Co-funded by
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6GSNS

TrialsNet: TRials supported by Smart Networks beyond 5G

Deliverable D5.1

Use Cases definition for Culture, Tourism, and Entertainment (CTE) domain

Project Details

Call	HORIZON-JU-SNS-2022
Type of Action	HORIZON-JU-IA HORIZON JU Innovation Actions
Project start date	01/01/2023
Duration	36 months
Grant Agreement No.	101095871

Deliverable Details

Deliverable WP:	WP5
Deliverable Task:	T5.1, T5.2, T5.3, T5.4, T5.5
Deliverable Identifier:	TrialsNet D5.1
Deliverable Title:	Use Cases definition for Culture, Tourism, and Entertainment (CTE) domain
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Contractual Date of Delivery:	30/04/2023
Submission Date:	29/04/2023
Dissemination Level:	PU
Status:	Final
Version:	1.0
File Name:	2023-04-30_TrialsNet_D5.1_Use Cases definition for Culture, Tourism, and Entertainment (CTE) domain.doc

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Deliverable History

Version	Date	Modification
V1.0	*29/04/2023*	*Final version, submitted to EC through SyGMa*

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List of Acronyms and Abbreviations

Acronym	*Description*
3GPP	3rd Generation Partnership Project
5G	Fifth generation of mobile communications
5GC	5G Core
5G CPE	Customer Premise Equipment
5G NR	5G New Radio
6DoF	Six Degrees of Freedom
AI	Artificial Intelligence
AR	Augmented Reality
AWS	Amazon Web Service
B5G	Beyond 5G
CDN	Content Delivery Network
COTS	Commercially available Off the Shelf
CTE	Culture, Tourism and Entertainment
DL	Deep Learning
EU	European Union
FoV	Field of view
GAM	Galleria d'Arte Moderna e Contemporanea
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GUI	Graphical User Interface
HD	High Definition
iOS	iPhone Operative System
IoT	Internet of Things
KPI	Key Performance Indicator
KVI	Key Value Indicator
Mbps	Megabits per Second
ML	Machine Learning
mmWave	Millimetre-Wave
MR	Mixed Reality
NFs	Network Functions
NoSQL	Non-Structured Query Language
NPN	Non-public Network
NSA	Non-Standalone
O-RAN	Open Radio Access Network
PC	Personal Computer
POLITO	Politecnico di Torino
QoS	Quality of Services
RAN	Radio Access Network
RGB	Red Green Blue (colours used on a digital display screen)
SA	Stand-Alone
SaaS	Software as a Service
SDI	Serial Digital Interface
SDK	Software Development Kit
SNS	Smart networks and Services
TOS	Terminal Operation Supervisor
UC	Use Case
UE	User Equipment
UPF	User Plane Function
VoD	Video on Demand
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
VR	Virtual Reality
YBVR	Yerba Buena Virtual Reality (company)
W-CDMA	Wideband Code Division Multiple Access
WebRTC	Web Real-Time Communication
WP	Work Package
XR	Extended Reality

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Executive Summary

TrialsNet (TRials Supported By Smart Networks Beyond 5G) [1], in the frame of the European Commission's (EC) SNS (Smart Network Services) Joint Undertaking, is an ambitious project that aims to implement large-scale trials of innovative Beyond 5G (B5G) applications. The project will involve the development of 13 representative use cases that incorporate a range of technologies, including cobots, metaverse, massive twinning, and the Internet of Senses. The use cases will be implemented in three relevant domains of the urban ecosystems in Europe identified as i) Infrastructure, Transportation, Safety & Security, ii) eHealth and Emergency, and iii) Culture, Tourism, and Entertainment.

TrialsNet's Work Package 5 (WP5) includes the following four use cases (UC) relevant to the Culture, Tourism, and Entertainment (CTE) domain, which will be implemented in three geographical clusters, namely in Spain (Madrid), Greece (Athens) and Italy (Turin). The use cases are shortly summarized below. Since the UC13 "Extended Reality (XR) Museum Experience" is going to be implemented in two sites, Turin and Athens, it will be detailed in different sub-sections.

Use Case 10 "Immersive Fan Engagement" (Madrid): This use case aims at increasing the engagement of people who are fans of sport, e.g., during a football match. Two applications will be developed: the first one for home use, taking the spectator to the front row of the match with Virtual Reality (VR) and immersive video on smartphones; the second one live in the stadium, bringing the action to the fan regardless of its seat (which often offers partial or limited view of the playing field and the players). With a low latency multiscreen application, the fans can follow all the details of the match on their tablet or smartphone. For both applications, some preliminary solutions have been identified for the data flow transmission along with the suitable equipment (cameras, server, VR, and smartphones). While the location of the trial has not been selected yet, its planning has been described in some detail.

Use Case 11 "Service Robots for Enhanced Passenger's Experience" (Athens): This use case aims at improving passengers' comfort at Athens International Airport, particularly during congested situations. With the use of Internet of Things (IoT) sensors and Artificial Intelligence (AI)-powered algorithms, the passenger flow would become smoother by reducing waiting times and queues, which frequently form in different areas of the airport, such as for baggage drop-off and reclaim, security screening, passport control areas. A solution will be developed to aggregate and analyse the passenger data (e.g., user profile, location, flight details, e-ticket, etc.). These will be collected from various applications, based on which AI-enabled robots will assist/inform/entertain passengers during their permanence at the airport. Various sensors will be installed in different areas of the airport, also to detect critical situations and promptly alert the terminal operator supervisor (TOS).

Use Case 12 "City Parks in Metaverse" (Turin): This use case develops around the social metaverse concept, centred on the idea of creating a virtual world where people can interact with each other, form social connections and participate in a variety of activities. It will take place in the Borgo Medievale, one of the main attractions of the Valentino Park of Turin, reproducing a village of ancient Piedmont. During its closure for renovation from 2024 to 2026, the use case intends offering, as alternative to the tourists arriving to the gate of the Borgo, a virtual visit enriched with a layer for gaming along with the possibility for multiple persons to join the visit with their avatars.

Use Case 13 "Extended Reality (XR) Museum Experience" (Turin): The goal of this use case is to create a modular metaverse platform for visiting museums in Turin through portable devices. The use case will entail creating new interactive experiences in collaboration with museums and will exploit two different metaverse platforms. Users will be able to visit collections with friends and family in remote locations and/or in presence in selected locations. A captivating narrative will also be developed to make the experience more engaging, interactive, and informative by reusing part of the results of the previous project 5G-TOURS [2].

Use Case 13 "Extended Reality (XR) Museum Experience" (Athens): In this use case an AR application developed on the 5G-TOURS project will be expanded to cover other subjects and areas of interest, such as the Acropolis, the historical triangle of Athens city, and the Corinth canal. This will allow visitors to explore and

learn about more exhibits and sightseeing areas. In addition, the possibility of upgrading the capabilities of the application to include VR technology will be explored.

WP5 will mainly contribute to two TrialsNet's overarching objectives, such as objective 1 (i.e., trialling a set of innovative 6G applications) and objective 3 (i.e., introducing societal benefits in different areas) as defined in D1.1 "Management Handbook" [3].

This report constitutes the first deliverable of WP5 that detailed information for each use case as their definition, implementation aspects, technical requirements and trials description, and that will be enabled by the B5G technologies adopted in TrialsNet.

Together with the two other vertical work packages (WP3 and WP4), WP5 will play a crucial role in the TrialsNet project by providing the requirements for platform and network solutions to WP2. Furthermore, WP5 will collaborate with WP6 to ensure that the use cases' Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) will be properly analysed and validated. In terms of ethics, WP5 will work closely with WP8 to ensure that the project will meet all ethical requirements. This will include the compliance with the ethics assessment plan defined in WP1 (see D1.2 "Ethics Assessment Plan" [4]) and ensuring that all project activities adhere to ethical standards and guidelines (see D8.1 "H - Requirement No. 1" [5]).

To ensure relevance of the results for the users, the methodology Design Thinking+ [6] will be adopted in all the use cases of WP5. This methodology, which will be described in D6.1 of WP6 aims at identifying the priorities of the users considering the specific constraints of each use case, as well as the technical and socio-economic requirements of the KPIs and KVIs.

Moreover, it should be highlighted that, being just few months after the start of the project, the use cases will be refined and better integrated during its activities, based on the progress of the work and the input from the other WPs.

1 Introduction

The WP5 of TrialsNet project focuses on conducting large-scale trials to implement a heterogenous and comprehensive set of innovative B5G applications. The trials will be based on various technologies such as robots, metaverse, sensors and cameras, and covering the relevant domain of the urban ecosystems in Europe identified by Culture, Tourism and Entertainment.

D5.1 represents the first deliverable of WP5, aiming to detail the use cases definition for CTE domain. Some aspects considered in this document night be adapted or further integrated depending on trials evolution, network solutions configuration, and new inputs from other WPs. Therefore, the deliverable D5.1 is considered as an initial document related to use cases definition, application design and trials execution (including KPIs and KVIs definition). The main sections of D5.1 are described in the following.

Section 2 describes the CTE domain overview highlighting the benefits brought by SNS networks and presenting the clusters in which the use case will be implemented.

Section 3 presents the use case definitions, implementation aspects such as application design, equipment and devices, infrastructure components and functionalities and trials description. A preliminary description of the use case trial is detailed in terms of both technical setup, test cases storyline and implementation steps, methodology and expected results.

Section 4 indicates technical requirements and evaluation methodology for each use. The technical requirements are reported (e.g., throughput, latency, coverage, etc.) that the platforms and network solutions should fulfil (i.e., input to WP2) to implement the use case. A description of the relevant KPIs is presented and how these will be measured at the application level (e.g., probes definition, statistic collectors, etc.). Preliminary qualitative aspects (towards KVIs) of the use case are also identified and defined as part of the evaluation methodology.

Section 5 reports the implementation time plan for each use case by defining the milestones related to its implementation phases (i.e., design, development, laboratory tests, on-field tests, and trials).

Finally, the Section 6 of conclusions, summarizes the main outcomes of the document, and reports the next steps related to WP5 activities.

2 Culture, Tourism, and Entertainment (CTE) domain overview

Culture, Tourism, and Entertainment play a central role in the development and deployment of Smart Networks and Services (SNS) and B5G technologies, as well as from a societal perspective, providing new and innovative ways for people to access and experience cultural events, tourist destinations, and entertainment.

2.1 SNS and B5G system benefits for CTE domain

The CTE domain offers the possibility to stretch the network performance requirements because it needs in all the scenarios low latency, high bandwidth availability and reliable performance for all the users involved. For example, VR and AR can be used to enhance the visitor experience at cultural heritage sites and museums, providing interactive and immersive experiences and educational opportunities. In the entertainment industry, B5G technologies can enhance the quality and reliability of streaming services, allowing for a more seamless and enjoyable experience for consumers. Therefore, the CTE domain can greatly benefit from B5G technologies. From a societal perspective, culture, tourism, and entertainment are significant drivers of economic growth, job creation, and social development. The integration of SNS and B5G technologies can help to further stimulate these industries by creating new business opportunities and improving the delivery of cultural and entertainment services. Additionally, it can also help to promote cultural exchange and understanding, fostering a more diverse and inclusive society. It is also important for stakeholders to consider the opportunities and challenges posed by these technologies and work together to ensure that they are used in ways that are beneficial for society. Some examples in which SNS and B5G technologies can impact the CTE domain are provided below.

2.1.1 Culture

Virtual and Augmented Reality: SNS and B5G systems can provide new opportunities for people to access and experience cultural events and heritage sites. For example, VR and AR can be used to create virtual tours of museums, historical sites, and cultural landmarks, allowing visitors to experience them as if they were there. This can help to promote cultural education and appreciation, as well as provide new opportunities for cultural organizations to reach a wider audience. It can also help to enrich the experiences onsite with more engaging experiences for different targets or to link different audiences on site and online, with multiple possibilities to promote unexpected interactions.

Online Collections and Exhibitions: Advanced network technologies can be used to digitize and preserve cultural heritage in many ways, making it more accessible and widely available to people around the world. Firstly, online collections and exhibitions can provide access to a wide range of cultural artifacts, artworks, and other historical items from anywhere in the world. People can learn about different cultures and civilizations, no matter where they are located. This type of digital access can be particularly valuable for those who cannot physically visit museums or cultural sites due to geographic or financial limitations. In addition, SNS and B5G systems can facilitate the creation of more immersive and interactive experiences for visitors, whether onsite or online. For example, visitors to a museum could use AR and/or VR to gain a deeper understanding of the collections or historical context of an exhibit. They could also access additional information, such as videos, audio recordings, or expert commentary, through their mobile devices or other digital platforms. Moreover, these technologies can also help to preserve cultural heritage for future generations. By creating high-resolution images, 3D models, and other digital records of artifacts, museums and cultural institutions can protect these valuable items from physical damage or loss.

Interactive Storytelling: Interactive installations and exhibits that use mobile network technology such as VR and AR can create immersive experiences that allow visitors to engage with cultural heritage in exciting and novel ways. For example, VR can transport visitors to different historical periods, allowing them to experience what life was like in ancient civilizations, or what it was like to live during pivotal moments in history. Similarly, AR can bring exhibits to life, overlaying additional information, animations, and interactive elements onto physical displays to enhance visitors' understanding and engagement. Beyond just exhibitions, SNS and B5G systems can also be used to foster a sense of community around cultural heritage which can be termed as “social metaverse”. For example, social media platforms can be used to share stories and anecdotes from different cultures, creating a space for people to connect and learn from each other. This can help to promote cross-cultural understanding and appreciation, which is particularly important in our increasingly globalized world.

2.1.2 Tourism

Virtual Tourist/Traveller Experiences: SNS and B5G systems can provide new and innovative ways for people to experience and explore tourist destinations, as well as to assist them with personalized services to organize their transportation needs. For example, VR can be used to create virtual tours of tourist/traveller attractions, allowing people to experience them as if they were actually there. This can help to promote accessibility to tourist locations (even the hardest ones to reach) for all and to attract people from anywhere in the world, even to lesser-known cultural locations. Additionally, virtual experiences can help travellers to have a real view of the airports before arrival but also during their visit to the airport. Through such services a traveller can complete the entire airport journey without experiencing delays, disruption or confusion.

