, cost, parking duration, time to flight arrival or departure, specific needs (e.g., accessibility), etc. Parking users will be provided with suggestions on their mobile devices, while administrative functions will also be provided to the operators of the parking facilities through web-based dashboards.

More specifically, this use case aims to:

- Design, implement and deploy a large number of parking space occupancy recognition sensors as well as relevant software required to communicate with a mobile application. The application will be updated about the time that the parking space was occupied, when the parking space was released and the number of the specific position occupied by the vehicle.
- Develop predictive algorithms in order to predict the availability of parking spaces, optimal management of demand/available parking spaces, and optimal routing for the drivers to these spaces.
- Develop a mobile application for the drivers, so they will be able to find a parking space via the optimum route and pay the parking fees for that location.
- Develop a Web-based application for controlling the parking area. This application will handle the data of the registered drivers when the position is occupied (occupied position, time, duration, etc.).
- Implement an administrative-supervisory system center through which all the individual applications can be managed centrally in order to manage the payment process.

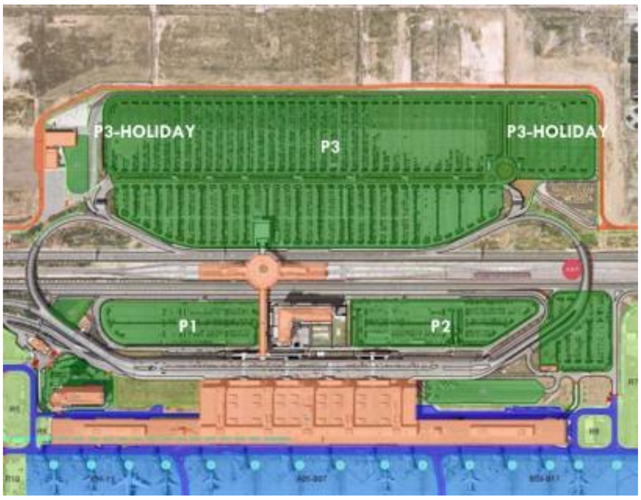

Figure 17: Athens International Airport Parking facility

3.3.1.4 Innovation potential

Real-time monitoring of a large area with the aid of dense-deployed sensors constitutes a typical use case example that requires new and more sophisticated system/network requirements. This use case falls within the Machine Type Communications (MTC), a new paradigm where a number of devices or 'things' are attached to the network and communicate with little or without human intervention. In the 5G era, new architectural solutions for MTC are currently under development to serve a huge number of 'things', introducing the so-called mMTC. Under this context, the objective of this use case is to attach a high number of low-rate, low-power MTC/IoT devices to the cellular network with the purpose to provide real time parking space data to the parking space administrator and parking users as they enter the parking area. Typically, these devices remain idle and provide UL user data, in small payloads.

The innovation of this use case regarding the user lies to the ability of the communication between the sensor and application that is available on the driver's mobile device. There is a (semi)-real-time view of occupied and available parking positions and the ability to dynamically predict available positions is offered. This prediction process is done in an optimal way taking into consideration factors like the departure and arrival time of the user's flight, the parking traffic on current timelines, the distance of the driver from the parking exit etc. The application manages the proposed parking positions in order to avoid traffic creation inside the parking area during high car entrance time.

3.3.1.5 Service level objectives

The main objective of this use case is to provide a solution that will enable the airport car park users to quickly identify a suitable parking place, saving time and energy, reducing emission and increasing passenger satisfaction. Covering a pre-defined parking area with low-rate sensors that generate small payloads in the UL is the way to go. The sporadic nature in UL/DL communication and the operators' requirement for quick MTC network deployment and expansion make the 5G network as a suitable core network for such use case.

3.3.1.6 Business and economic implications

A key benefit deriving from this use case is the reduction of time spent in searching for a free parking spot. This allows any parking operating with the particular smart parking system to become more attractive to customers. This is expected to also contribute to the attractiveness of AIA. Moreover, travellers spending more time within the airport may spend more time inside the airport building potentially shopping or using other airport facilities (e.g. cafes, restaurants, etc.). From the perspective of a parking operator the smart parking system will provide useful insights on the overall operation and occupancy of the parking spots, which can be exploited for optimising pricing strategies, etc.

3.3.1.7 Social and environmental benefits

The use case contributes to the reduction of unnecessary driving, since with the advanced forecasting algorithms there will be safe predictions about whether or not there is a free parking space. This will consequently also contribute to emission reduction, which is a great environmental benefit.

Another big social benefit regarding the user is the reduction of the time spent looking for parking places inside the airport. This will be feasible as drivers will be directed to areas with free parking spot and will not need to roam randomly looking for possibly available spot, spending time and gas money.
So, the social benefits can be summarized as:

- ***Optimized parking*** – Users find the best spot available, saving time, resources and effort. The parking lot fills up efficiently and space can be utilized properly by commercial and corporate entities.
- ***Enhanced User Experience*** – A smart parking solution will integrate the entire user experience into a unified action. Driver's payment, spot identification, location search and time notifications all seamlessly become part of the destination arrival process.

The environmental benefits are:

- ***Reduced traffic*** – Traffic flow decreases as fewer cars are required to drive around in search of an open parking space.
- ***Reduced pollution*** – Searching for parking burns important amount of oil a day. An optimal parking solution will significantly decrease driving time, thus lowering the amount of daily vehicle emissions and ultimately reducing the global environmental footprint.

3.3.1.8 General requirements

- ***General Non-Technical Requirements*:**
  - Acting passengers/drivers (around 100).
  - More than one acting police officer. This will enable testing communication between two or more officers.
- ***From the network point of view/telecom operator:*** The access network should provide a good coverage of the parking area so as no data is lost from the sensors that detect empty spaces in the parking lot. There should be a Multi-access Edge Computing (MEC) type architecture that could collect data from the sensors in real time, process them and have a quick communication with the RAN network.
- ***From the network point of view/ network KPIs:*** Accurate and effective testing, for service & network KPI measurement & validation, will be introduced in order to verify the expected level of network quality. The KPI Validation Platform (KVaP) via the use of Network probes, positioned in key interface parts of the end-to-end network, will accumulate appropriate network parameter metrics at various points of the live network. The measurements will be transmitted and stored to a Cloud Server for further processing. Measurements such as latency, reliability and data rates, and other indicators are essential for validating the network performance. Furthermore, the large amount of data will be analysed and presented in a user-friendly format in order to identify possible weak points and undertake corrective action for network optimization and performance improvement. The last two eventually lead to improved end-user experience and service acceptance.
- ***From the application point of view:*** The MTC/IoT type sensors will provide their data (i.e. location and real time parking space occupancy) to a parking management application server when needed, i.e. when the associated parking space gets empty/occupied. Communication and user data exchange between the MTC/IoT type devices and the application server is done via a virtual Evolved Packet Core (vEPC) node and 4G RAN possibly capable to provide dual connectivity to the core network (in phase 01) and via the version 5G System (v5GS) core and 5G NodeB (gNB)-RAN (in phase 02). The network shall be able to accommodate several thousands of these devices and have the needed capacity to allow low data rate exchange in the UL direction but high data rate exchange in the DL i.e. in the direction between the application server and the driver's smart phone application. The latter is needed as the car driver needs to be updated real time about free parking space data, i.e. distance/direction from available parking spaces using moving vehicle position as reference, while the vehicle is moving inside the parking area. Quickest possible update

in parking space availability is also needed for better end user experience thus low network latency is required.

Note that the MTC/IoT devices will have long term energy autonomy and be able to be easily administered e.g. software upgrade via the application server.