Location-based Services: SNS and B5G systems in combination with navigation and robotics technologies can also provide new and improved location-based services to help tourists explore new destinations more easily and efficiently. This can also provide new opportunities for local businesses to promote their services and reach a wider audience. In addition, with the use of robotics technology airports have the potential to improve the whole travel experience and make the airport industry safer, more efficient and commercially successful. Airports can offer optimized passenger experience as location-based services and robotics technology can offer tools that enable passengers to know their current location, look for points of interest, calculate the best route, and see distances and travel times required. These services can significantly improve the travellers’ experience by providing relevant information, personalized assistance and seamless navigation.

Personalized Tourist/Traveller Experiences: SNS and B5G systems can also be used to provide personalized tourist/traveller experiences, based on their preferences and interests. For example, tourists/travellers can use technology such as AI and machine learning to create their own custom itineraries and recommendations, based on their interests and travel history or other items of interests (sustainability, accessibility, age, etc.) Additionally, with the use of AI, real-time information and real time data sharing and analysis, travellers can have a seamless passenger experience inside and outside the terminal and being informed with personalized data and thus feel relaxed and entertained throughout the airport.

2.1.3 Entertainment

Improved Streaming Quality: SNS and B5G systems can provide improved quality and reliability for streaming services, allowing for a more seamless and enjoyable experience for consumers. With 5G technology, consumers will be able to stream high-quality video and audio content with minimal latency and interruption, allowing for a more immersive entertainment experience.

Interactive Entertainment: SNS and B5G systems can also provide new opportunities for interactive entertainment. For example, virtual and augmented reality can be used to create immersive gaming experiences, allowing players to interact with each other in new and innovative ways. Targeted strategies could specifically improve experiences for some vulnerable categories, incl. physical and mental disabled.

Live Events: SNS and B5G systems can also be used to enhance the experience of live events, such as concerts, sporting events, and theatre performances. For example, 5G technology can be used to create virtual reality experiences that allow people to attend live events from anywhere in the world, providing a more accessible and inclusive entertainment experience and promote cross collaboration and interaction as well as democratizing cultural experience for all.

2.2 TrialsNet Cluster Overview

Large-scale trials in the context of CTE domain requires the identification of the proper locations and sites where to perform the experimentations. In this section, the current sites that have been identified for the involved clusters are introduced.

2.2.1 Turin Cluster

The city of Turin, located in the north-western region of Italy, is known for its rich cultural heritage and vibrant art scene. Indeed, the city and its surroundings offer visitors and tourists more than fifty attractions including museums, cultural heritage, castles, residences and exhibition centres which represent an international cultural offer. This rich heritage has its roots in Savoy dynastic collecting, which had increased public organisational structure since the first half of eighteenth century.

Some famous museums in Turin that will be considered for their possible inclusion in the use cases implementation are the following:

- **Palazzo Madama:** Palazzo Madama is a historic palace that has served as the city's seat of government for centuries. Today, the palace houses the Museo Civico d'Arte Antica, which showcases an extensive collection of art and artifacts from the ancient world, including Roman and Etruscan sculptures, mosaics, and ceramics. In addition to its impressive collection, Palazzo Madama is also notable for its architecture. The palace is a unique blend of styles, incorporating elements from both the Renaissance and Baroque periods. The building's rich history and stunning architecture make it a must-visit destination for anyone interested in Turin's cultural heritage (Figure 1).
- **Galleria d'Arte Moderna e Contemporanea (GAM):** This museum showcases a collection of modern and contemporary art from the 19th and 20th centuries, including works by artists such as Modigliani, De Chirico, and Balla.
- **Borgo Medievale:** The medieval village of Turin, better known as Borgo del Valentino or simply Valentino, is an artificial village built for the Italian general exhibition of 1884, dedicated to medieval architecture. Today, the Borgo can be indeed considered an open-air museum with over 500,000 visitors a year.
- **Museo Pietro Micca:** Pietro Micca was an Italian soldier who became a national hero of the Duchy of Savoy for his sacrifice in the defence of Turin against the siege of the French troops on the night of 29–30 August 1706, by exploding a bomb in a tunnel that blocked the enemies' invasion. The museum explains in detail the importance of the siege, the conditions, the people involved, and the tactics.

Other museums in Turin may be considered for their inclusion during the project activities.

Figure 1. Palazzo Madama in Turin.

2.2.2 Madrid Cluster

Madrid capital of Spain, located in the centre of the country, was named World Capital of Sport for 2022. It hosts countless major sporting events ranging from high level competitions (football, basketball, etc.), with highest level teams in the world.

Different sports venues in Madrid are being studied as locations for TrialsNet trials activities. Medium sized venues like Basketball arenas such as Wizink Center (Figure 2) or Magariños; tennis courts such as La Caja Mágica; or large venues like Football stadiums such as Bernabeu or Civitas Metropolitano will be prospected for selection as possible options. Small-medium scale venues would fit better for the trial proposed in this project as an affordable field of trial.

Figure 2. Wizink Center in Madrid.

2.2.3 Athens Cluster

The Athens International Airport (AIA), so-called "Eleftherios Venizelos" is the largest and busiest international airport in Greece. It serves its capital, the city of Athens, and Attica region, located 30 km east of Athens. The AIA is a member of Group 1 of the Airports Council International [7] supporting over 25 million passengers annually and in fact, it hosts more than 370 companies with more than 16.000 employees servicing approximately 100.000 passengers and 800 flights per day during peak periods (Figure 3). Furthermore, AIA consists of two passenger terminals, the "Main Terminal" and the "Satellite" Terminal, which are connected through an underground link. Moreover, the Athens Airport is embedded Greece's road and rail transport systems to support passengers' traffic and cargo movement. Indeed, airports are critical infrastructures as they must operate efficiently 24/7 to process and support all these passengers and cargo transport services and relevant operations.

Figure 3. Waiting area at Athens International Airport.

Moreover Athens, the capital city of Greece, is home to many major monuments and museums that showcase the country's rich history and cultural heritage. Below are some that will be considered for Use Case 13.

- **Acropolis of Athens:** This ancient citadel sits atop a rocky hill overlooking Athens and is home to several iconic structures, including the Parthenon, the Temple of Athena Nike, and the Erechtheion. The Acropolis has been designated a UNESCO World Heritage site [5].
- **The historical triangle of Athens city:** The historic triangle of Athens is considered as the area formed by Syntagma, Monastiraki and Omonia Squares. It consists of the city's biggest bank institutions and other important sights, like the Parliament and many Ministries.
- **The Corinth Canal:** The Corinth Canal is an artificial canal that connects the Gulf of Corinth in the Ionian Sea with the Saronic Gulf in the Aegean Sea. It cuts through the narrow Isthmus of Corinth and separates the Peloponnese from the Greek mainland. It is 6.4 kilometres in length and only 24.6 metres wide at sea level, that is too small for many modern ships. It is currently mainly a tourist attraction.

3 Use cases detailed description

This section will describe the various use cases, highlighting the goals, actors, and the steps involved in each scenario. Additionally, the section will also describe the expected outcomes and the benefits that our solution can provide to the end-users in each of the use cases.

3.1 UC10: Immersive Fan Engagement

Immersive video (360° and 180° video) and VR headset players have brought new possibilities in sports for fan engagement, joining the reality of video images with the immersion experience of VR devices. YBVR (Yerba Buena Virtual Reality) has developed a new technology that blends the maximum video quality resolution with optimized bandwidth for live and Video on Demand (VoD) video streaming [9]. Also, other sports event information can be inserted into the immersive video, such as TV feed overlapped as a jumbotron over the game, real time scoreboard, additional analytics of the players and the teams, etc.

YBVR's technology also provides an interactive experience allowing fans to switch between different cameras at any time during the event, in a seamless experience, without any buffering or cuts, only selecting the new position in the camera's map and clicking on the desired new position. Also, a TV multiscreen view is included in the experience, giving fans the opportunity of being the director of the TV production. Fan engagement increases when it combines the immersive video (feeling to be there), the personalized experience (every fan will focus to different players and positions) and interactivity (changing the position renews attention), and all these advantages can be enjoyed from the comfort of the fan's home. The same YBVR technology can be used also for the fans into the venue. Immersive video doesn't add value to the experience of being in the stadium if you are already there, but this technology can offer a multiscreen experience in the mobile device of the audience with the feeds of TV at this moment. Then, for example, a fan can watch images of a penalty kick on the smartphone and celebrate the goal with the rest of the fans in the venue.

In general, the use case of immersive fan engagement offers an unparalleled experience to sports enthusiasts by allowing them to watch live games from the front row of the stadium, from a distance inside the same venue or from the comfort of their own homes. This is made possible by using cutting-edge immersive technologies such as 360° and 180° videos and virtual reality headsets, coupled with state-of-the-art communication technology. However, to fully optimize the potential of immersive fan engagement, B5G technologies must be implemented. B5G has indeed the potential to significantly improve the viability, quality, and scalability of current technologies, such as fibre, Wi-Fi, or the commercial 5G deployments currently in use. Higher data rates, lower latency, improved reliability, and more robust security are the main requirements that need to be fulfilled that the current technology can't satisfy. This allows YBVR to facilitate operations more efficiently and cover more use cases in the future and develop new and updated services. With faster data transfer rates and lower latency, fans can enjoy a full and seamless viewing experience. Furthermore, robust security features can provide greater confidence in the security and privacy of the fan's data. This use case will demonstrate such benefits and improvements thanks to the B5G technologies provided by TrialsNet.

3.1.1 Use case definition

This use case reaches the possibilities of B5G networks to improve fan engagement in sports events using immersive technologies. Immersive video (360° and 180°) and streaming technologies can enrich the fan experience by taking them to the front row of a sport event by bringing them closer to the action at the sporting venue and at the same time providing very high-quality video contents.

To explore these possibilities, two different scenarios will be developed:

- **At-home:** this scenario virtually brings the fan to the front row of the sporting event. The key in this situation will be VR technology and immersive video that are enabled by B5G streaming features,
- **In-venue:** this scenario takes the action to the fan, regardless of the seat at the stadium. With a low latency multiscreen application, the fan can follow all the details of the match in their portable device.

The current technology limits impose the camera location to be in a fixed positions with existing fibre paths (Figure 4.). However, the use of B5G technology will allow immersive cameras installed in the venue to upload the video flows from any position to an Edge Computing video server for a more efficient image processing. Wireless connectivity opens new possibilities but requires high upload throughput (between 50 and 100 Mbps per camera).

Figure 4. 360 degrees camera rig.

This use case will enable fans to access different immersive cameras using their mobile devices from home and/or from the actual venue, watching the event from a close-to-play position, even if their seats are in the upper tier of the stadium. They can change the camera at any time, at their own will, simply by clicking on the mobile screen (Figure 5.). All these possibilities require the highest capabilities of mobile data massive download in an indoor well-defined coverage area in the venue.

Figure 5. Example of camera selection interface.

3.1.2 Implementation aspects

In the following sections the implementation aspects enabling the two depicted scenarios are reported.

3.1.2.1 Application design

The YBVR solution has been designed to support both at-home and in-venue use cases. While both scenarios share most of the application components, they can be implemented as standalone architectures, depending on the specific requirements of the event.

The YBVR suite of modules comprises various software and hardware components that work together to provide an immersive video experience for live sports and events. Here is a detailed overview of each module.

At-home scenario

The main components of the at-home scenario application are detailed in the following Figure 6. The YBVR suite of modules includes Stitching, Live Production, and Ingest Server software that is customized for YBVR developments and installed on customized hardware. These modules work together to transform camera feeds into immersive spherical videos, including jumbotron inserts and scoreboard data feeds.

YBVR has also developed Field of View (FoV) optimization and synchronization modules that keep the 8K video quality in the field of view while dramatically reducing the required bitrate. Content Delivery Network CDN resources are employed to scale the delivery of the video stream to a large audience.

Finally, YBVR's App player is a software module optimized for Quest, Android, and iPhone Operative System

(iOS) devices, providing an immersive video reproduction with the option to switch between different camera feeds in the venue. This player carries out FoV adaptation to provide 8K-equivalent resolution with low-bandwidth streaming, making camera changes seamless for the viewer.

- **Stitching, Live production and Ingest server modules** are commercial software customized for YBVR and YBVR developments, installed on customized hardware. These modules transform the camera feeds in the immersive experience, building the spheric videos, inserting the TV feed as a jumbotron and the data feeds of scoreboard or others.
- **FoV optimization and synchronization modules** are developed by YBVR. Live origin is open-source software tunned and customized by YBVR. All are installed on public cloud. This module optimizes the immersive video signal keeping the 8K video quality in the field of view but reducing dramatically the required bitrate.
- **CDN resources** are commercial services used to escalate the delivery of the video stream to a huge number of users.
- **YBVR App player** is a software module developed by YBVR for Quest, Android and iOS devices. This player provides an immersive video reproduction (360° or 180°) with the option of selecting the feed between different cameras located in the venue. The player is optimized to carry out the FoV adaptation to provide the equivalent 8K resolution with low bandwidth streaming and to make the change of camera in a seamless way.

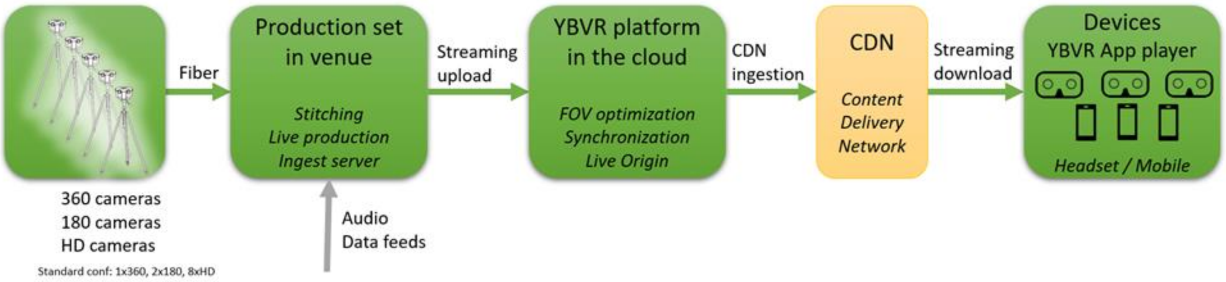


Figure 6. Application components for the At-home scenario.

In-venue scenario

The main components of the in-venue scenario application are detailed in the following Figure 7. The in-venue UC scenario application of VR involves several key components, including specialized software modules, customized hardware, and cloud-based media servers. These components work together to create immersive, multi-camera experiences for users, both in the venue and remotely.

- **Mosaic construction module** is an appliance including software developed by YBVR and customized hardware used to build the multi-screen experience and to adjust the bitrate.

- **Media servers are software modules:** with customized tuning deployed in the cloud or the Edge to deliver the video streams to users. A hierarchy of media servers would be needed if the number of users is above 1.000 users.
- **YBVR App player:** is a software module developed by YBVR for Android and iOS devices. This player reproduces a multicamera view selecting as principal screen the camera feed selected by the user. The user can change the selection of the principal camera at any moment. The player is optimized to reduce the latency and to carry out the change of camera in a seamless way.

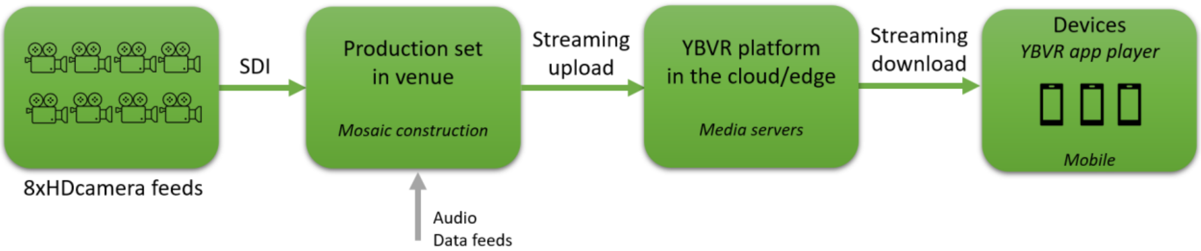


Figure 7. Application components for the In-venue scenario.

3.1.2.2 Equipment and devices

Commercial equipment and devices are required for this use case are given in Table 1:

Table 1. Equipment and devices for UC10.

Equipment	Item	Description	Quantity
	High Definition (HD) cameras TV/video camera with Serial Digital Interface (SDI)	They can be provided by the TV producer or by YBVR HD video camera 10.2-mega-pixel Live MOS sensor with dual native ISO technology for exceptional low-light video performance	8
	Lumix BGH1 with Fisheye lens (Laowa MFT 4 mm or Meike 6.5 mm model) [10]	Provided by YBVR. They are commercial video cameras set up with the appropriate lens: Lumix BGH1 integrates a high-sensitivity 10.2-megapixel Live MOS sensor with Dual Native ISO technology. This camera allows to record high quality video in 4K (240fps, max 10x slower at 24p)	2 or more
	360-degree camera (ONLY AT-HOME-APP) 4 x Lumix BGH1 camera with the fisheye lens (Meike 6.5 mm) or Insta360 Titan	A set of 4 Lumix BGH1 video cameras set up with the appropriate lens, mounted on a customized rig, or a compact 360 camera	Rig of 4 cameras or a compact multi-lens camera

	Meta Quest 2 [11] or similar	Devices required to test the player and the user experience. 20 pixels per degree and fast response LCD screen with 1832 x 1920 pixels per eye	1
	Smartphone high end	Mobile devices required to test the player and the user experience. Operating system: Android At least 16GB RAM with 5G and Wi-Fi connectivity	1
	iPhone high end	Mobile devices required to test the player and the user experience. Operating system: IOS At least 16GB RAM with 5G and Wi-Fi connectivity	1
	Titan insta360 [12]	360-degree video camera 8x micro four-thirds sensors 11K VR photo + video Crystal View Livestreaming 360 VR	1

3.1.3 Infrastructure components and functionalities

The network infrastructure to be deployed for this use case will be a 5G/B5G Ericsson Non-Public Network (NPN) to which all the experimental devices will connect to, while the commercial devices will use the public network. A diagram of the infrastructure is depicted in Figure 8.

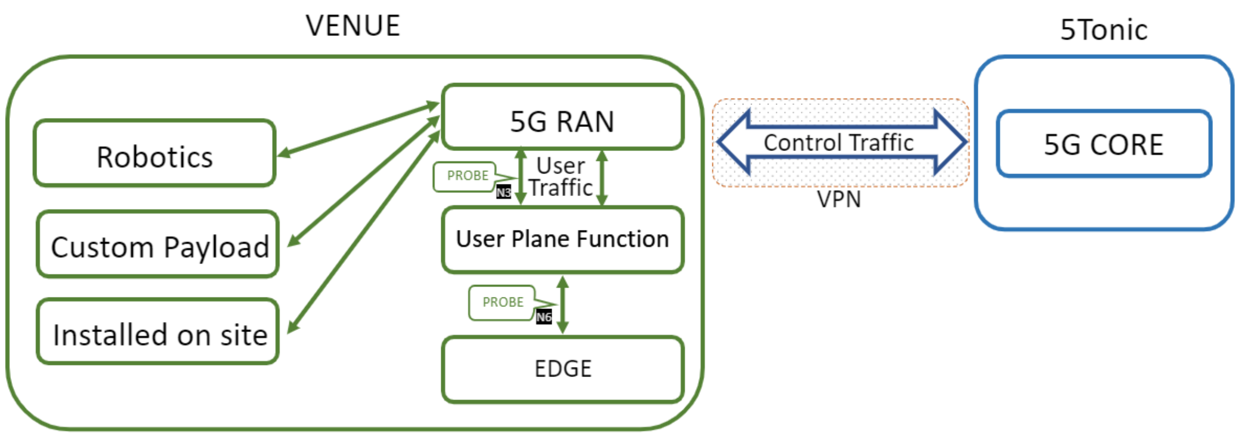


Figure 8. 5G/B5G Ericsson NPN infrastructure.

The Ericsson 5G NPN infrastructure is a distributed 5G Stand-Alone (SA) network. The 5G SA architecture adopts the new concept of Service-Based interfaces. This means that the Network Functions (NFs) that include logic and functionality for processing signalling flows are not interconnected via point-to-point interfaces but instead exposing and making available services to the rest of NFs. Thus, there is a separation that broadens the range of possible locations in which the network elements can be located. The RAN and the User Plane Function

(UPF) are installed at venue premises, while the rest of components of the 5G Core (5GC), the control plane components, are running at 5Tonic (Leganés, Madrid) [13]. This model is interesting because verticals do not need to have their own full 5G deployed, making the service a lot more cost-efficient for them. With this solution, the 5G RAN (Radio Access Network) equipment splits the user plane traffic and the control traffic. The use case traffic is directed via the UPF towards the vertical applications. This way, the user plane traffic remains geographically close to the end user devices, keeping a very low latency. Complementarily, the control and management planes of the 5G equipment are done from a remote location in 5Tonic via Virtual Private Network (VPN), as control traffic does not require as low latency and high-speed levels as the local user plane traffic.

On-site installed elements such as cameras will access the 5G network using 5G Customer Premise Equipment (CPEs) depending on the required technology (mid-band or mmWave).

For the application modules, some servers dedicated to this application will be needed to implement the use case as described in Figure 6 and in Figure 7. They can be hosted in the venue or, depending on the network capabilities, in the Edge. Also, some services in the cloud are required (see Table 2).

Table 2. Infrastructure components for UC10.

Equipment	Item	Description	Quantity
	Stitching, Live production and ingest servers (ONLY AT-HOME-APP) Generic PC servers with Windows OS with Nvidia RTX 3080Ti graphic card (or similar one) [14]	ON PREMISES: Industrial PCs are required to host the stitching and live production Migration of this function to the Edge will be studied as part of the project	4
	Mosaic generator (AT-HOME & IN-VENUE APP) Generic PC servers with Ubuntu OS with Nvidia RTX A5000 graphic card (or similar one) [15]	the mosaic generation and the ingest server modules	1
aws	YBVR platform Amazon Web Service (AWS) or similar [16]	YBVR platform optimizes immersive video streaming and capture analytics and provides monitoring tools	Software as a Service

3.1.4 Trial description

The 5G network infrastructure will be used to download the content from the YBVR platform in the Edge cloud to the users' portable devices, on which the YBVR App player is installed. Depending on where the users with devices are located, 5G NPN or 5G commercial network will be used. Three different phases will be needed to complete the objectives of the trial as described below.

Phase 1: Definition and scope

- First, a trial venue must be selected, and the scope of the trial review according to the network capabilities available at this date.

- The data flow transmission will be supported by the 5G network infrastructure. Two methods for up-linking the content have been identified for this: In the first method, fibre is used to send traffic from each camera to the production set in the venue, creating a mosaic of audio and visual data.

Phase 2: Pre-trial

- Two testing profiles must be selected, each for every App: in-venue fan and at home fan. In the pre-trial phase, both scenarios (In-venue and At-home) will be tested in 5Tonic with the already defined priority sections, if they can be implemented in the trial network. The results of these pre-trial tests will define the modules of the trials provided by the 5G network.
- Then the product set in venue will create a streaming that will use the 5G/B5G network infrastructure to reach the YBVR platform in the Edge. The second approach is similar the first one, but in this case, the 8 camaras will directly reach the production set in the venue. This approach is expected to be very demanding in terms of upload throughput even for the actual 5G deployment, and it will be analysed if the actual technology could fulfil the requirements.

Phase 3: Trial

- Then the network infrastructure and the UC modules described above must be deployed in the venue. In this trial phase, both Apps will be tested (sharing infrastructure and deployment) with the specific target customer profile and analytics and survey will be collected.

The envisaged trial is schematically described in the Table 3 below.

Table 3. UC10 trial description.

Trial ID / Name	**Trial 10.1 / Immersive fan engagement**	
Infrastructure / Venue	**5Tonic pre-trial / venue in the trial to be selected**	
Description	Test the improvement in the fan experience the immersive fan Apps using advanced 5G capabilities. Different sports venues in Madrid are being studied as possible usch as Basketball arenas such as Wizink Center or Magariños; tennis courts such as La Caja Mágica.	
Components and Configuration	Components	• For at-home App: Immersive cameras, HD cameras, Production servers, Mosaic generator and user devices • Probes to measure the network KPIs. • 5G connection to enable real-time data sharing and communication. • 5G connection to enable real-time data sharing and communication.
	Configuration	As explained below at 4.1.1 some priorities per scenario will be tested in this project: • Camera contribution and Live production at Edge (Priority 2 in at-home and Priority 3 in in-venue) • Upload streaming with B5G (Priority 1 in at-home and Priority 2 in in-venue) to the YBVR platform in the cloud/Edge and download streaming to the YBVR player App installed in the user devices (Priority 3 in at-home and Priority 1 in in-venue). • Monitoring tool: probes should be installed in different parts of the network, to measure network KPIs.

Test procedure	Pre-conditions	• YBVR pre-requisites. • For the live test VPN should be configured to reach the 5Tonic lab with the CORE equipment. • Probes should have access to the influx database in 5Tonic through the VPN. • 5G Control functions should be configured through VPN. • Applications deployed in the Edge (the final allocation of modules between local and edge environments will be decided on the last design steps, depending on the B5G network features available)
	Test Case steps	At-home scenario: • Users access the experience with a mobile device and with VR headset using the APP deployed for the trial. • Into the App, the user can select, at any time, the immersive camera to feel of being at the front row or become the director of the TV production, selecting the TV camera preferred at any time. • User fills in the survey. In-venue scenario: • Users access the experience with a mobile device using the APP deployed for the trial. • Into the App, the user can become the director of the TV production, selecting the TV live camera preferred at any time. • User fills in the survey. Downlink throughput will be monitored using YBVR-App probes. Uplink throughput will be measured with network throughput tools. Glass to glass latency will be measured by YBVR personnel. Fans will be able to enjoy the *immersive* experience from home or in venue using 5G advanced features, and TrialsNet partners will be able to gather and analyse KPIs and user's feedback surveys.
Measurements	Methodology	Downlink throughput will be monitored continuously, uplink throughput and end to end latency will be measured at the beginning, in the course and the end of the trial. YBVR platform is receiving continuous data from the player tracking bitrate, buffering and connected devices.
	Complementary measurements	Ericsson has developed a SW probes tool (a component that extracts KPIs from the end-user traffic with the granularity of flow for IP traffic) that are installed in different points of the network and would be used as complementary sources of measurements. For example, Ericsson has a probe installed in the User equipment (UE) and collects data related to the KPIs as latency, jitter, user data rate and send to a database. This information is later processed and used as complementary measurement.
	Calculation process	The complementary measurements that Ericsson would monitor are the KPIs: user experience data rate, jitter and latency.

		• User experienced data rate: Is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput is measured during active time and is the number of correctly received bits over a specific period of time. • User plane Latency: This KPI measures the time delay of a data packet to travel between the User Equipment (UE) and the application located in the Edge. • User experienced Jitter: This KPI measures the variation in the delay of data packets as they are transmitted over a network. This KPI represents absolute value of the difference between the user plane latency of two consecutive received packets belonging to the same stream.
Expected results	• It's expected that KPIs will be as close as possible of the requirements. • For APP-at-home: Uplink throughput up to 100Mbps per immersive camera. Downlink throughput up to 20 Mbps. • For APP-in-venue: Uplink throughput up to 15Mbps per mosaic. Downlink throughput: 5.000 users with 10Mbps per user.	

The trial descriptions reported in Table 3 is be complemented with the KPIs/KVIs definition and measurement of the specific use case reported in section 4.1.2.

3.2 UC11: Service Robots for Enhanced Passengers' Experience

This use case involves the experimental validation and development of prototypes of the envisioned services supported by robots, AI algorithms, IoT sensors and B5G technologies. The combination of these technologies can help airports provide a seamless and personalized passenger experience while increasing efficiency and reducing costs. The combination of B5G technologies and IoT sensors can enable airports to improve the passenger experience by deploying robots and AI mechanisms. The B5G network capabilities are required to increase the network capacity, to provide high reliability and to support higher device density. This can be particularly useful in a busy terminal environment, where there are many passengers moving around simultaneously and generating large amounts of data that need to be processed in real-time. Passengers' experience is highly connected to the airport operations, especially during the check in process, the baggage drop-off and the baggage reclaim, as well as during the security screening process and the passport control areas.

3.2.1 Use case definition

The scope of UC11 is to develop a connected airport ecosystem that leverages the power of AI algorithms and data from diverse connected sources to optimize passenger flows and enhance the overall passengers' experience. The high-speed connectivity and low latency provided by 5G/B5G networks will facilitate the deployment of smart service robots that can inspect passengers' flows and assist passengers with relevant information and services.