3.3.1.9 Preliminary technical requirements

This use case involves providing parking assistance to airport parking customers so that drivers are given guidance to next available parking space while driving and looking for free parking space within the airport parking. The following communication-centric technical requirements are dictated by current use case:

- ***Latency*****:** Updates on parking availability should be provided regularly, in short time intervals and with latency in terms of milliseconds.
- ***Density*****:** the network infrastructure should be able to accommodate communication for few thousand MTC devices/sensors (at full deployment) and hundreds of application users. However, around 100 devices are a reasonable amount for the demo purposes.
- ***Coverage*****:** the service is targeted to a confined geographic area, so the deployed radio network should be such that all designated area is given radio connection with expected QoS (see below) with mobile RAN.
- ***Data rate per user/device -DL/UL*****:** this highly depends on the information expected to be provided in real-time to the driver by the parking assistance application. The application needs to provide the minimum distance and direction to the closest available parking space or provide several parking space(s) as options for the driver to select from. Overall low to moderate data in DL direction per user is expected. In addition, the data rate per MTC device – DL/UL is expected to be low to carry update(s) on parking space availability on the UL direction. In the DL direction, low to moderate bit rate is expected primarily during MTC device firmware upgrade/maintenance.
- ***Location*****:** location accuracy in terms of few meters is needed to ensure trust of users to the service.

The main KPIs are summarized in Table 9:

Metric	Required value
Density	~ 100 devices in total
Throughput	Low data rate per device
Latency	< 10 sec
Reliability	99.99%

Table 9: Preliminary network requirements – use case 10

3.3.1.10 Location and site facility

The smart parking use case will take place on the Athens trial site, particularly in the location of the AIA (Spata area of Attica). The trial will provide 5G connectivity to the airport, which covers a substantially large area (around 5 Km2). The area covered by the deployment is depicted in Figure 18. The 5G solution will be installed at one of AIA’s parking lots (P1) and will inform the parking customers on the availability and exact location of free parking slots and assist the driver to go directly to the designated free slot avoiding any unnecessary routes.

Figure 18: Athens International Airport

3.3.1.11 Trial Overview

A small parking space within the airport area will be reserved for the purposes of the trial. The main concept of the Smart Parking System is the identification, in real – time, of the number of available parking slots and their respective and specific location. The sensors should be glued to the ground and will determine whether the parking spaces are occupied or available. This data is routed to a gateway and relayed to a central cloud-based smart parking platform, to create a real time parking map. Drivers use this map to find parking faster and easier instead of blindly driving around searching. The trial will include the installation of sensors in a small number of parking slots, up to 100 units. The solution will consist of a Web-based and mobile application platform which will provide business users with information on free or occupied parking spaces while helping parking customers to view various parking areas and choose the space from available slots, gathering information from sensors installed at parking slots through 5G technology and data transfer. These applications will be used from a number of end-users during the trial in order to test and improve the smart parking functionalities.

3.3.1.12 Stakeholders

In the case of Smart Parking, the main stakeholders include the following:

- Users in general.
- Application providers.
- Hardware manufacturer (e.g. for the sensors).
- Network providers that can enhance their service offerings by providing the network infrastructure required for the smart parking.
- Infrastructure owners: hosting the computing, storage and networking infrastructure needed to run the use case.
- Airports.
- Parking operators.
- Municipalities (operating parking spaces).

3.3.1.13 Security requirements

The main security requirements are the safety of acting occupants and emergency resource personnel during the Parking Process. With respect to GDPR (privacy), consent forms for approval from acting occupants, or any other users involved will be required. Specific deliverables of the project are planned in order to ensure project compliance with the ethics requirements and to supervise and monitor their application in the trials involving final users.

3.3.2 Use case 11 - Video-enhanced ground-based moving vehicles

3.3.2.1 Domain overview

It is of paramount importance that the operations of the Airport's Apron are efficient and effective towards providing follow-me service to an aircraft, responding to emergencies, as well as maintaining a safe environment for all concerned users of the Apron. Current issues on the Apron, which airports are con-fronted with, mostly concern the efficiency of follow-me provisions for an aircraft during their arrival and departure from parking positions which inevitably results in departure delays, staff's misdemeanours (exceeding speed limit or smoke), safety hazards such as fuel spillages which could lead to life-threatening circumstances.

In respect to the issues and concerns mentioned above, 5G technologies via the installation of High Definition Cameras on the Follow-Me Vehicles with live video feeds to not only the Airport Services Operations Center (ASOC) but also to other concerned third parties and stakeholders, will most certainly expedite the response to Aircraft during arrival and departure from parking positions which will deter flight delays, for emergencies as they occur, and when responding to such matters as fuel spillages, will positively benefit the safety of the Apron Area. Enhancing the ground-based moving vehicles with these technologies which 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 and for other stakeholders (emergency resource personnel – Police, Greek national medical authority, Fire Brigade) in efficiently responding to emergencies.

3.3.2.2 Target customer

The aviation vertical value chain are the Airport operators, Airlines, Air Traffic Management (ATM), Ground Handlers etc. For airport operators, the AOC and the Crisis Management Center (CMC) require live feed from the apron area in order to obtain a situational awareness regarding any developing incident. This ability is critical for the decision making and the coordination of response teams, towards responding to the security and safety issues faced during the Airport's everyday operation. This will allow for the remote access of additional crisis management centers from stakeholders, such as emergency response units, police, firefighting and ambulance services, Air Traffic Control and Regulatory Authorities, such as Civil Aviation Authority.

3.3.2.3 Use case description

On September 10th, 2021, during the night shift at 01:20 hours, an Airside Monitoring Inspection Specialist (AMIS) was driving northbound on the apron and encountered two vehicles which had just collided, and the drivers appeared to be slightly injured. The AMIS proceeded to notify the ASOC to summon the assistance of the necessary emergency resource personnel.
As the AMIS continued to carry out the duties of the position and was driving along the airside service road, she noticed that there was a fuel spillage on the tarmac near parking position B3. At the same time, there was a ground services employee who was about to light a cigarette and she proceeded to promptly inform this employee that smoking was prohibited on the tarmac.

During the peak morning hours at approximately 04:30 – 05:30, when there were several departures the AMIS must facilitate, the AMIS were unable to accommodate all departing aircrafts which resulted in departure delays of an aircraft. Simultaneously, the arriving aircraft were also kept delayed in their parking positions due to congestion.
This use case covers mobility efficiency from the scope of follow-me vehicles, which facilitate by leading aircrafts to parking positions, monitor and oversee the activity at the airport's airside area, and attend incidents, emergencies and critical events. Within the context of this use case, AIA's follow-me vehicles will be enhanced with mobile units equipped with HD cameras; the scenario will demonstrate how live video feeds sent to the AOCs and other stakeholders improve both day-to-day airport operations and response activities to emergencies. This will result to a dramatic increase of the situational awareness of the stakeholders responsible for the handling of the airport's operations. Moreover, in case of an emergency or a developing incident, the AOCs can have an immediate overview and decide all 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 AOC has direct viewing

capability of the area or not. In this respect, the AOC can respond to incidents that are not predefined and are dynamically evolving to non-standard events.
Furthermore, the video feed can be propagated in real time to multiple stakeholders required for the incident resolution such as police, special forces, firefighting, ambulance, civil protection etc., regardless of their proximity to the airport.

3.3.2.4 Innovation potential

This use case falls within eMBB service type. eMBB is a natural evolution to existing 4G networks that aims to provide Giga bps data rates, and therefore a better user experience than current mobile broadband services. An eMBB service type is characterized by large payloads and by a device activation pattern that remains stable over an extended time interval (as compared to other typical cases).
The objective of an eMBB-optimized network slice is to maximize the data rate, while guaranteeing a moderate reliability. Ultimately, this will provide the basis for specific content delivery services that is expected to enable fast and incorruptible HD video streaming, while users are on the go. The specific use case offers a great chance to benchmark a 5G network that is configured as an eMBB slice and is equipped with novel algorithms and applications. The demanding scenario of sharing live video feeds with high rate (and resolution), while moving with moderate speed makes the trial even more challenging and hence offers the opportunity to draw useful conclusions. Indicative QoS parameters to be considered are video quality, video disruption statistics, Start-up delay (the duration elapsed from making the content request and the start time of the video playback), and latency in live streaming that refers to the time gap between the true progress of the event being streamed and what is being played back at the user device side.