Creating a connected airport operation has long been one of the airports' priorities. With the use of AI-powered algorithms and data coming from different sources such as cameras, motion detection sensors, etc., the passenger check-in process can become more efficient and effective by reducing waiting times and the long queues that today exist in the check-in areas. Passengers who must proceed to the check-in counter first, to deliver their hold luggage, usually have to wait in a queue, not being aware of the time needed for this process to be completed. Utilising images coming from cameras, AI-powered mechanisms will analyse passenger flows and will detect anomalies in the queues. Additionally, other cameras will be placed at the main entrances of the terminal. This will allow the detection of any anomalies in the flow and volume of the passengers that enter the terminal (Figure 9). All data captured from the cameras and potentially other sensors, the system's historical data, in combination with the capabilities of B5G technology, will be analysed in real time. In cases of anomalies, as well as in cases that the system recognizes that a problematic passengers flow will occur in front of a specific check-in counter, the system will alert the Terminal Operations Supervisor (TOS) and their office assistant in real-time.

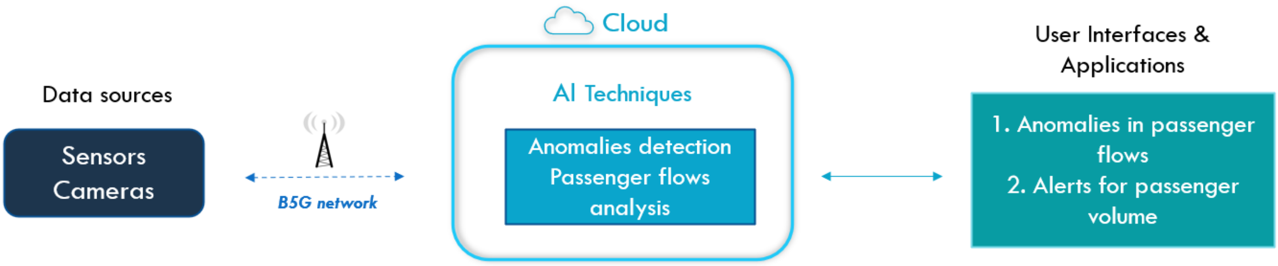


Figure 9. High-level scheme for anomalies and alerts proviosion.

The TOS will have the ability to control remotely the AI enabled robots to act immediately to prevent congestion in front of the check-in counters. The robots will help passengers by providing them personalized information regarding their flights. The robots will confirm the correct check-in counter and propose to the passengers the most appropriate one, with less waiting time needed to fulfil their luggage drop off. Thus, the smart service robots will help airports to balance the demand of check-in counters used by airlines, by assisting in the decision-making process of the TOS and successfully optimizing the waiting times of passengers. The airport operators will have the tools to offer improved passenger service and experience, as the flows will be constantly analysed and will be optimized with the support of the smart service robots. The smart service robots will be also available in the airport facilities for additional services. By combining data exchanged from the various airport applications and interactions with the building and objects, smart service robots will be able to provide passengers with relevant, information and services to assist them with their boarding gates, with more personalized retail offers and suggestions as well as with airport services that passengers may need. Finally, the service robots will be able to inspect passengers' circulations areas for infrastructure faults, defects, cleanliness, and general housekeeping. Deficiencies in such matters will be alerted to the relevant help desk (Figure 10.).

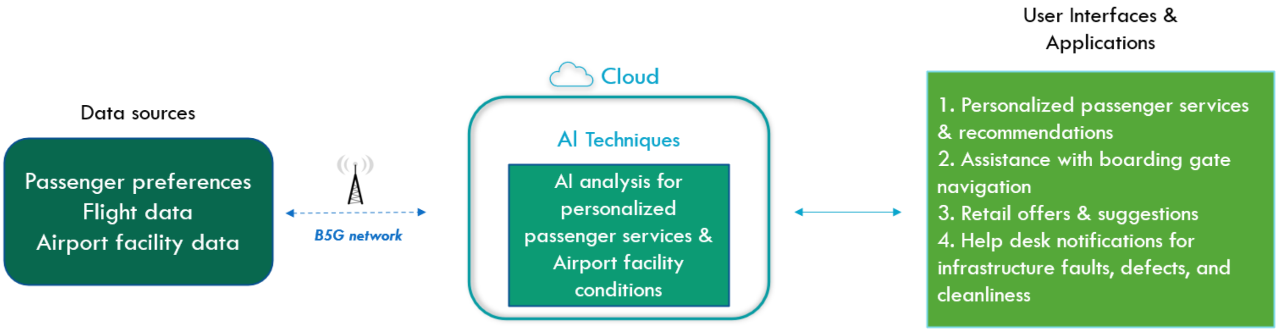


Figure 10. High-level scheme for personalized assistance and support.

3.2.2 Implementation aspects

The application design and the equipment and devices for UC11 are given below.

3.2.2.1 Application design

The application design of this use case involves various software modules and functionalities, including IoT sensors, AI-powered algorithms, B5G technology, mobile applications, backend systems, and smart service robots. The system consists of several modules that work together to optimize the passenger check-in process and improve the overall airport experience. The Graphical User Interface (GUI) of the application will have a user-friendly interface that allows the TOS and their office assistant to access real-time data and alerts about passenger flows and anomalies. The GUI will display a dashboard with visualizations of passenger flow data and insights, such as the number of passengers waiting in each check-in queue, the average waiting time, and the estimated time to process each passenger.

The suggested application design (Figure 11) incorporates several modules to collect, process, and analyse data collected from cameras placed in different areas of the airport. The modules work together to optimize passenger flows, reduce waiting times, and provide a better passenger experience. The design aspects as well as the interactions between the software modules and components are described below.

- **Data Collection Module:** This module will be responsible for collecting data from cameras placed in different areas of the airport, including check-in counters, terminal entrances, and other relevant areas.
- **AI Analytics Module:** This module will process the data collected by the cameras in real-time and identify anomalies and potential congestion in passenger flows. The AI algorithms will use machine learning models to analyse the collected data and generate insights on passenger traffic volumes, waiting times, and anomalies in the passenger flows. These can be used to optimize passenger flows and reduce waiting times.
- **Service Robots Module:** This module will be responsible for controlling the service robots that will assist passengers in finding the correct check-in counter and providing personalized information on their flights. The service robots will also be able to provide additional services to passengers, such as retail offers, suggestions, and general assistance.
- **Visualization Module:** This module will provide a Graphical User Interface (GUI) for the TOS to monitor passenger flows and congestion areas. The GUI will display real-time data on passenger traffic volumes and waiting times, as well as alerts on potential congestion areas. The TOS will be able to remotely control the robots to prevent congestion and optimize passenger flows.

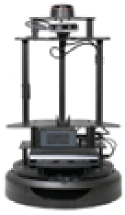
Figure 11. Application design and module interactions for UC11.

WINGSPARK++ [17] (see section 3.2.3.2) is a fully integrated management system for transportation and infrastructure, which will be utilized to process and analyse data from the various modules. The software modules will interact with each other to analyse data and provide real-time alerts to the TOS and their office assistant. The sensors and cameras will capture passenger flow data, transmit them to WINGSPARK++, where AI-powered algorithms will analyse them to detect anomalies, passenger concentration and flows. By interacting with the platform, the robots will provide personalized information and assistance to passengers, suggest check-in counters with the least waiting time, and offer additional airport services. The B5G technology will enable real-time data exchange, live streaming and high-speed communication between the different modules of the system.

3.2.2.2 Equipment and devices

The list of main equipment and devices is given in Table 4. To use the LoCoBot WX250 in this use case, the robot would need to be modified and adapted to meet the needs of an airport environment. With the addition of new sensors, connectivity, and AI algorithms, the robot could help improve the passenger experience. In addition to the mentioned sensors and modules, a tablet, microphone, and speakers will be added to the robot for interacting with passengers, to become even more capable of providing personalized assistance and guidance to them throughout their journey in the airport.

Table 4. Equipment and devices for UC11.

Equipment	Item	Description	Quantity
	LoCoBot WX250 [18]	The LoCoBot WX250 robot is a versatile robot designed for use in various industries, including transportation, logistics and healthcare and is capable to be transformed into different forms by adding sensors, screens, or even a 3D printed body to form a more visually pleased robot for better interaction with humans. The robot can be equipped with stereo camera, lidar, a 5G wireless module, and Global Positioning System (GPS) equipment, making it an ideal tool for the airport operations use case described. With its powerful depth sensing capabilities that can capture both Red Green Blue (RGB) and depth images the robot's internal computer can generate depth maps of the environment, thus accurately detecting the presence of people and objects in the airport terminal with estimation of their distance from the camera. The high-resolution video can be sent to the cloud platform for further analysis of the environment and crowd analysis.	1
	Intel® RealSense Depth Camera D435 [21]	The integrated Intel RealSense Depth Camera D435 can capture high-quality images and videos, can be used for a variety of tasks, such as passenger recognition, tracking, and anomaly detection.	1
	RPLIDAR A2M8 360° lidar [20]	The robot is also equipped with lidar, which use laser beams to detect obstacles in the environment. The lidar can be used to map the airport, and also detect passenger flows and congestion. Specifically, the RPLIDAR A2M8 360° lidar is a powerful sensor that can scan the area around the robot and create a detailed 3D map of the surroundings, which can be used to accurately detect the presence and position of people and objects. In the context of the use case described, by using the 360° scanning capabilities of the lidar, the robot can create a detailed map of the check-in area and detect any anomalies in real-time, allowing it to alert the TOS and their office assistant and take action to prevent congestion and improve the passenger experience.	2
	Quectel RM500Q-AE wireless module [21]	The 5G wireless module (Quectel RM500Q-AE) allows the robot to communicate with other devices and systems in real-time. This feature is essential for the airport operations use case as it enables the robot to receive data from sensors and transmit information to the TOS. The Quectel RM500Q-AE is a 5G cellular module designed for high-speed data transmission in various industrial applications supporting download speeds of up to 2.5 Gbps and upload speeds of up to 660 Mbps over different cellular network standards, including 5G New Radio (NR), LTE-A Pro, LTE-A, and Wideband Code Division Multiple Access (W-CDMA), allowing it to	2

		operate in different network environments. The module features built-in of most Global Navigation Satellite Systems. The module is designed for industrial applications that require reliable, high-speed data transmission and accurate positioning information. Its multi-mode support and industrial-grade design make it suitable for use in various environments and applications.	
	NUC8i3BEH MiniPC [22]	With the utilization of the sensors the robot can use its cameras and lidars to inspect the airport facilities for infrastructure faults, defects, and cleanliness issues. It can alert the relevant help desk if any issues are detected. The initial computation is done at the robot internal computer an Intel NUC NUC8i3BEH Mini PC which is a compact desktop computer that is powered by an 8th Gen Intel Dual-Core i3 processor with 8GB of DDR4 RAM, which provides ample processing power and memory for these computing tasks. The NUC8i3BEH also comes equipped with WiFi, Bluetooth 5.0, Gigabit Ethernet, Thunderbolt 3 and USB C connectors allowing connection to the internet and other devices with ease.	1

3.2.3 Infrastructure components and functionalities

The UC11 implementation will use a 5G network infrastructure and the WINGSPARK++ platform.

3.2.3.1 5G network infrastructure

To support the operation of smart service robots, a public 5G network will be used leveraging its high-speed connectivity, low latency, and wide coverage. Specifically, the network will use Non-Standalone (NSA) architecture and operate at a frequency of 3.5 GHz. The allocated band for this network is 80-100 MHz, which will provide high-speed connectivity and low latency to support the data-intensive applications required by the use case. Future versions of the public network will also be used.

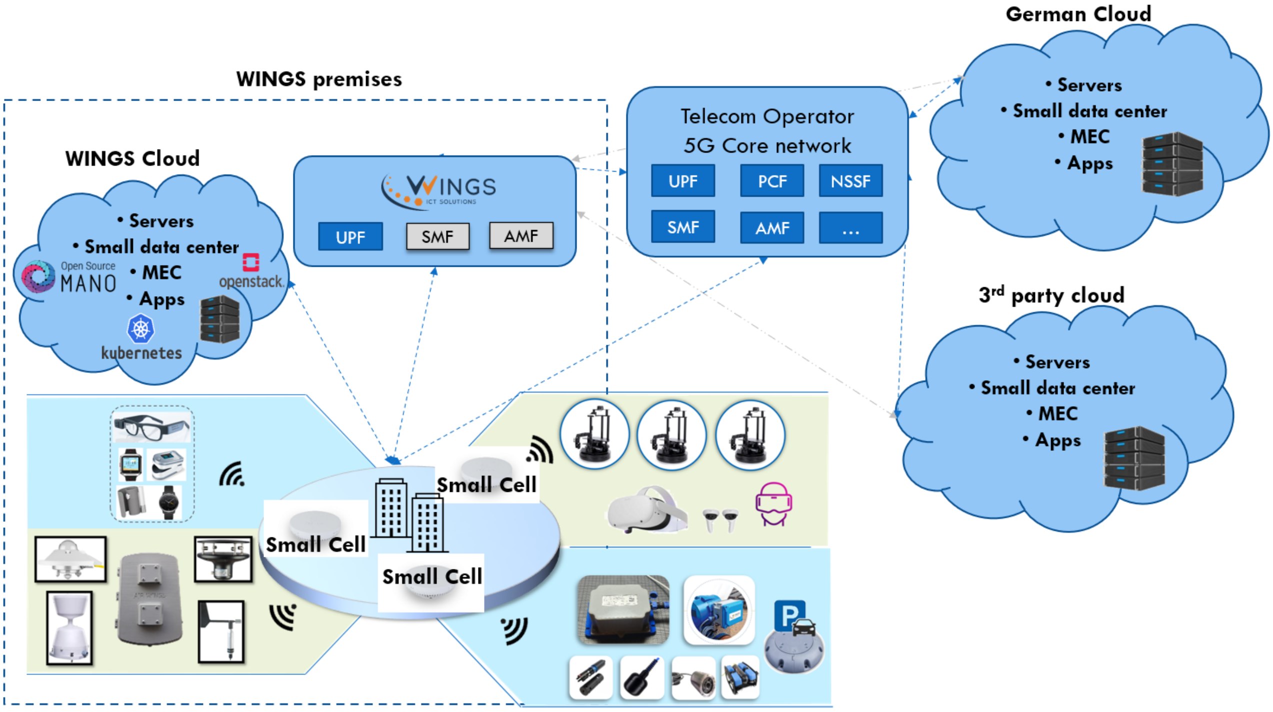


Figure 12. Architecture of WINGS private network infrastructure.