3.3.2.5 Service level objectives

Service level objectives would be to:

- Facilitate the airport staff (AMIS, ASOC) in expediting the response to emergencies.
- Efficiently and accurately inform emergency resource personnel (police, security, ASOC, fire brigade, medical response teams etc.).

3.3.2.6 Business and economic implications

The increased capability for Follow-me Vehicles to respond to the requirements of an aircraft upon arrival and departure, thus avoiding delays and additional airport charges as well as the capability of immediate response to emergency situations will both enhance business reputation with the customer (airline) and will limit the potential departure delays which are known to financially burden either the airline or the airports. Should the airport be deemed responsible for causing aircraft delays, airlines are entitled settlement by the airport.

The airport will have the ability of early detection and response to evolving issues and effectively compensate any disruptions and delays, thus increasing the effective capacity of the aircraft movements and passenger throughput. Aircraft delays have a cascade effect such as passengers missing connecting flights, airport resources being underutilized and aircraft delaying subsequent flights as the same aircraft would have to be used to carry out the subsequent flights.

3.3.2.7 Social and environmental benefits

Environmental Benefits - This use case will display the benefits on the environment by the capability of expedited response to fuel spillages, potential smokers on apron etc., all of which could lead to explosions and thus have a direct environmental impact.

The efficient operations and the early mitigation of issues arising at the apron have a significant environmental impact. Non-efficient apron operation leads to increased aircraft movements, prolonged use of aircraft engines and increased use of an Auxiliary Power Unit (APU) of the aircrafts which produce the emission of air pollutants at the airport premises.

This use case does not have and direct societal benefit.

3.3.2.8 General requirements

- ***General Non-Technical requirements***:
  - More than one acting police officers. This will enable testing communication between two or more officers.
  - Acting AMIS.
  - Physical equipment (high visibility vests, etc).
- ***From the network point of view/ network providers:*** The access network should provide a high coverage of the area of interest so that the high capacity produced by the moving cameras will not be limited by the network. Also, the UL bandwidth should be large in order to accommodate the production of high data rates. The latency in the access network should be low enough in order to have the high quality produced from the video equipment.
- ***From the network KPIs:*** Accurate and effective testing, for service and network KPI measurement and validation, will be introduced, in order to verify the expected level of network quality. The KVaP, via the use of Network probes, positioned in key interface parts of the end-to-end network, will accumulate appropriate network parameter metrics at various points of the live network. The measurements will be transmitted and stored to a Cloud Server for further processing. Measurements relate to latency, reliability, data rates, and other indicators, that are essential in validating the network KPIs.

  Furthermore, the large amount of data will be analysed and presented in a user-friendly format in order to identify possible weak points and undertake corrective action for network optimization and performance improvement. The last two eventually lead to substantial improvement in both the end-user experience and the service acceptance.
- ***From a security point of view:*** The Video-enhanced ground based moving vehicles use case involves all runway vehicles (follow-me vehicles) and airport administration vehicles equipped with eMBB-type mobile devices to provide live video feeds to the AOCs and other stakeholders. Communication and user data exchange between the eMBB devices and the Operation Centers is still done via vEPC node (in phase 01) and via the v5GS core (in phase 02) and the corresponding RAN network i.e. 4G RAN possibly capable to provide dual connectivity to the core network and gNB-RAN, respectively. Both the core and access network shall be able to accommodate high data rate in the UL direction to allow HD video streaming with low latency from multiple sources and sustain video quality even when an eMBB device is moving at moderate to high speed. To enable high end user service experience, the eMBB devices shall be assigned public safety related QoS that will allow the necessary quality of service and service continuity even in network congestion conditions, in which the communication streams, both control plane and user plane, of these devices shall be given priority by the network.

3.3.2.9 Preliminary technical requirements

This use case involves providing live video feeds to the AOCs and other stakeholders from multiple sources, primarily airport vehicles. Following communication-centric technical requirements are dictated by current use case:

- ***Latency***: to offer optimum live video experience, low latency, in terms of milliseconds, is expected.
- ***Reliability***: this application may be considered critical; thus, it is expected to be associated with public safety QoS thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%.
- ***Density***: the network infrastructure should be able to accommodate communication from few tens of video sources.
- ***Mobility***: the service is expected to be offered to moderate or even high-speed moving vehicles, so no special mobility requirements are imposed by current use case to the mobile network.
- ***Coverage***: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile RAN at expected quality of service.
- ***Data rate per user/device -DL/UL:*** this highly depends on the quality of video feed. At minimum a few Mbps in the UL direction is needed to support adequate quality video (or tens of Mbps in case of HD video).

The main KPIs are summarized in Table 10.

Metric	Required value
Density	Few tens of video sources
Throughput	25 Mbps in the UL
Latency	< 10 ms
Reliability	99.99%
Mobility	moderate or even high-speed

Table 10: Preliminary network requirements – use case 11

3.3.2.10 Location and site facility

The suggested site is the south east side of the apron/tarmac area within the AIA.

3.3.2.11 Trial Overview

The area of the apron which will be utilized during low operational hours in order to perform the trial(s) is yet to be decided, however, it may be the south-east side of the apron/tarmac or, as has been the case in retrospect, it may also be located in the north-west side of airport near the airport's perimeter.

3.3.2.12 Stakeholders

The main stakeholders are:

- Passengers.
- Employees of all companies/organizations working at the Airport.
- All Emergency Resource Personnel (Police and Security entities).
- Airport Operators.

3.3.2.13 Security requirements

- **Physical security:** Safety of acting staff and emergency resource personnel during the process. In respect to GDPR (privacy), the collection of signatures of approval from acting occupants etc.
- **System security/Privacy:** Provided that the use case includes user system interaction, all the applications will follow https protocol, and will be GDPR compliant.
- **Network security:** The access network should provide security of the transported data in the network. The RAN network including the data aggregation gateway and the cameras should be part of a local network providing isolation of the transported data.

3.3.3 Use case 12 - Emergency airport evacuation

3.3.3.1 Domain overview

Evacuation of an Airport Terminal in case of an emergency is fundamental for ensuring the protection of human life 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 either 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 such as that which 5G will provide by way of automated dynamic emergency routes from the affected area up to the muster areas, is of the utmost importance. The 5G capability will 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 building and in regard to the real-time flow management of 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.

3.3.3.2 Target customer

The vertical customer are the airports in particular and any public enclosure in general.

3.3.3.3 Use case description

Airport terminals are very large and complex public venues with a large number of travelers, 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 so as 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 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 travelers 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, will be created 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 travelers' individual needs and limitations, such as their age, health status and mobility capabilities, etc. The location of the travelers 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 an evolving emergency and timely alarm airport response units. Enhanced location services will be made available through the 5G network.

An indicative scenario for this use case would be the following:
One day at gate A37 of the Satellite Terminal Building (STB), a suspect backpack has been located underneath a seat within the area by a passenger destined to depart from the same gate. Most passengers for this flight have already arrived to the gate and are awaiting to board.
The passenger in question begins to ask other passengers in the immediate vicinity if the backpack is theirs, however, to no avail. At the same time, a male Caucasian, presumably a passenger on the same flight is seen briskly walking away whilst efforts are still being made to locate the potential owner. At 22:48, the passenger approaches the airline staff at the departure gate informing them of the package and suspect behavior. At 22:49 hours, the gate attendant immediately reports the above details to the Airport Services Operations Center Security Staff (ASOC Security). The ASOC Security immediately informs the Security Duty Supervisor (SDS) and proceeds to summon the assistance of uniformed security staff and the Police at the area in order to investigate the unattended backpack and suspect passenger.
While the developments at the gate continue to prevail, at 22:55 hours, the Airport's Call Center receives an anonymous call from a female voice stating that there will be an attack on flight AX375.
The Call Center staff immediately informs ASOC Security. The ASOC who had shortly before been informed of the imminent unattended package threat and suspect at Gate A37 from which flight AX375 will be departing, immediately inform the Airport Duty Officer (ADO), the SDS and ASOC Security of the developments. At 22:58, arrangements are made by the ADO, to call in the Threat Evaluation Committee with regards to the telephone threat, also taking into consideration the current developments at gate A37.
While the congregation of the committee is underway, at 22:49 a Security Foot Patrol Officer arrives at Gate A37 to protect the area of the unattended backpack until the arrival of the Police. At 22:54, two police officers arrive on site and have commenced their investigation of the unattended package and are monitoring the behavior of the suspect passenger.
At 22:58, after the careful on-site investigation conducted, the Police inform their operations center that an evacuation of the area is deemed necessary as they are not able to determine the nature of the suspect item which remains a threat. At 22:59, this information is communicated by the Police to the Threat Evaluation Committee and the Threat Evaluation Committee decide to initiate the evacuation of the relevant areas affected within the STB.

All occupants circulating within the affected area are evacuated from the boarding bridges of exits at Gates A37, A39 and from the staircase between the two (2) gates.

3.3.3.4 Innovation potential

It becomes apparent that the evacuation use case is in principle a representative example that falls within URLLC service type. In this case the rate is relatively low but there are strict requirements to ensure a high reliability level. From the infrastructure point of view, it is of great interest to try different approaches and topologies with the goal to achieve the requirements imposed by this service type. For instance, a more powerful RAN is expected to achieve high reliability, with diversity mechanism considered in frequency or in spatial domain. This is because the strict requirements in latency enforce that a URLLC transmission should be localized in time. Generally, URLLC service type differs a lot from eMBB in terms of target specifications and this heterogeneity imposes the need for a fundamental re-design of traditional network components and architectures. Based on the above, this use case offers a great chance for network providers to try network fine-tunings and evaluate how network solutions react to such demanding environments.
The security and safety risks at an airport can include events like fire, terrorism and a number of threats or uncontrolled actions that can disrupt normal operations. Managing these threats is a daunting task, since many different areas in an airport facility need to be monitored and immediate response from security practitioners is needed. In August 2018, the Police evacuated part of a terminal at Germany's busiest airport after a security official mistakenly allowed a family that hadn't completed required security checks into a secure area. Federal police stopped flights from boarding and kept passengers out of area A of Frankfurt Airport's Terminal 1 for about two hours because of concerns that at least one person had entered without being properly screened [22]. From the physical security perspective human safety takes absolute priority, and airport authorities need to take advantage of the best available state-of-the-art technologies when deciding, planning and executing a public space evacuation.

The evacuation process is very complicated considering the variety of individual features. One of the most important factors in indoor emergency response operations is situational awareness, which can be created only after carefully analyzing all information available in a 3D digital model of the threatened area. Numerous investigations and cases indicate that casualties are primarily caused by poor decision-making and navigation during an evacuation. Thus, the provision of a dynamic indoor emergency plan that supports informed navigation strategies and improves situational awareness is crucial. Moreover, the time it takes to communicate critical information in an emergency can mean the difference between safety and catastrophe. The ability to accurately deliver the right information, to the right audience, at the right time is crucial to any emergency planning effort. The aforementioned needs from a security point of view regarding increased situational awareness and real time communications will be witnessed by all involved parties during the implementation of UC12. More specifically, all involved stakeholders will be able to assess the capabilities that 5G network offers regarding the following:

- the availability of communications and network capacity available to emergency workers, creating an 'always connected' experience that allows them to use high-quality content for improved situational awareness and navigation capabilities.
- real-time device-to-device communications for enhanced and personalized navigation to the nearest exit.

For the security stakeholders with expertise in indoor evacuations, the use of the 5G technology innovations can advance the efficiency of emergency services and improve existing Standard Operating Procedures (SOPs).

3.3.3.5 Service level objectives

Over the past few decades there have been innumerable examples of how, despite our best efforts, we humans are still vulnerable to a plethora of man-made dangers. When the worst does happen, and emergency assistance is required, it is essential that first responders and emergency service personnel are equipped with everything they need, including an appropriate network connection. With technological advances enabling more efficient, better prepared and higher quality emergency services than at any other time in history, the underlying foundational architectures that will enable us to utilise the emergency service innovations of tomorrow will need to be established. This is where 5G technologies will become essential. In order to assess the service effectiveness and efficiency of the UC12 the following objectives have to be realized:

- Compare of the statistical information for each exit. At each exit of the station the individuals who passed over time will be counted in contrast with the current situation.
- Minimize anxiety levels of the individuals.
- Reduce the average time to reach exit.
- Adapt evacuation plans to the current conditions.
- Support civil protection authorities in the formation and validation of proper safety procedures for crowd management.
- Provide a clear, easy to use set of safe evacuation instructions for the citizen/tourist/visitor.
- Improve performance, reliability and speed of evacuation response operations.

Service level objectives are:

- Expedite the evacuation of occupants.
- Facilitate the Airport staff (Security and Police) in locating individuals who have potentially been left behind.
- Facilitate guidance of occupants from the building in a more efficient manner.
- Efficiently and accurately inform emergency resource personnel (Police, Security, ASOC, Fire Brigade, Medical Response teams etc.) whilst at the Threat level and while evacuation is in progress.

3.3.3.6 Business and economic implications

The increased capability in the handling of evacuation processes will enhance safety and therefore business reputation for tourists and visitors to the airport and simultaneously increase the possibility of their return.

Increasing the return and repeated use of the airport by passengers and visitors will bear positive economic implications and result in an increase in both aeronautical and non-aeronautical revenues.
In case of non-efficient evacuation, the airport may be held liable for compensation and reimbursement of injured passengers and airport personnel which will lead to both a financial and reputational impact.

3.3.3.7 Social and environmental benefits

Safety is currently a major societal concern in Europe. 5G-TOURS will address emergency threats by leveraging 5G technology to improve evacuation strategies in a location as sensitive as an airport. Through the implementation of this UC, the Consortium will not only be able to demonstrate the technical capabilities of 5G networks in stressful situations but also it will be able to demonstrate that the emergency response landscape will be enhanced in such way that many social benefits concerning the safety of individuals will be realised.
The effect of social connections, that is the influence of individuals' social connections in their decision to either evacuate or not evacuate, or the evacuation route certain individuals will follow in an ordered evacuation should be left outside the objectives of this use case.
Societal Benefits – By exercising the evacuation use case, an organization such as an airport becomes better prepared in the handling of an emergency evacuation which inevitably mitigates the risk of loss of human life. An evacuation plan or system such as the one described in the use case encompasses the efforts of all concerned users of an airport and adequately prepares the neighbouring areas in an actual evacuation of an airport and the direct impact it may carry (vehicular congestion, potential need to use facilities, hospitals venues, etc.).
Environmental Benefits – The use case does not have a direct environmental benefit.