In addition, a WINGS owned, private network infrastructure will be also utilised, to conduct testing activities, validation, and demonstration, prior to the deployment in the field. The Figure 12 depicts the architecture in a high-level manner. The WINGS testbed provides end-to-end 5G/B5G functionality, along with extensive cloud and edge computing capabilities, leveraging the 3GPP (Release 16 and beyond) PNI-NPN with shared Control Plane (at a first phase) and isolated, SNPN, with all network functions (UP and CP) inside WINGS premises, isolated from the public network in the final phase. The site offers a range of 5G/B5G services and will be gradually evolved to 6G. It supports various vertical domains, with WINGS providing the necessary hardware, software, and configurations to enable the testbed to handle these use cases. WINGS testbed serves as a testing ground for services, equipment, and new features before they are commercially released. Detailed description of the testbed will be provided in D2.1.

3.2.3.2 WINGSPARK++

The high-level infrastructure, WINGSPARK++ will support several functionalities, such as:

- Human detection and recognition, to detect passengers with luggage in real-time at an airport.
- Anomaly detection of passenger flows, queues, and volumes using Machine Learning (ML) algorithms. Anomalies may include unexpected congestion, delays, or a sudden surge in passenger traffic.
- Predictive analytics where the system will be able to predict future passenger flows and potential issues, such as congestion or delays, using historical data and machine learning models.
- Decision making support to the Terminal Operators and supervisors for suggesting the most appropriate check-in counters and optimal routes for passengers using various algorithms.
- Robotics control smart service robots' movement and action control based on the output of the algorithms.

WINGSPARK++ [17] is a fully integrated management system for transportation and infrastructure that provides solutions for various stakeholders, such as public and private transport providers and infrastructure operators. It utilizes advanced monitoring, fault detection, performance optimization, security, and configuration capabilities in the areas of i) infrastructure, ii) parking, and iii) stations.

For transportation hubs like airports, ports, and train stations, WINGSPARK++ provides mapping tools that show crowd concentrations and flow, as well as conditions like air quality and health aspects. Critical events and predictive maintenance tasks can also be detected, and itineraries can be provided to passengers. Additionally, insights can be provided to stakeholders, such as operators and retailers, to improve overall efficiency and people safety, including evacuation plans.

In the scope of the 5G-TOURS [2] project WINGS extended its WINGSPARK++ platform to monitor in real-time the parking facility at Athens International Airport by leveraging on its 5G-enabled Smart Parking Occupancy sensors. This work also comprises a mobile application utilizing 3D graphics to assist users in finding and navigating to the airport spot leveraging on AI. As part of the TrialsNet project and UC11, data collected from multiple sources within an airport will be transmitted through a 5G network using KAFKA, enabling further data extraction and processing (Figure 13). The resulting data will be ingested into a highly scalable datastore, which will serve as input for AI processing. WINGSPARK++ will leverage advanced AI and Deep Learning (DL) technologies to analyze data and provide insights, such as passenger traffic volumes, waiting times, and anomalies in the passenger flows. In addition, the platform will enhance its user interfaces with-a dashboard that will provide insights and alerts to the TOS. To further improve accessibility and convenience, mobile apps will also be developed for the passengers, providing users with easy access to information and insights on the go. The service robots will also receive input from AI algorithms, while interacting with the user interfaces of WINGSPARK++.

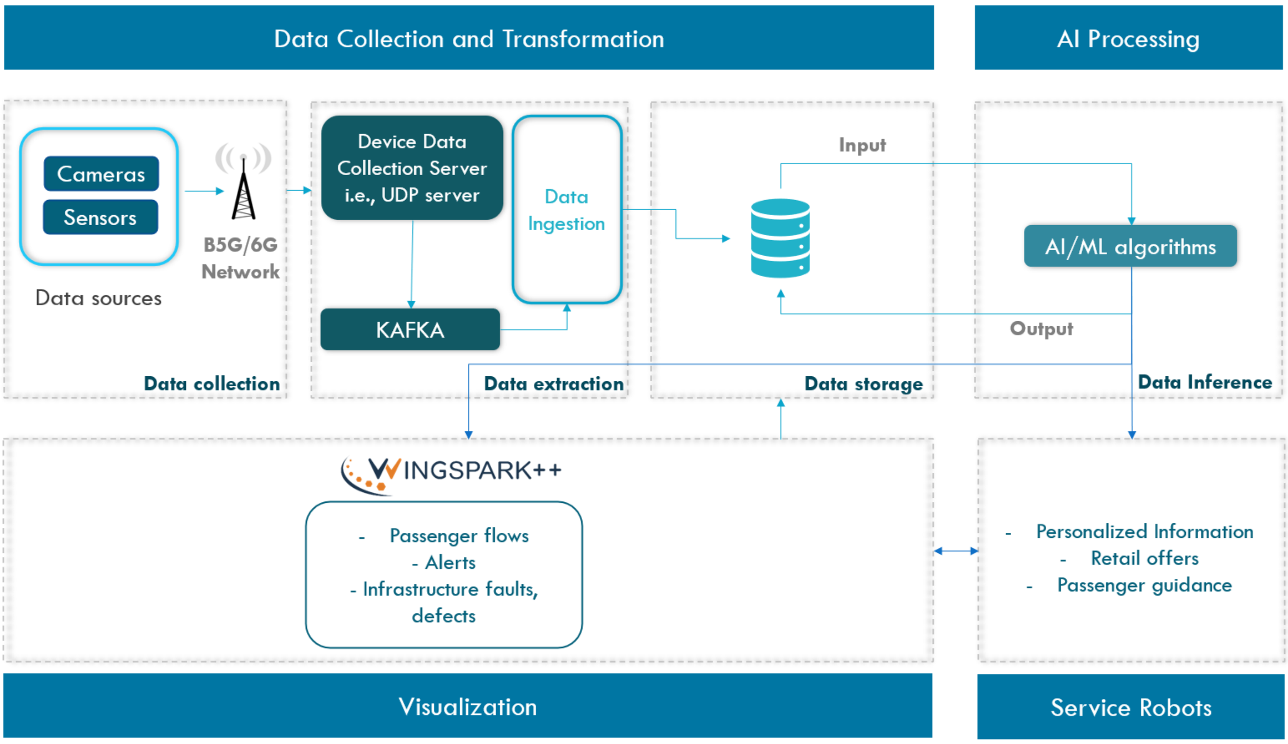


Figure 13. High-level architecture of WINGSPARK++

3.2.4 Trial description

The trial will take place at the Main Terminal Building of Athens International Airport, Departures level, check-in area. A WINGS owned, private network infrastructure will be utilised, in order to conduct testing activities, validation and demonstration, prior to the deployment in the field. A public 5G network will also be used for the trials. The participants of the UC will be people from the participating partners and employees in their organizations. The pre-trial activities consist of the following three phases.

Phase 1: Preliminary Analysis

- Indication of a potential place that could be suitable for the trial.
- Verification of the current and future 5G coverage in the Airport in terms of availability and strength.
- Verification of GPS coverage inside the Airport.
- Identification of whether a simulation platform can be used initially.
- Design Thinking+ methodology to be examined. The utilization of Design Thinking+ methodology can aid in identifying user priorities, to ensure relevance of the results for the users.

Phase 2: Implementation

- Design of the solution, its objectives, contents, and functionalities.
- Development of AI algorithms, airport staff application and passenger application.
- Integration of cameras, applications, sensors on the robotic equipment
- Testing and refining the solution in order to verify that it satisfies the intended aims and objectives.
- Deployment and test of the integrated system.

Phase 3: Initial tests

- Initial tests will be carried out in WINGS laboratories, to examine the functionality of the robots in a safe space and under different conditions.

The following Table 5 describes the trial for the enhanced passenger experience.

Table 5. UC11 trial description.

Trial ID / Name	**Trial 11.1 / Enhanced airport experience**	
Infrastructure / Venue	**5G commercial network / Athens International Airport**	
Description	This test case involves the experimental validation and development of prototypes of the envisioned services supported by robots, AI algorithms, sensors and 5G technologies in the context of an airport operation. The purpose is to improve the passenger experience by deploying robots and AI technology to reduce waiting times and congestion in check-in areas and to optimize the flows of walking passengers. Additionally, this can help detect anomalies in the queues and passenger flows in real-time, enabling airport operators to offer improved passenger service and experience. Ultimately, the goal is to create a connected airport operation that can provide a seamless and personalized passenger experience while increasing efficiency and reducing costs.	
Components and Configuration	Components	• Robot • Robotic Operating System • Robotic Applications • Cameras • Sensors • Mobile devices (Tablets, Smartphones) • Mobile Application • AI software (analysis and prediction of potential damages and hazards) • Cloud-based storage for collected data and analysis. • 5G internet connection to enable real-time data sharing and communication
	Configuration	• The robot, cameras, sensors should be connected to the airport's small cells 5G network to enable real-time data collection and analysis. • The mobile devices should be configured to access info and receive live events and alerts over the network. • Monitoring tool should be installed on the devices, to measure latency and throughput.
Test procedure	Pre-conditions	• The devices should be fully charged and properly configured to connect to the small cells 5G network. • Before executing the test case, the robot should be deployed at the airport to collect data. • The test signals from the cameras and sensors should be sent to WINGSPARK++ to verify connectivity and ensure proper data collection and analysis.
	Test Case steps	The trial will include at least 2 scenarios: a) passengers' guidance and b) inspection of malfunctions (e.g., debris etc.) • The robots are deployed to monitor and do crowd analysis. • The robots use their sensors to track foot traffic, monitor wait times, and detect any anomalies or issues in the various airport processes. • The robot will combine mobility capabilities, sensors and touchscreen for tasks such as showing the

		way in the airport, mobile sensing, and in general human-robot interaction. • Object detection is used to identify debris, litter, and potential hazards that could lower passenger experience. • WINGSPARK++ analysed the collected data using Neural Networks and Deep Learning for predictions. • Based on the assessment, the AI platform sends alerts to the airport authorities. • Remote experts access the mobile application to view and check any issues that require attention.
Measurements	Methodology	• KPIs such as latency, service reliability, service availability, throughput, etc, will be monitored and compared against the target values (see Table 16 in section 4.2.2). Users will be provided with questionnaires to provide input on KVIs (see Table 17 in section 4.2.2). Demonstrations to relevant stakeholders will be made to obtain further feedback.
	Complementary measurements	• Accuracy, specificity and precision of AI mechanisms.
	Calculation process	• Repeated tests will be performed to collect a large sample of KPI values and measurements. Different methods will be used (see also section 4.2.2). The average value will be compared to the target value set. The overall functionality of the system will be assessed to ensure that the system "behaves" as it should. Usability will be measured via questionnaires.
Expected Result	• The KPIs will be as close as possible to the requirements. • Reduction in passenger waiting times at check-in counters and other key areas of the airport, leading to improved passenger experience. • Increased efficiency and effectiveness of airport operations, leading to reduced costs and improved profitability. • Improved accuracy and speed of anomaly detection and response, leading to fewer disruptions in passenger flows and less congestion. • Higher levels of passenger satisfaction and engagement, measured through surveys, feedback, and other means.	

The trial descriptions reported in Table 5 is complemented with the KPIs/KVIs definition and measurement of the specific use case reported in section 4.2.2.

3.3 UC12: City Parks in Metaverse

The metaverse is a virtual world that is accessible through the Internet. In an outdoor environment, the metaverse can provide a variety of experiences by extending the physical world and adding value to it. A park in the metaverse is thought of as a virtual recreation space where users can interact with each other in an immersive and interactive environment. As anticipated, the selected location in Turin is "Borgo Medievale". Indeed, this a unique area in Turin, reproducing a Medieval village in between one of the most important – even in terms of natural heritage – Park in Turin, the Valentino Park (see Figure 14 and Figure 15).

Figure 14. View of the Borgo Medievale and la Rocca.

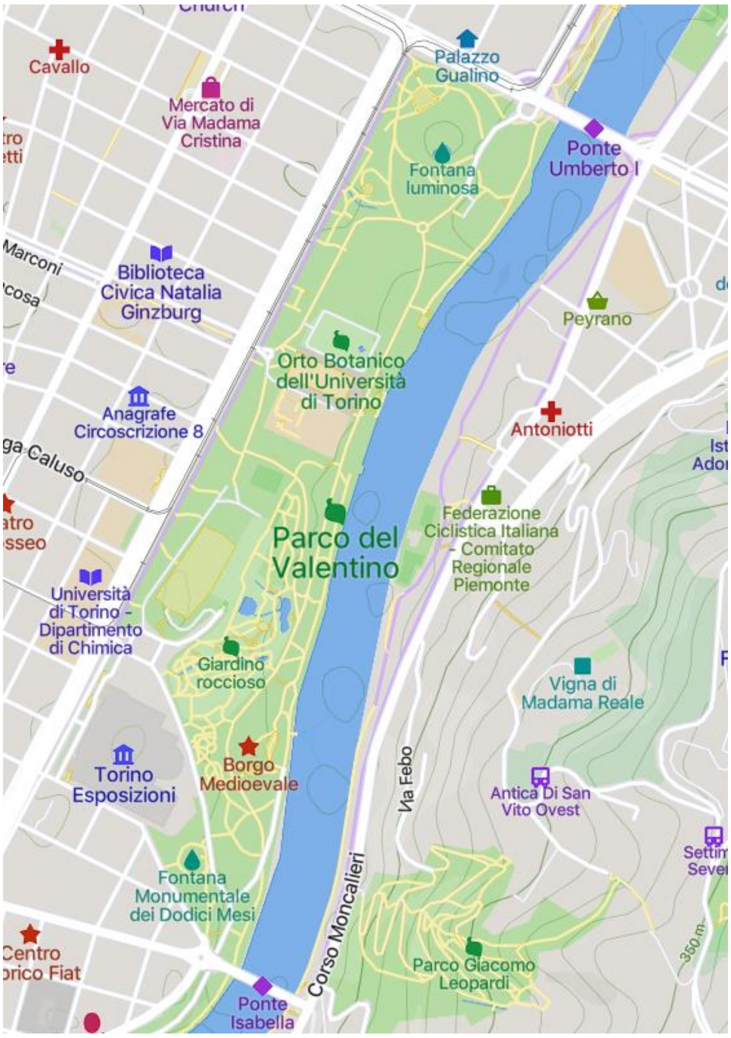


Figure 15. Map of the Valentino Park.

3.3.1 Use case definition

The Borgo Medievale is going to undergo major restoration and renovation works, which will start at the beginning of 2024 and should be completed by 2026. Therefore, the concept of the "Park in metaverse" is particularly strategic in this framework for the following reasons.