3.3.3.8 General requirements

- ***General Non-Technical Requirements***:
    - Acting passengers (they will be actors): several (perhaps 100 to 150).
    - 4 Acting Police officers.
    - 6 Acting Security officers.
    - Physical equipment (blow horns, high visibility vests, etc).
- ***From the network point of view/ network providers*:** The indoor environment should provide a high coverage even in dead spots so that there will be no null covered area. In this respect, perhaps there will be a necessity to also have Wi-Fi installation to extend the coverage in all areas since it is important that all areas are well covered by the access network.
- ***From the network KPIs point of view*:** Accurate and effective testing, for service and network KPI measurement and validation, will be introduced, in order to verify the expected level of network quality. The KVaP via the use of Network probes, positioned in key interface parts of the end-to-end network, will accumulate appropriate network parameter metrics at various points of the live network.

  The measurements will be transmitted and stored to a Cloud Server for further processing. Measurements relate to latency, reliability, data rates, and other performance indicators, that are essential in validating the network KPIs. Furthermore, the large amount of data will be analysed and presented in a user-friendly format in order to identify possible weak points and undertake corrective action for network optimization and performance improvement. The last two eventually lead to improved end-user experience and service acceptance.

- ***From a security point of view*:** The Emergency airport evacuation use case involves notifying all airport attendees about an emergency situation and providing evacuation guidance in a personalized manner. The latter implies the need of an ultra-reliable and low latency communication network to support both high user data rate, primarily in the DL direction, and high control plane traffic, primarily to support network triggered end user location retrieval. Communication and user data exchange between the end user's device and the Operation Centres is done via vEPC node (in phase 01) and via the v5GS core (in phase 02) and the corresponding RAN network i.e. 4G RAN possibly capable to provide dual connectivity to the core network and gNB-RAN, respectively. Dedicated public safety QoS will allow the necessary quality of service and service continuity even in network congestion conditions in which public warning communication stream shall be given priority. Particularly on location retrieval, the solution shall ensure high location accuracy to achieve guidance in personalized manner.

The design, planning and execution of evacuation procedures addressing: (1) incoming movement - entrance of individuals into a facility, (2) roaming - movement inside the facility and (3) outgoing - exit from the facility via designated or emergency exits and/or terminal gates, should be sensitive to the procedures in place for the others; e.g. emergency evacuation procedures should be sensitive to the procedures in place for security.
In addition, the proposed model and evacuation simulation method should provide options to simulate the behaviour during evacuation in individual aspects, such as navigation or re-routing.

3.3.3.9 Preliminary technical requirements

This use case involves notifying all airport attendees about an emergency and providing evacuation guidance in a personalized manner. Overall, this use case requires an URLLC network to support both high user data rate, primarily in the DL direction, and high control plane traffic, primarily to support network triggered end user location retrieval. The following communication-centric technical requirements are dictated by the current use case:

- ***Latency*****:** low latency, in terms of milliseconds, is required to provide up-to-date evacuation assist information in personalized manner.
- ***Reliability*****:** this application is considered critical; thus, it is expected to be associated with public safety QoS thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%.
- ***Density*****:** the network infrastructure should be able to accommodate communication towards a few thousands of users (airport attendees). However, only several users per m2 is expected to suffice for the demo purposes.
- ***Mobility*****:** the service is expected to be offered to low/moderate speed users, so no special mobility requirements are imposed by current use case to the mobile network.
- ***Coverage*****:** the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile RAN at expected QoS.
- ***Data rate per user/device -DL/UL*****:** this highly depends on the info provided and the rate of updates towards the end user. At minimum a few Mbps in the DL direction, at the user plane, is needed per user. Note that the network should be able to support moderate capacity particularly for the location service.
- ***Location*****:** location accuracy is terms of few meters is needed to provide evacuation assistance information in personalized manner.

The main KPIs are summarized in Table 11.

Metric	Required value
Density	Several users per m2
Throughput	few Mbps in DL
Latency	< 10 ms
Reliability	99.99%
Mobility	low/moderate speed users

Table 11: Preliminary network requirements – use case 12

3.3.3.10 Location and site facility

The suggested site is Gate A36 within the STB within AIA.

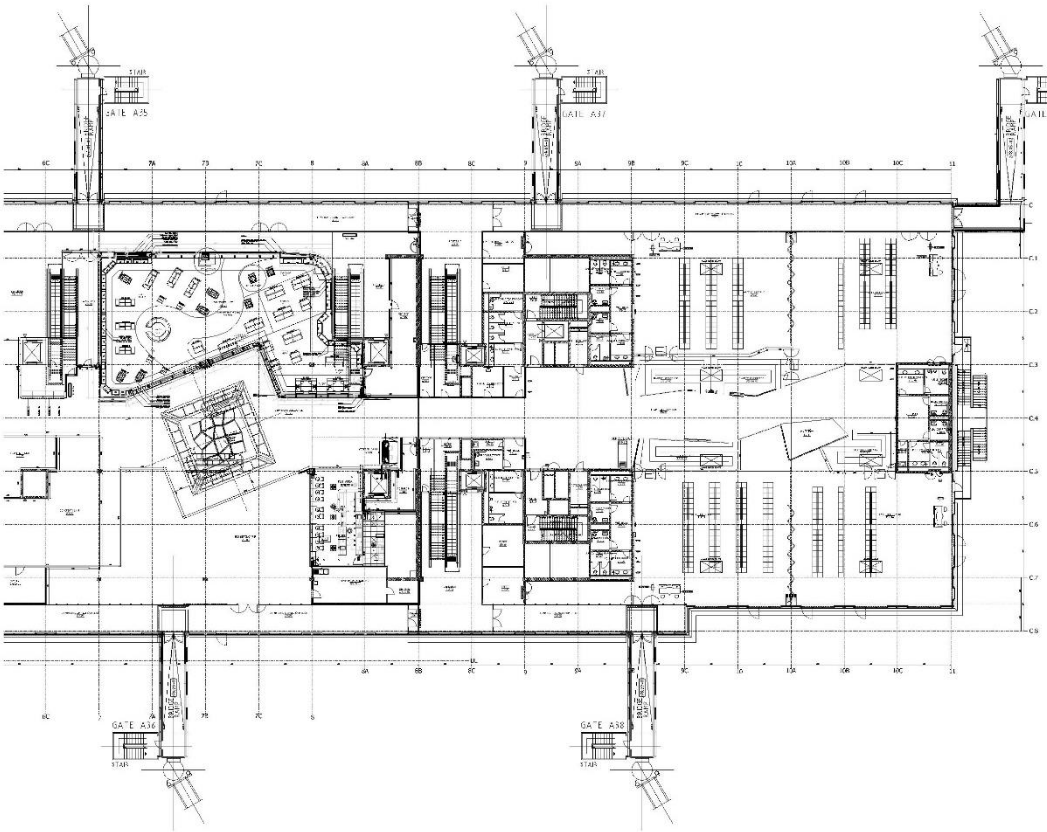

Figure 19: Layout of the use case area

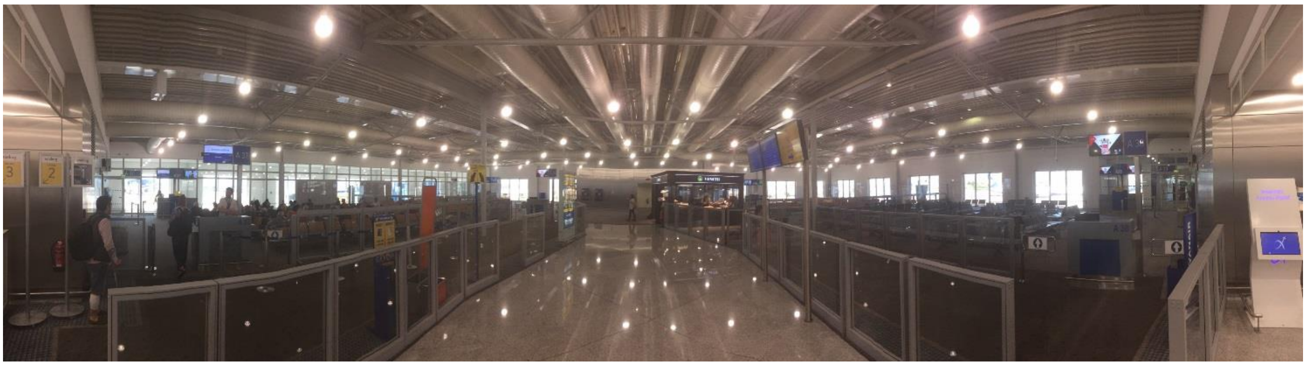

Figure 20: West gate area of the Satellite Terminal Building

3.3.3.11 Trial Overview

The STB which is remotely located from the Main Terminal Building will be utilized during low operational period and hours in order to perform the trial(s).
Volunteers will be acting as evacuees which will presumably be brought from higher educational institutions and Airport employees.

3.3.3.12 Stakeholders

In an Emergency Airport Evacuation, the target customers are the following:

- Passengers.
- Visitors of the airport.
- Employees of all companies/organizations working at the airport.
- Neighbouring entities (nearby districts).

- Police and Firefighting services
- Airport operators (Emergency response personnel such as Airport Security).

3.3.3.13 Security requirements

- ***Physical security***

Traditionally, evacuation and security have been viewed as competing issues, particularly when it comes to outgoing movement: the security function limits access to certain airport areas, while an ordered evacuation requires unrestricted access to same areas, adjacent to evacuation scene airport areas.

Aside from the security considerations, even a well-managed and carefully executed evacuation also poses a potential safety issue for facility visitors (and facility personnel in some cases) for other reasons: the potential of exiting into unfamiliar areas with aircraft transport, baggage handling, vehicle traffic and other hazards. As the evacuees would be unfamiliar with these areas, their exposure to the inherent safety concerns of these areas is more significant compared to airport workers familiar with the areas.

There is also a well-documented tendency for people to prefer familiar routes and avoid entering completely unfamiliar spaces during an emergency. This is made worse in an environment where security is such a high priority and where such behaviour would be strongly sanctioned.

Managed, an evacuation would require additional coordination and personnel but would reduce associated exposures to hazards and dependency on the unfamiliar. As a security requirement it will be challenging to test whether 5G innovative services can offset the need of additional resources to execute an evacuation in a facility such an airport without compromising the security level.

- ***Safety***

Safety of acting occupants and emergency resource personnel during the evacuation process. In respect to GDPR (privacy), the collection of signatures of approval from acting occupants etc.

- ***Network security***

The network should be secured not only in terms of data security but also in terms of provisioning. In an emergency case there is a high need that the network is uninterrupted and has a ceaseless operation. It should be able to accommodate a high number of connections to all persons who are located inside the airport.

3.3.4 Use case 13 - Excursion on an AR/VR-enhanced bus

3.3.4.1 Domain overview

In the wider frame of tourism, use case 13 focuses on those instances in which people are transported on buses so that they can visit a site of interest. In this context, the use case focuses specifically on the example of school students travelling to a destination of educational interest during a field trip or excursion, thus providing the 5G-TOURS project with a link to the domain of education.

The role of education is central to society, and the advent of the 5G era has given rise to expectations for an unprecedented positive impact of the new technological capabilities on the quality of the learning experiences offered to students within and outside their classrooms. This use case deals in particular with the rich learning opportunities that arise when students participate in educational field trips and excursions, as well as the learning opportunities that can and should arise in the -quite often- considerable time that students need to spend daily on school buses when commuting to and from their schools. The overall goal is to prove in practice how 5G technologies can enable rich, digitally enhanced experiences on the go: directly, learning experiences for school students; and, indirectly, information, learning and entertainment experiences for everyone transported on a bus to a visit destination.

3.3.4.2 Target customer

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.

In the context of the 5G-TOURS trials the target customer is more specifically the school of Ellinogermaniki Agogi (EA). EA is a big private school located in the suburb of Pallini in the north east of Athens. The school covers all levels of education from pre-school to upper secondary education. EA's approximately 2200 students come from all parts of the wider city area. For their daily transportation between the school and their homes, which may last up to an hour or more depending on the area where the student lives, as well as for educational field trips and excursions in the region, the school operates a fleet of 150 school buses. It is noted that EA's school buses are equipped with Global Positioning System (GPS) sensors and monitoring systems that allow parents to be informed about the exact location and arrival times of the school bus transferring their child.

Figure 21: Part of Ellinogermaniki Agogi's fleet of 150 school buses

3.3.4.3 Use case description

Use case 13 aims at improving the learning and entertainment ('infotainment') experience of the passengers of a bus that is transporting them so that they can visit a site of interest. The improved user experience will be realized in two locations:

- On the bus while traveling to the visit destination and/or returning from it.
- At the destination, while visiting the site.

Using new possibilities offered by 5G, visitors will be provided with digital content, media and applications that will enhance both the experience of traveling to the visit destination, and the experience of visiting the site of interest, complementing and extending relevant conventional content and activities.
In particular, the use case is materialized with a focus on the example of:

- School students traveling to a site of educational interest in the context of an excursion or field visit.
- The use of XR applications as the enablers of the digitally enhanced passenger and visitor experience, i.e. involving the introduction of digital objects in the real and/or 3D virtual world.

Through the example of educational field trips and excursions, the use case demonstrates the potential also for the realization of equivalent or similar activities in the sector of tourism, i.e. involving travelers visiting sites of touristic interest.
The use case includes two focal points: a) the enhanced experience on the bus; and b) the enhanced experience at the exhibit. These are presented below.
UC13.a: Enhanced bus experience: During their transfer to the destination, students will be presented with rich informational and educational content preparing them for the visit to the site of interest, through the use of VR technologies on the bus. Additionally (or alternatively), students can also be presented with relevant content through VR while traveling after they have completed the visit, in the context of wrap-up and follow-up learning activities. High quality rich content will be delivered simultaneously to a number of users (up to 20-25) on the bus. It is desirable that the distribution of content to the users be personalized, in accordance with their preferences and requirements. The content will include different objects (video, audio, etc.) and the user will decide which object to interact with.
UC13.b: Enhanced exhibit experience: While on site, students will visit an exhibit, with which they interact richly through digital content (in the form of text, images, videos, interactive 3D digital objects) blended with the exhibit and the surrounding environment thanks to the use of AR technologies. Approaching the exhibit, students will have the opportunity to use their 5G-enabled handheld devices to see and interact with relevant digital content projected on the physical world. This may include information on the exhibit and its wider cultural/historical/scientific/… context, visualizations of invisible processes or of extensions or analyses of the physical object, etc. The digital content may also include 3D items that the user will be able to interact with (e.g. by viewing and examining them from different angles and distances, etc.).

Some important elements for the design of the learning experiences are listed below:

- The content and design of the learning experiences is based on the consideration of relevant learning needs and objectives; the design process involves teachers as orchestrators of the learning experiences and in close collaboration with experts providing them with technological enablers and support.
- The aim of using XR (VR and AR) is to enhance the interaction between students and the learning content, making them more engaged and motivated to probe deep into the targeted area of learning.
- It is desirable that students participate in personalized experiences adapted to their characteristics, needs and interests and shaped according to their demands and decisions.
- Elements of gamification may be included in the design of the learning experiences, to increase user motivation for active participation and engagement with the learning through playful interaction with content and peers. For example, possible elements of this kind are the following:
    - Users may be playfully motivated to provide information about themselves so that the experience can be adjusted accordingly (e.g. through the use of a mini-game at the start).
    - Users may have the opportunity to collaborate with each other around and in relation to the exhibit and/or the theme of the excursion, e.g. by co-creating relevant digital content (e.g. collaborative drawing/painting), or by collaboratively solving a puzzle.
    - ‘Treasure hunts’ and searching for clues may be included in the design to motivate users to look for hidden information and gather points/tokens etc. that will allow them to advance though the gamified experience.