- It will allow to live part of the Borgo and of the park, even during its 2-year closure both for citizens and tourists from Italy and abroad.
- It will help reinforce a strong cultural/touristic vocation of the Borgo and the Park with a strong technology/futuristic vision.
- It will showcase how real and virtual can be combined to make cultural heritage live and impact on citizens/touristic even during construction works.

This use case will develop around the social metaverse concept, centred on the idea of creating a virtual world where people can interact with each other, form social connections, and participate in a variety of activities and events and create a sense of community. The metaverse can provide several advantages for visiting and exploring the Borgo Medievale, some of which include the following.

- **Virtual Environment:** The Borgo will have a 3D digital twin that simulates the real-world, complete with walking paths, shops and the castle.
- **Social Interactions:** Users will be able to interact with each other in real-time, either through avatars or other virtual representations. They could engage in social activities like playing games or simply chatting with friends, thus creating social connections and a sense of community.
- **Customizable Experience:** Users will be able personalize their experience in the park by choosing the appearance of their avatars, selecting their clothing, and even changing some parts of the environment around them.
- **Virtual Reality**: The park will be designed also for VR devices, to provide users with an even more immersive experience. This will allow them to move around in the virtual environment and interact with objects and other users in a more natural way.
- **Accessibility**: The social metaverse allows users to visit the Borgo Medievale from anywhere in the world, without the need to physically travel to Turin.
- **Virtual Tour**: The social metaverse can provide a virtual tour of the Borgo Medievale, allowing users to explore the medieval village in a virtual environment. This can provide a sense of what it would be like to visit the Borgo Medievale/Valentino Park in person, even if the physical location is closed.
- **Immersive Experience:** The social metaverse can provide an immersive experience for users, allowing them to feel like they are there. By incorporating virtual reality technology, users can feel like they are walking through the alleys of the Borgo Medievale, interacting with the buildings and other elements of the environment.
- **Educational Opportunities**: The social metaverse can provide educational opportunities for students, teachers, and other interested individuals. For example, they can learn about the history of the Borgo Medievale and its significance, as well as other aspects of medieval life and culture.

Visitors in an open-air setting near the entrance of the Borgo Medievale will use their tablet, smartphone and/or VR headset to visit the Borgo during its closure for its total renovation (Figure 16). Besides individual citizens, users would include e.g., cultural guides, teachers and schools, trainers, groups of friends, families. While the number of possible uses of the metaverse in a public space are infinite, for the TrialsNet project an application will be designed and implemented to stress the current 5G mobile network, e.g., in terms of bitrate and latency, and to demonstrate a playful application of the metaverse. Moreover, the used platform will be open source, thus allowing other creators to develop new applications on the same infrastructure.

Figure 16. Example of metaverse of the Borgo Medievale.

3.3.2 Implementation aspects

The implementation aspects of UC12 are described in the following sections.

3.3.2.1 Application design

A multi-player mobile game sandbox application (Figure 17) will be developed allowing the upload of scanned spaces and the ability to drop layers of interactive game content onto a virtual space. Thanks to its ability to create and customize virtual spaces, this app will provide various possibilities for social gameplay and exploration.

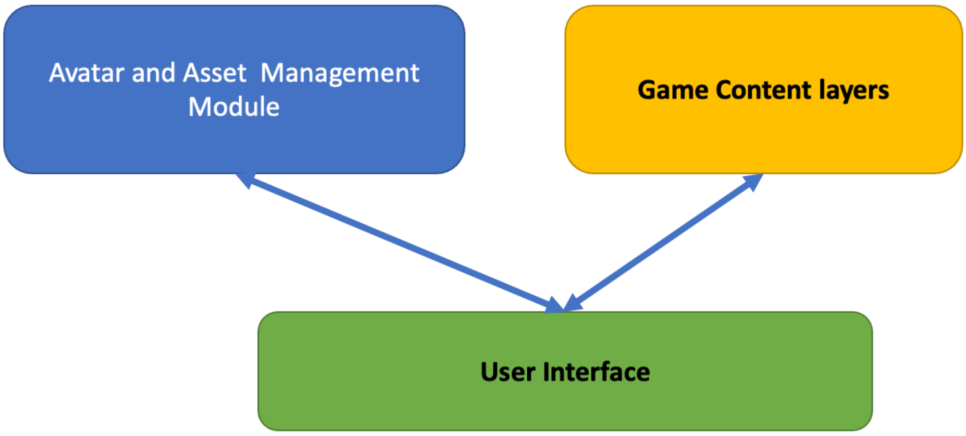


Figure 17. High-level design scheme of multi-player application.

Users will be able to experience the app both on phones and tablets as well as in augmented reality, creating an even more immersive and interactive experience. The block diagrams of the multi-player mobile game sandbox app can be broken down into the following main components:

- **Game Content Layers manager**: This component enables users to add game assets to the virtual space. The app will include modular game components, which can be customized by users to suit their preferences.
- **Avatars manager**: This component allows users to customize their own avatars and navigate through the virtual space. The app uses ReadyPlayerMe [24] to generate avatars that can be customized with various features such as facial features, clothing, and accessories. A navigation system will allow users to move their avatars through the virtual space, interact with objects and other avatars, and communicate with each other.
- **User Interface manager**: This component is how users interact with the app. The app's user interface is designed to be intuitive and easy to use, with a clear and consistent layout. The app must also have

features and functionality that enable users to upload scanned spaces, customize avatars, navigate the virtual space, and communicate with other users. Additionally, the app must be compatible with different platforms, such as iOS, Android, and Apple glasses, to ensure that it can reach a wide audience of users.

3.3.2.2 Equipment and devices

The list of the identified equipment is given in Table 6 below.

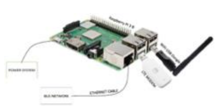
Table 6. Equipment and devices for UC12.

Equipment	Item	Description	Quantity
	META QUEST 2 [11]	Advanced all-in-one VR headset with a visor and controller only (smartphone app required). Six Degrees of Freedom (6DoF). With 6DoF technology, the visor tracks head and body movements and then translates them into VR with realistic accuracy. No external sensors are required. Fast-switching LCD display. Resolution of 1832x1920 per eye. Support for 60, 72 and 90 Hz refresh rate. This device may be replaced by Apple Glasses if they become available by the end of 2023 with the required features Also Meta Quest III is expected by the end of 2023.	5
	APPLE IPAD PRO [25]	11-inch Liquid Retina display footnote with ProMotion, True Tone, and P3 wide color. Pro cameras with LiDAR Scanner, and Ultra-Wide front camera with Center Stage. Wi-Fi 6E for fast Wi-Fi connections. And 5G for superfast downloads and high-quality streaming.	2
	APPLE IPHONE 14 PRO MAX [26]	Brighter 6.1” Super Retina XDR display. 48 MP Main camera with an advanced quad-pixel sensor for up to 4x resolution. A16 Bionic chip.	2
	APPLE MAC BOOK PRO [27]	12-Core CPU 19-Core GPU 16GB Unified Memory. 1TB SSD Storage 16-core Neural Engine 14-inch Liquid Retina XDR display.	1
	Samsung Tablet S8 5G [28]	TFT LCD, 120Hz, 1600 x 2560 pixels, 16:10 ratio (~274 ppi density), Android 12, upgradable to Android 13, One UI 5, Chipset Qualcomm SM8450 Snapdragon 8 Gen 1 (4 nm), CPU Octa-core (1x3.00 GHz Cortex-X2 & 3x2.50 GHz Cortex-A710 & 4x1.80 GHz Cortex-A510), camera: 13 MP, f/2.0, 26mm (wide), 1/3.4", 1.0µm, AF 6 MP, f/2.2, (ultrawide) Video 4K@30/60fps, 1080p@30fps	2

	Samsung S22 [29]	Internal memory of 256 GB storage with 8 GB RAM Triple main camera at back side body with 50 MP f/1.8 for standard wide + 5 MP f/2.2 for 3x optical zoom + 10 MP f/2.4 for 120 degree ultra-wide.	2

In addition to the equipment and devices reported above, it is also planned to deploy a set of sensors will be utilized to create the digital twin of the Borgo Medievale. Depending on the installations and logistic constraints in the area of the Borgo Medievale, the list of devices that has been considered for deployment are presented in Table 7 below.

Table 7. Sensors to be installed in the Borgo Medievale.

Devices	Item	Description	Quantity
	Dropper Counter sensors [30]	These sensors use Machine Learning to understand people's flows. It listens to signals emitted by measuring the number of people inside a defined space.	5
	Dropper sniffer Wi-Fi sensors [31]	This system researched and used by Dropper, called Wi-Fi counting, is realized through the technique of Wi-Fi sniffing, a system used for People Counting, that is, counting people in both indoor and outdoor areas.	5
	Dropper mmWaves radar antennas [32]	Millimetre-wave sensors use short-wavelength electromagnetic waves to intercept reflected waves and derive data on an object's distance, speed, and orientation.	5
	CNIT Wi-Fi-sensors [33]	Wi-Fi sniffer counting nearby people by analysing periodic "probe-request" messages sent by smart devices carried by people. The device uses state-of-the-art algorithms to address the counting errors due to randomization.	1 for each sensored area/room

3.3.3 Infrastructure components and functionalities

Choosing a metaverse platform with a wide audience can increase social interaction, economic activity, and cultural exchange. A larger and more diverse user base offers more opportunities for creativity and collaboration. Easy client installation, programming extensibility, open-source modularity, and sustainability are important for virtual and augmented reality development. The two platforms that will be utilized are described in the following sections.

3.3.3.1 The UNITY platform

The Unity platform [34] (Figure 18) is a popular game engine and development platform that is increasingly being used for creating metaverse applications. Unity provides a suite of tools for building immersive and interactive experiences, including 3D modelling, animation, physics simulation, and networking.

The block diagram for a Unity-based metaverse application includes the following components:

- **User Interface manager:** This component provides means through which users interact with the metaverse application. The user interface typically includes menus, buttons, and other controls for managing user accounts, accessing the virtual space, and interacting with other users and virtual objects.
- **Network Engine:** The network engine component is responsible for managing the communication between users and virtual objects within the metaverse application. This includes the transmission of data such as avatar positions, game state information, and other events.
- **Virtual Environment manager:** The virtual environment manager provides a framework for the implementation of the virtual space where users can interact with each other and virtual objects. The it uses 3D modelling components and libraries and includes features such as lighting, terrain, and physics simulation.
- **Avatar Manager:** The avatar manager provides tools for users to create and customize their own virtual avatars that are customized based on the application to be developed. They include tools and libraries for creating and manipulating the avatar's appearance, as well as controls for animating the avatar's movements and actions.
- **Game Objects manager:** Game objects are the virtual objects that populate the virtual environment. These can include buildings, vehicles, weapons, and other objects that users can interact with. The game objects manager is based on 3D modelling components and include properties such as physics and collision detection.
- **Scripting Engine:** The scripting engine component provides a means for developers to create custom scripts that control the behaviour of game objects and other elements of the metaverse application. The scripting engine can be used to create complex gameplay mechanics, AI behaviour, and other features.
- **Audio and Visual Effects Manager:** The audio and visual effects manager provides a means for creating immersive audio and visual effects within the metaverse application. This includes tools for creating and manipulating sound effects, music, and other audio elements, as well as visual effects such as particle systems and lighting effects.

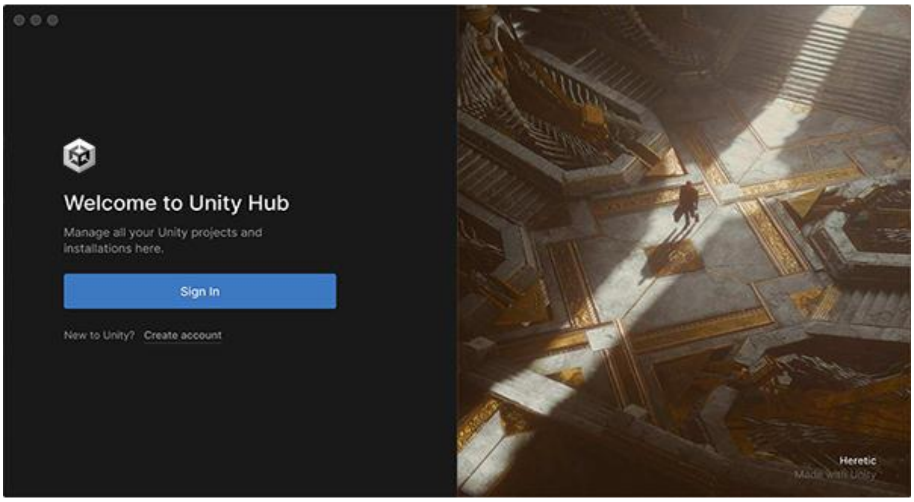


Figure 18. Unity Hub design and development tool.

3.3.3.2 TIM XR Streaming Platform

The TIM XR Streaming Platform is an experimental a platform developed by TIM that enables the creation of a mixed reality app with a multiplayer collaborative virtual 3D environment, based on XR Cloud Rendering paradigm, that, thanks to the advantages of 5G networks, allows high-end extended reality visuals directly into the headset or smartphone from across the internet. TIM XR Streaming platform, actually, is based on NVIDIA CloudXR solution [35] (Figure 19) for streaming virtual reality (VR), augmented reality (AR) and mixed reality (MR) contents from a remote server, where computation actually takes place, to a XR device, allowing the final device to display high quality content.

Figure 19. NVIDIA CloudXR.

The NVIDIA CloudXR Software Development Kit (SDK) is a GPU-accelerated mixed reality (XR) streaming platform that has been built to stream OpenVR [36] -based applications from a remote server. Using CloudXR, VR/AR content can be streamed over Ethernet, Wi-Fi, cellular, and other standard networking technologies. XR content is streamed from a Windows server to an XR client device, which provides access to a high-powered graphics server from a relatively low-end client (Figure 20). The main CloudXR components and features are summarized hereafter:

- **CloudXR content provision:** Streams content from any OpenVR backend running on a remote server (e.g., cloud, data centre, or Edge) over wireless or wired networks to any end device (untethered or tethered thin client)
- **CloudXR Server:** Allows, via a virtual HMD driver to SteamVR [37], OpenVR applications to see the HMD as locally connected (no changes at the application level). Receives frames and audio from the OpenVR application and subsequently encodes them and transports them to the CloudXR client. Supports different Cloud Service Providers (AWS, Google Cloud and Microsoft Azure).
- **CloudXR Client App:** Receives and decodes the frames and audio and presents them to the end device runtime. Relays controller and HMD tracking data and other inputs back to the server. Supports different device types such as Head Mounted Displays (HTC Live, Valve, Meta Quest, Pico) and mobile devices (Google ARCore [38] supported devices and Apple Augmented Reality supported devices).

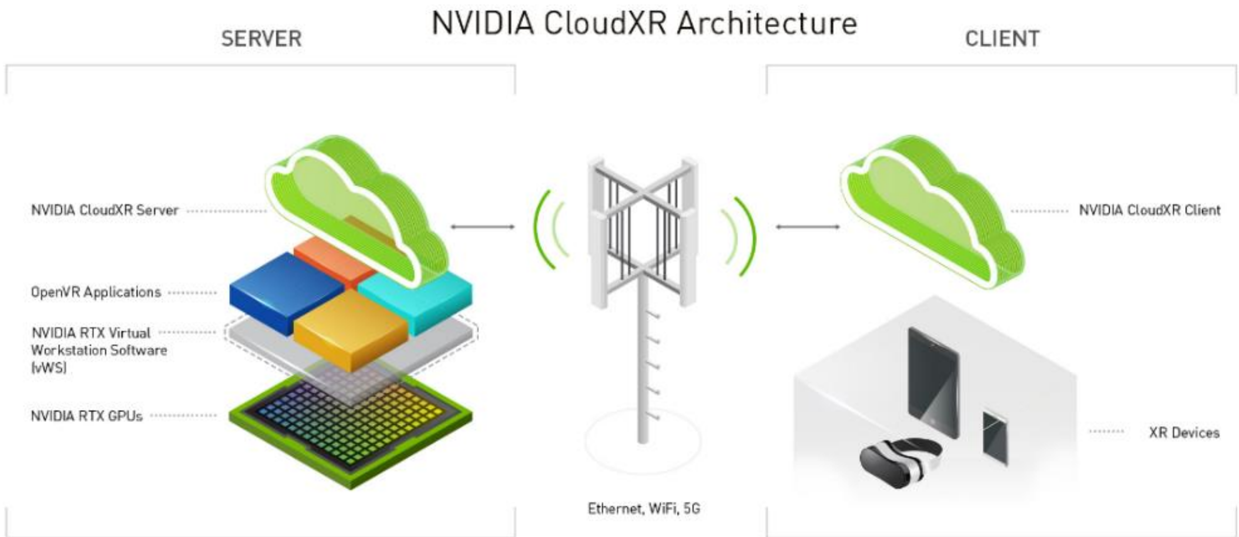


Figure 20. NVIDIA CloudXR Architecture.

In this virtual environment, players are represented by animated avatars and can communicate with each other and interact with the 3D models present in the scene (Figure 21). The main key features are:

- XR Cloud rendering paradigm
- Audio communication
- Animated avatars
- Integration in the use of ReadyPlayerMe avatars
- Interaction with 3D models
- Multi-platform VR and AR, through VR headset (e.g., Oculus Quest 2) and AR devices (e.g., Android e iOS Smartphone/Tablet)
- Using the platform Photon/Fusion for multiplayer and Voice over Internet Protocol (VoIP) communication

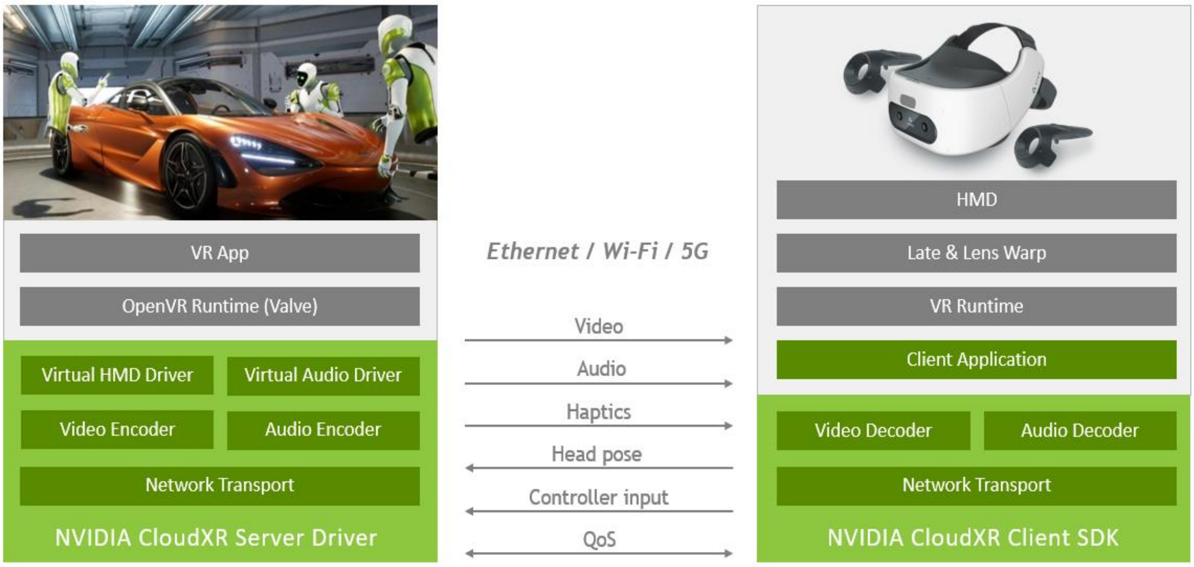


Figure 21. NVIDIA CloudXR Functional Components.

The collaboration offered by the platform follows the key concepts behind the metaverse trend, offering much more captivating graphic experiences. Based on the CloudXR platform TIM created different apps over its experimental XR Streaming Platform that provides the following features.

- Rendering of immersive content moved to Edge cloud.
- Very high resolution and level of detail, even on thin clients.
- Freedom of movement and extraordinary realism, limiting the costs of user devices.
- Interaction with digital twin, multiplayer and avatar/VoIP communication.

Figure 22 shows a Smart Retail app built within the TIM XR Streaming Platform.

Figure 22. Smart Retial application based on TIM XR Streaming platform.

3.3.3.3 5G network infrastructure

The 5G connectivity for the use case implementation will be provided by the commercial network deployed by TIM in Torino (details will be provided in D2.1). Preliminary on-field measurements have been already performed in Parco del Valentino in the surrounding of the Borgo Medievale, where the use case will be implemented (Figure 23). The measurements aimed at checking both coverage and performances (i.e., downlink and uplink throughputs, E2E latency) of the commercial 5G network and will be used as the baseline towards the technical requirements of this use case. Further measurements and tests with devices will be performed during the different development phases of the use case.

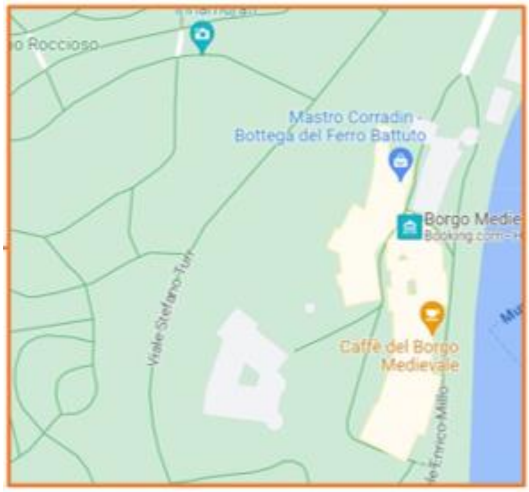


Figure 23. Borgo Medievale area.

3.3.4 Trial description

Valentino Park is a popular public park in Turin and one of the most visited in Italy. It is located along the west bank of the Po River. It covers an area of 500,000m². The exact place where the trial will take place has not been defined yet. This has been discussed with relevant Municipal Departments since there are many constraints that have to be respected. Many areas of the park will be under complete renovation during the project time, including the Borgo Medievale, thus the trial should not interfere with the open working sites also for safety reasons. The trial activity will be articulated in the following four phases:

Phase 1: Preliminary Analysis

- Provision of a map of Valentino Park (including Borgo Medievale) with an indication of the potential sites that could be suitable for the trial in the targeted period for the project.
- Verification of the current and future 5G coverage in the park, concerning the availability and strength of the current 5G network in the park, compared to the needs and network KPIs of the use case.
- Production and/or gathering, verification and upgrade of available high-quality 3D digital images of the selected areas, to generate the metaverse.
- Identification of most suitable metaverse platforms.

Phase 2: Design Thinking+ and Master Plan

- Start of Design Thinking+ activities with a relevant sample of local representatives, final users' representatives, technology providers and cultural experts to co-design the "metaverse experience", paying attention to create a solution of public interest, with the aim to be inclusive, sustainable, accessible for all, educational. The target functionalities will be object of the Design Thinking+ phase and could include an interaction event, the mixed fruition of the park (physical and virtual), music, gamification experience, etc.
- Define the implementation phase, showcasing one or more usages, covering the project and post project period.

- Prepare a Master Plan, i.e., the schematic of the whole implementation phase with all details of resources, equipment, costs and timeline.

Phase 3: Implementation

- Design of the experience, its objectives, contents and functionalities on the basis of the Master Plan.
- Build the metaverse platform and connection to back-end. This includes creating 3D models, designing the virtual space, and coding any interactive elements.
- Test and refine the project: before launching the metaverse project, it's important to test and refine it to ensure that it meets the desired goals and objectives. This includes testing for usability, accessibility, and user engagement in line with the Design Thinking +.
- Deployment and test of the integrated system.

Phase 4: Trial

- The trial will include two scenarios: a) remote usage of the metaverse (only virtual) and b) interaction between virtual and real.
- The duration, methodology and target group of the trial will be specified after the Design Thinking+ phase.
- In principle, the system could be first tested among a volunteer group of practitioners, selected from the Design Thinking+ group. The test field experience would be open for one month or more.

The following Table 8 describes the trial for City Park in Metaverse use case.

Table 8. UC12 trial description.

Trial ID / Name	Trial 12.1 / City Park in Metaverse	
Infrastructure / Venue	**5G commercial network / Parco del Valentino**	
Description	The trial will improve the application of social metaverse in the fruition of selected area of the public park “Parco del Valentino”.	
Components and Configuration	Components	• Advanced all-in-one VR headset • Mobile devices • Sensors • PCs • Metaverse Platforms • 5G Network
	Configuration	the sensors are connected to the IoT platform running at the Edge cloud
Test procedure	Pre-conditions	• Identification of potential sites useful for the trial • Verification of current and future 5G coverage • Production and/or gathering, verification and upgrade of available high-quality digital material of the targeted areas. • Design Thinking+ activities to co-design the metaverse experience

	Test Case steps	Implementation: • Organization of contents and design of the experience and functionalities. • Realization of the application part. • Integration/Implementation of the network. Trial: The trial will include at least 2 scenarios and at least 2 trials period: • remote usage of the metaverse (only virtual) • interaction between virtual and real.
	Methodology	The target functionalities will be object of the Design Thinking + phase and could include an interaction event, the mixed fruition of the park (physical and virtual), a concert, gamification experience, etc. The duration, methodology and target group of the trial will be specified after the Design Thinking+ phase. In principle, the system could be first tested among a volunteer group of practitioners, selected from the Design Thinking+ group. This may be linked to possible new applications developed via the open calls. The test field experience would be open for one month or more.
Measurements	Complementary measurements	• Engagement: This KVI measures how much time visitors spend in the VR experience and how many interactive features they engage with. It can help museum curators understand what content is most engaging to visitors and adjust the experience accordingly. • Retention: This KVI measures how many visitors return to the VR experience after their initial visit. It can help museum curators evaluate the overall satisfaction of the experience and the likelihood of visitors recommending it to others. • Learning outcomes: This KVI measures how well visitors absorb and retain information presented in the VR experience. It can help museum curators evaluate the effectiveness of the VR experience as an educational tool. • Social sharing: This KVI measures how many visitors share their experiences on social media or other platforms. It can help museum curators evaluate the overall reach and impact of the VR experience. • Conversion rates: This KPV measures how many visitors purchase tickets or merchandise related to the VR experience. It can help museum curators evaluate the ROI of the VR experience and determine whether it is worth investing in similar experiences in the future.
	Calculation process	• Engagement: The engagement metric can be calculated by measuring the time spent by visitors in the VR experience, the number of

		interactive features engaged with, and the frequency of revisits. These metrics can be tracked through VR analytics tools that capture visitor data such as session duration, click-through rates, and the number of interactions. • Retention: The retention metric can be calculated by tracking the number of return visitors to the VR experience over a given time period. This can be done through visitor tracking tools or by offering incentives such as discounts or rewards for returning visitors. • Learning outcomes: The learning outcomes metric can be calculated through pre- and post-visit surveys, quizzes or assessments that measure the visitor's knowledge acquisition, and retention of information presented in the VR experience. • Social sharing: The social sharing metric can be calculated by tracking the number of shares, likes, and comments on social media platforms using social media analytics tools. • Conversion rates: The conversion rates metric can be calculated by dividing the number of conversions (e.g., ticket sales, merchandise purchases, etc.) by the total number of visitors to the VR experience, and then multiplying by 100 to get a percentage. This can be tracked using visitor tracking tools that capture conversion data.
Expected Result	• Increased accessibility and fruition of the Borgo Medievale during closure and beyond (for instance for visitors who live at long-distance or are unable to travel physically), including of non-accessible areas. • Enhanced the quality of the experience for real and virtual visitors, through interaction (engaging in social activities like playing games, having virtual picnics, or simply chatting with friends), customization (by choosing avatars, selecting clothing, changing the environment, etc). • Increased educational and cultural opportunities for students, teachers and individuals, through an immersive historical and cultural experience.	

The trial descriptions reported in Table 8 is complemented with the KPIs/KVIs definition and measurement of the specific use case reported in section 4.3.2.

3.4 UC13: Extended XR museum experience (Turin)

An extended XR (Extended Reality) museum experience is a digital, immersive experience that blends physical and virtual elements to create a unique, interactive experience for visitors. XR offers museums an exciting opportunity to engage visitors in new and innovative ways and to provide them with more immersive and interactive experiences This use case will take advantage of the functionalities of B5G technologies to open up new opportunities for visitors of museums to enjoy an exhibition through their mobile devices.