There is flexibility about the thematic content of the learning experiences. This can be finally defined at a later stage, and should ideally link naturally to the nature and location of the destination that will host the trials. One of the options is the use of historical, cultural and scientific content relating to the “Myrtis, face to face with the Past” exhibition, which presents the results of an important interdisciplinary enterprise. The focal exhibit is the reconstructed face of an anonymous 11-year-old Athenian girl who was, along with Pericles, one of the tens of thousands of victims of typhoid fever in the year 430 Before Christ (BC). Step by step, the exhibition describes the documentation process towards the full reconstruction of the girl’s face. Using cutting-edge VR and AR technology, visitors will be invited, individually or as part of teams, to find out about various aspects of everyday life of people in the past, in the context of an innovative approach to visitor engagement with historical artefacts. This exhibition, addressed to diverse visitor groups (school groups, individual visitors, families, scientists), can be easily transferable and adjustable to various physical contexts, offering differentiated experiences according to the visitors’ needs and interests through a wide set of predefined scenarios. An adequate part of this content can be exhibited in an area of the Athens airport such as the existing museum area or an equivalent exhibition area, where not only the visiting school students but also other airport users (travelers, tourists) can have access. An additional thematic possibility for the envisioned learning experiences is a focus on science learning centered on explaining why airplanes can fly. Through VR and AR content students will be able to observe, interact with and thus better understand the physics of flight, on the background of their physical experience of watching airplanes taking off and landing in front of their eyes during their visit to the airport.

3.3.4.4 Innovation potential

The use case described above falls within eMBB service type as the trial in use case 11 that demonstrates video-enhanced ground-based vehicles. Hence, from the network provider point of view this trial has similar value with use case 11. However, from the network infrastructure point of view, some extra capabilities seem to deserve more emphasis in this trial. More precisely, mobile networks traditionally had radio functions near the antenna and mobile processing functions at a centralized core. Today, mobile network functions are being split up, distributed and virtualized to provide the best combination of latency, throughput and cost effectiveness for various potential applications. Operators can run virtualized radio functions in large centralized data centers, smaller distributed sites, or a combination of both. The great benefit that this architectural shift offers is the on-demand elasticity that is a native capability of cloud-based functions. In telecom domain this means traffic volumes will also dynamically scale up and down and dynamically routed to various processing points, regardless if it is user or control traffic. This routing must be flexible so that it can make the appropriate real-time adjustments.

Hence, in the context of this trial is seems valuable to evaluate how a 5G network behaves in terms of dynamicity and with the constraint of a larger coverage area in which smooth handovers might be triggered without experiencing service interruptions.

The enhancement of out-of-classroom learning activities with digital content is a well-documented requirement in the domain of education and something which educational technologies have tried to provide in the last at least two decades. However, previous technologies and infrastructure did not allow for the delivery of rich multimedia content over mobile devices and more generally the realization of rich, immersive mobile learning experiences without disruption or considerable limitations. As AR/VR applications require high amounts of computational resources and therefore the use of computing power external to the AR/VR equipment, low latency and high bandwidth are necessary. In addition, the use is required of advanced broadcast technologies (e.g. appropriately combining multicast and unicast). 5G can now offer a promise to provide the basis for such rich, immersive mobile learning activities, as the rich content can be reliably transmitted over the 5G network.

3.3.4.5 Service level objectives

To provide students with opportunities for rich, digitally enhanced interactive learning experiences while traveling on the bus to (and/or from) a visit destination, and during the visit.

3.3.4.6 Business and economic implications

The sectors of education, culture, and tourism constitute large and very important parts of today’s and tomorrow’ European societies and economies. This use case will shed light on business and economic potential generated by 5G technologies in the sector primarily of education, and indirectly also in the sectors of culture and tourism, as well as in the ICT sector, by demonstrating the added value of offering 5G-enabled rich VR and AR experiences to school students and other citizens travelling in groups to visit a site of interest. Through the on-bus

VR-enabled experience, from time lost travel time becomes part of the active time used for the intended purposes (learning or other). During the visit, the use of the 5G-enabled AR technologies increases the content and quality of the experience in front of an exhibit. All this results in opportunities for the provision of more, better quality, more satisfying, more impactful, more diversified content and services to the participant by various actors in education, culture and tourism (e.g. schools and education systems, designers, developers and publishers of content and services, transportation actors, etc). Business and economic potential is also generated for all relevant technology and technological solution providers (AR/VR content development, end-user hardware and software, infrastructure providers and network operators, service providers, etc), who will be given opportunities for testing that can lead to improved end-user experience and acceptance.

3.3.4.7 Social and environmental benefits

The potential demonstrated through this use case is important and extending far beyond the specific example that is materialized in the context of the trials of the 5G-TOURS project. In education, as well as in several other sectors including tourism, it is expected that 5G will enable a new era of digital interaction in seamless amalgamations of rich virtual worlds and in the physical world. XR will revolutionize the learning experience (or, indeed, the tourism experience) by providing people with information and learning opportunities through very rich immersive multimedia content, on demand, everywhere – thus taking learning beyond the walls of classrooms, making it truly experiential and hands-on, as well as personalized.

3.3.4.8 General requirements

- ***From the network KPIs point of view*:** Accurate and effective testing, for service & network KPI measurement & validation, will be introduced, in order to verify the expected level of network quality. The KVaP via the use of Network probes, positioned in key interface parts of the end-to-end network, will accumulate appropriate network parameter metrics at various points of the live network. The measurements will be transmitted and stored to a Cloud Server for further processing. Measurements relate to latency, reliability, data rates, and other measurements, that are essential in validating the network KPIs. Furthermore, the large amount of data will be analysed and presented in a user-friendly format in order to identify possible weak points and undertake corrective action for network optimization and performance improvement. The last two eventually lead to improved end-user experience and service acceptance.
- ***From the application point of view:***
  The AR/VR enhanced bus use case involves presenting AR/VR type educational/cultural content to the students while on the move. Different requirements are posed to the network depending on type of enriched content i.e. AR or VR. While VR type of content may be predefined and broadcasted by the network to the end user the AR type of content may be correlated to the bus surroundings. Thus, eMBB and URLLC requirements may be posed to both the access and core network to support the content delivery. Thus, the network shall accommodate high user data rate, primarily in the DL direction, with low latency and location accuracy particularly for the AR type of content delivery. In addition, to support undisruptive service experience while the end user moves across mobile cells, the handover completion delay shall be kept to the minimum. Communication and user data exchange between the end user's device and the Content Delivery sever is done via vEPC node (in phase 01) and via the v5GS core (in phase 02) and the corresponding RAN network i.e. 4G RAN possibly capable to provide dual connectivity to the core network and gNB-RAN, respectively.For the trials, a school bus with up to 20-25 students will be provided by EA.
  Software to enable the VR and AR experiences will need to be developed. EA will provide the educational design and content for the development of the VR and AR applications, collaborating closely with the technical partners involved in the development of the applications.
  The 5G-enabled hardware required includes VR and AR equipment to be used by each of the participating students. Options range from wearables such as VR headsets or possibly also haptic hands-tracking equipment to the mere use of 5G smartphones (to which VR equipment is attached, or which are used as displays of VR content in combination with a simple frame headset holding the smartphone in front of the user's eyes, or which are used for camera-based AR on the handheld device.
  In addition, parts of the applications which are location-aware (e.g. the exhibit-based AR) may require equipment such as beacons, etc.

3.3.4.9 Preliminary technical requirements

This use case involves presenting AR/VR type educational/cultural content to the students while on the move. Different requirements are posed to the network depending on type of enriched content i.e. AR or VR. While VR type of content may be predefined and broadcasted by the network to the end user the AR type of content may be correlated to the bus surroundings. Following communication-centric technical requirements are dictated by current use case:

- ***Latency*****:** Latency is particularly relevant to AR applications so that small movement (or change of direction) of the AR device is reflected as fast as possible in the augmented video. Thus, latency should be ~10 ms end-to-end round-trip for optimum end user experience but also <100msec round trip would provide an acceptable end user experience.
- ***Reliability*****:** this application isn't considered critical; thus, overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%.
- ***Mobility*****:** the service is expected to be offered to moderate/high speed users, so no special mobility requirements are imposed by current use case to the mobile network.
- ***Data rate per user/device -DL/UL*****:** At minimum a few Mbps in the DL, at the user plane, is needed per user.

Furthermore, RAN network should provide a good coverage of the area in which the bus is travelling. The DL bandwidth in this case should be high enough and possibly support multicast services to all users in the bus since the same media should be transferred simultaneously to all users. The installation of a MEC network it may be necessary to have a quick transfer of data to the main gateway.
The main KPIs are summarized in Table 12.

Metric	Required value
Throughput	500 Mbps
Latency	< 100 ms
Reliability	99.99%

Table 12: Preliminary network requirements – use case 13

3.3.4.10 Location and site facility

The bus-based activities will be performed close to and/or within the area of AIA, depending on the availability of appropriate space with 5G coverage. The exhibit-based activities will be located within the airport in an appropriate space, and, ideally, somewhere where the exhibit could be visited by travellers using the airport, too, and not just the students participating in the trials. A possible route is depicted in **Error! Reference source not found.**21.

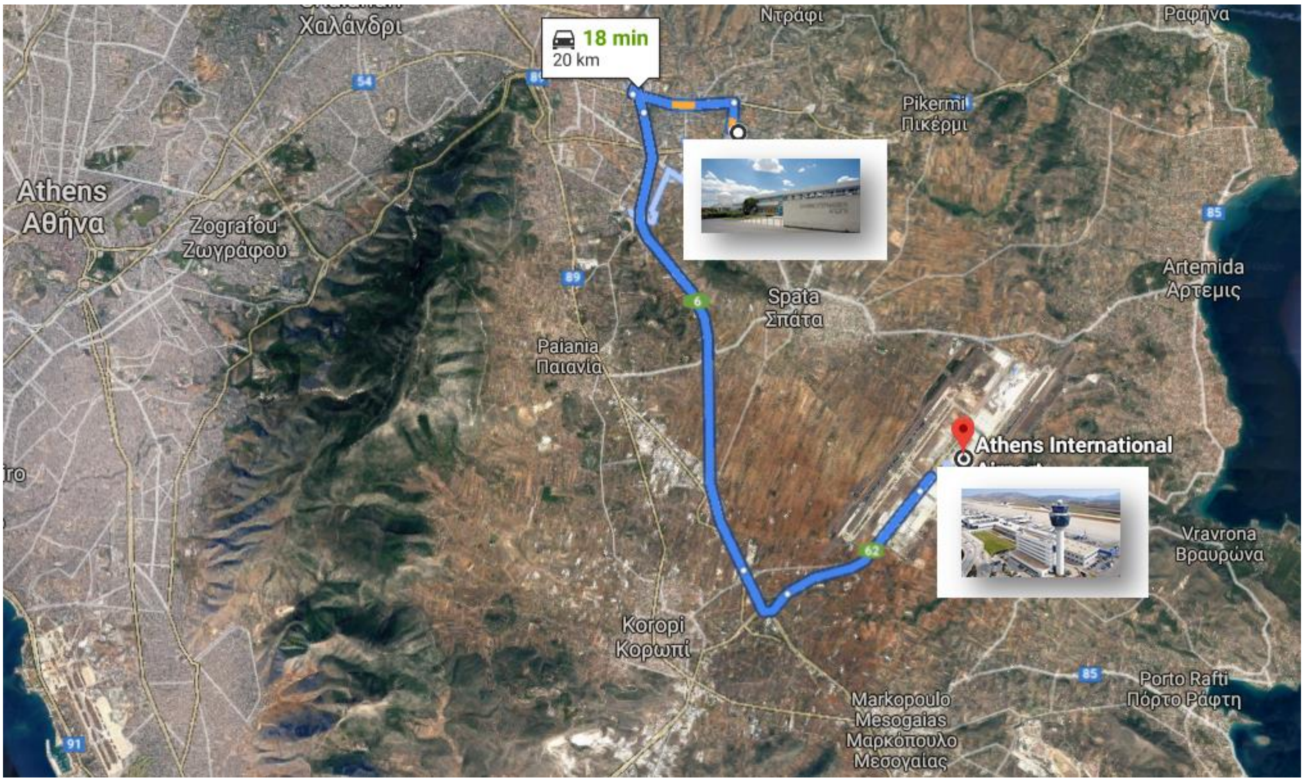

Figure 22: The 20-km bus route from the school (EA) to the airport (AIA)

3.3.4.11 Trial Overview

- A group of approximately 20-25 students travels on a bus (probably one of EA's school buses) from the school campus of EA, which is located in the suburb of Pallini in north-east Athens, to the airport of Athens (or any other site of interest that may be used additionally/alternatively to the Airport).
- When the bus reaches and moves in the area with 5G coverage for the purposes of the trials, students use the equipment to experience a VR-based informational and exploratory activity while traveling.
- At the airport students visit the exhibit and experience the AR-based activity.
- Optionally, while returning to school after the visit, students can also interact with appropriate VR-based material and activities on the bus.

3.3.4.12 Stakeholders

The stakeholders involved in the use case of the excursion on an AR/VR-enhanced bus include:

- End users, i.e. the school community including students, teachers and students' parents/families; indirectly, also everyone transported on a bus to a visit destination, and the tourism industry actors transporting groups of people to visit a site of interest.
- Content and service providers (designers, developers, publishers), i.e. providers of educational content and services, e.g. in the form of pre and post-visit informational and educational materials, as well as providers of cultural content, services and experiences such as in the form of an exhibit/exhibition.
- Product owners offering the service to the public, i.e. predominantly the education providers (the school of EA), but possibly also those responsible for the visited site (the Athens airport).
- Technology and technological solution providers (AR/VR content development, end-user hardware and software, infrastructure providers and network operators, service providers, etc).
- Network infrastructure providers and infrastructure owners that provide 5G technology to enable the use case

3.3.4.13 Security requirements

A dedicated networks slice will be used to deploy the service. This network slice will be logically isolated from the rest of the network, thus providing the SLA required to perform it and avoiding any intrusion.
In addition, given the involvement of underage participants (school students) in the trials, it is required to pay careful attention to the application of all relevant ethics requirements in the design and implementation of the activities, covering all relevant aspects of participants' ethical rights, privacy, and data protection regulations and principles (including identifying, recruiting, informing, protecting the participants and appropriately collecting and processing the data from the trials). The UC will be conducted in accordance with the provisions of the relevant laws and the General Data Protection Regulation.

Conclusions

The document provides general description and initial analysis on the thirteen use cases addressed by 5G-TOURS grouped by the three themes defined by the project – the touristic city, the safe city and the mobility-efficient city.
To build this document, each use case owner was provided with a standard framework for describing the various aspects of the use case. Since each use case has a distinct eco-system of suppliers and users, this exercise provided an ideal illustration and case study of the reality of the forming of a new eco-system around the use case concepts. This has resulted in a different emphasis in terms of the merits of technology and business value propositions across the use cases. This initial view provides an ideal platform for subsequent refinement and analysis into the business and technology evolution aspects as the project progresses.

Lastly, from the preliminary technical analysis done on each one of the use cases, it appears that the success of these innovative use cases is highly coupled with the ability of the 5G networks to deliver its promise, namely eMBB, URLLC and mMTC.

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