3.4.1 Use case definition

XR has a lot of potential and could transform how museums display and share collections. By combining physical, digital, and virtual elements, museums can create an environment that is both educational and entertaining, making the museum visit an enjoyable and memorable experience for visitors of all ages located in different places. In addition, the metaverse would increase accessibility for those unable to visit physically, due to distance, mobility, or disability. Digital content, such as 3D models, videos, and audio, provide visitors with a rich, multimedia experience that enhances the museum visit. This is more ambitious if conceived as an integrated path in the city, integrating "augmented" experiences spread in different city areas. As compared to the current VR usage in museums, 5BG technologies and the metaverse will allow visitors to be accompanied by their remotely located friends or families to accompany through the visit and exchange opinions and observations about the artworks.

The scope of the UC13 in the Turin site is to integrate, under the same platform, augmented/virtual reality experiences that were developed in previous European Union (EU) projects (notably 5G-TOURS, AI for museums [39], 5G EVE [40], etc.) and to build an enticing narrative, and make them more accessible through official channels of Turin municipality. This use case will provide an extended reality experience, with several steps related to selected museums/cultural point of interests, which final users could enjoy entering from a single stop shop. These different experiences will be linked thorough common storytelling and could be organized as a path, leading users from one museum to another. Experiences could be indoor or outdoor and will be meaningful contents enabling to attract people from outside or to augment and make the visits inside more immersive. Targeted engaging techniques will be identified to approach different targets (adults, youngsters, schools, etc.). Special attention will be given to the design of accessible experiences for all, including the physical and mental disabled. Sensors will be leveraged to estimate passively the number of visitors in a particular area/room, which will used to evaluate the popularity of museum sections and to make more immersive visit by augmenting the experience with the digital twin of the people in the area/room. Furthermore, such estimation can be also exploited to plan and allocate properly the communication and computation resources needed in the network infrastructure.

In short, thanks to AR/XR devices, visitors would interact with exhibits, view high-resolution images, watch videos and read content descriptions and listen to anecdotes stimulating their curiosity. The contents will be enjoyed on XR headset or on mobile, tablets and PC depending on the exhibition area, targets, level of complexity/immersivity of the experience.

In the initial phase of the project, together with the Turin municipality and Fondazione Torino Musei, existing material gauging the appreciation of visitors of new features of past exhibitions have been already analysed during the Design Thinking+ process. This will allow to design the platform and application to adhere as much as possible to the wishes of the visitors.

3.4.2 Implementation aspects

3.4.2.1 Application design

The application architecture for UC13 in Turin is composed by different blocks as described below (see Figure 24).

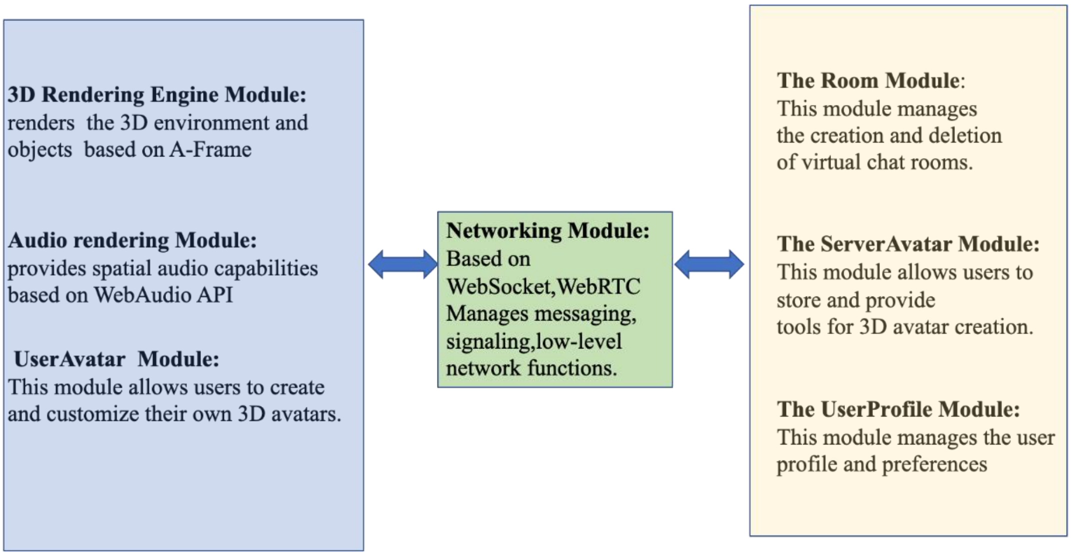


Figure 24. Simplified application modules.

Client: The client-side code is primarily built on A-Frame [41], an open-source web framework for building virtual reality experiences. A-Frame is a powerful tool for creating 3D environments and objects, and it uses HTML-like syntax that is easy for web developers to understand. The A-Frame library includes support for physics, animations, and other 3D graphics capabilities. The client communicates with the server using WebSocket [42] and Web Real-Time Communication (WebRTC) [43] protocols. WebSocket is a protocol that enables bi-directional communication between the client and server, allowing for real-time messaging and data exchange. WebRTC is a set of communication protocols that allow for peer-to-peer communication between clients, including video and audio streaming. is a set of communication protocols that allow for peer-to-peer communication between clients, including video and audio streaming.

Server: The server-side code is written in Node.js [44], a popular JavaScript runtime for building scalable web applications. Node.js allows for fast, efficient server-side code that can handle large numbers of concurrent connections. The server-side code is deployed on cloud platforms such as AWS or Heroku [45]. The server-side code uses Redis [46] and MongoDB [47] to store user data and room information. Redis is a fast, in-memory data store that is ideal for caching and other high-performance use cases. MongoDB is a document-oriented Non-Structured Query Language (NoSQL) [48] database that is well-suited for storing large amounts of semi-structured data.

Modules: The application is built with a modular architecture that allows developers to create custom modules and add new features to the platform. Here are some of the core modules:

- **The Client-Side Rendering Engine:** This module is responsible for rendering the 3D environment and objects on the client side. It uses A-Frame and other libraries to provide a rich, immersive experience for users.
- **The Networking Module:** This module handles WebSocket and WebRTC communication between clients and servers. It manages messaging, signalling, and other low-level network functions.
- **The Audio Module:** This module provides spatial audio capabilities, allowing users to hear sounds coming from different directions in the virtual environment. It uses Web Audio API and other technologies to provide a realistic audio experience.
- **The Avatar Module:** This module allows users to create and customize their own 3D avatars. It provides a variety of customization options, including clothing, hair, and facial.
- **The Room Module:** This module manages the creation and deletion of virtual chat rooms. It allows users to create private or public rooms, and it provides tools for managing permissions, access, and other settings.
- **The video streaming module:** in addition to the live video streaming component described earlier, the system also provides a way to stream pre-recorded videos from remote servers directly into virtual spaces. This allows users to display videos as part of their virtual environment, without the need for local storage or additional plugins. The content video streaming component in Mozilla Hubs works by

using a media player to stream videos from a remote server. The media player is integrated into the platform and can be accessed through a variety of methods, such as by adding a video object to the virtual space or by clicking on a video link. When a user clicks on a video object or link, the media player opens and begins streaming the video from the remote server. The video is then displayed in a window within the virtual space, allowing other users to watch it in real-time.

- **Movement module:** The adopted sensors will be able to estimate the number and position of people using complementary technological approaches, always transparent for the people and in compliance with General Data Protection Regulation (GDPR) [49]. Such number will be used to augment the reality with the digital twin of people in the area, shown with proper avatars. This approach is supposed to provide a more immersive and comfortable way to interact in the generated virtual environment.

3.4.2.2 Equipment and devices

The equipment and sensors envisaged for the UC13 in Turin are the same that will be used for UC12 (Table 7 and Table 8). An equivalent amount will be needed for UC13.

3.4.3 Infrastructure components and functionalities

This section describes the different platforms that will be used for the implementation of the UC13 in Turin. A brief description of the 5G network infrastructure is also provided.

3.4.3.1 Mozilla Hubs (XR Platform)

Mozilla Hubs [52] is a browser-based virtual reality platform that allows users to create and interact with 3D spaces using just their web browser, without the need for any specialized software or hardware. In Mozilla Hubs, users can create their own virtual spaces, or "rooms", which can be customized with 3D objects, images, and videos. These rooms can be shared with others, who can join and interact with each other in real-time, using avatars to represent themselves. Users can also communicate with each other through voice chat or text chat, making it a social experience. Figure 25 shows an example of Mozilla Hubs' main screen, which is user friendly both for users and developers.

In Mozilla Hubs, users can create their own virtual spaces, or "rooms", which can be customized with 3D objects, images, and videos. These rooms can be shared with other users, who can join and interact with each other in real-time, using avatars to represent themselves. Users can also communicate with each other through voice chat or text chat, making it a social experience.

To use Mozilla Hubs, one needs a web browser that supports WebVR, such as Firefox or Chrome, and a device with a keyboard and mouse, or a virtual reality headset. The platform is free to use, and there are no limits on the number of users or rooms one can create.

Mozilla Hubs is built on top of WebVR, a web-based technology that allows developers to create virtual reality experiences using standard web technologies like HTML, CSS, and JavaScript. This means that Mozilla Hubs can be accessed from any device with a web browser that supports WebVR, including desktop computers, laptops, smartphones, and virtual reality headsets like the Oculus Quest and HTC Vive.

Mozilla Hubs also includes a variety of tools for creating and customizing virtual spaces. Users can import 3D models from external sources like Sketchfab [53], Google Poly [54] or create their own custom 3D models using tools like Blender [55] or Tilt Brush [56]. These 3D models can be placed and arranged within the virtual space using simple drag-and-drop controls.

In addition to 3D models, users can also add other types of content to their virtual spaces, such as images, videos, and audio files. For example, a virtual art gallery might feature 3D sculptures alongside video installations and ambient music. Mozilla Hubs also supports a variety of lighting and sound options, which can be used to create immersive and engaging virtual environments.

Finally, it's worth noting that Mozilla Hubs is an open-source platform, which means that anyone can contribute to its development. This has led to the creation of a vibrant community of developers and designers who are working to improve and expand the capabilities of the platform.

Given the extreme flexibility and scalability by design granted by its open nature, user-friendly interface, and possibility to support real-time, multi-player collaboration through voice chat or text chat amongst avatars in the same room, with no capacity limits, Mozilla Hubs was deemed a most suitable platform to implement this use case.

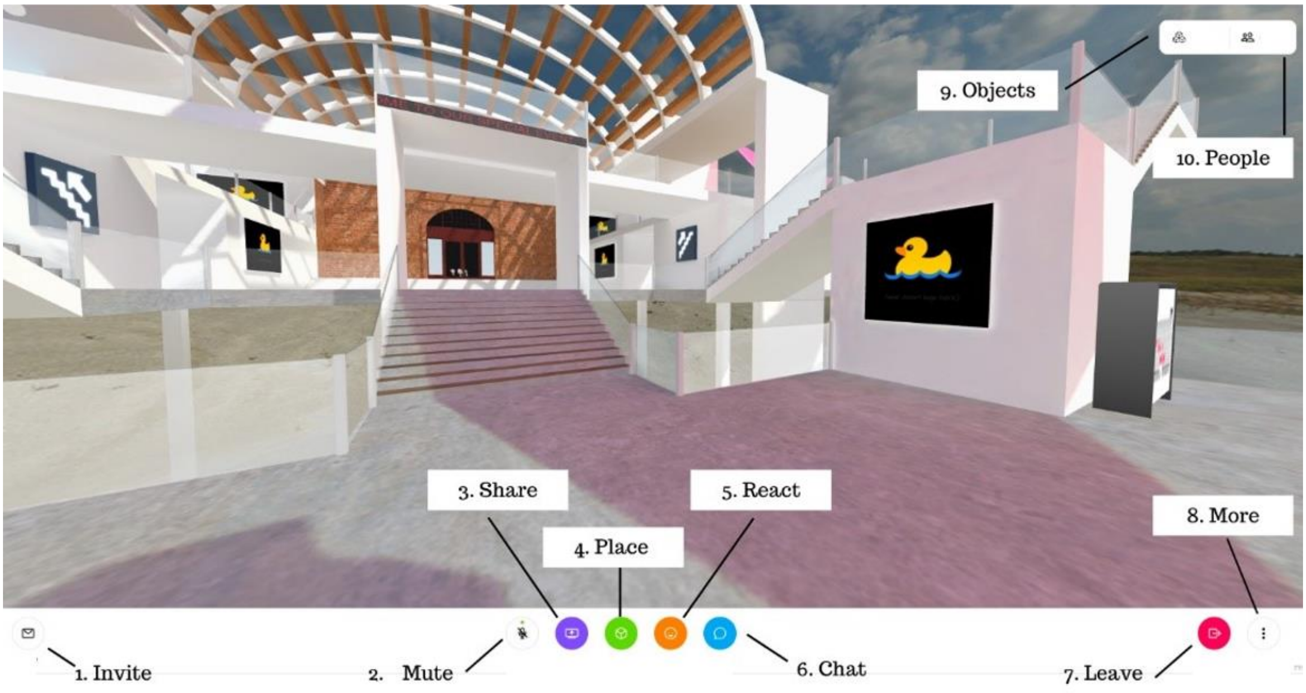


Figure 25. Example of Mozilla Hubs client rendering, with the options to include various items.

Mozilla Hubs will be customised for a metaverse for museums in several ways, including the following:

- **3D models and environments:** custom 3D models of museums' exhibits and design immersive environments can be created that transport visitors to different locations and time periods.
- **Interactive exhibits:** Hubs can be customized to include interactive exhibits that allow visitors to engage with museum content in new and exciting ways.
- **Multiplayer experiences:** Visitors can explore the museum with other people from around the world, allowing for shared experiences and social interactions.
- **Virtual tours:** Museums can create virtual tours of their physical locations or design entirely new spaces that can be explored in Hubs.
- **Accessibility features:** Hubs can be customized with accessibility features such as text-to-speech and closed captioning to make museum content accessible to all visitors.
- **Personalization:** Visitors can create avatars and customize their appearance, creating a more personalized experience.
- **Integration with other platforms:** Hubs can be integrated with other platforms such as the TIM Cloud based rendering platform, which will provide a richer experience to reach a wider audience.

3.4.3.2 TIM XR Platform

The XR Platform developed by TIM (Figure 26) is a multi-tenant cloud-native solution available as Software as a Service (SaaS) and main capabilities are the following:

- Multi-player AR and VR experiences for different scenarios.
- Enables real-time modification of AR and VR contents without having to update end-user apps.
- Provides user-friendly web dashboards for creating and managing AR and VR experiences.
- Provides cross-platform SDKs/packages (Android, iOS, PC) that can be easily integrated into apps.
- Enables augmentations of near real-time data generated by third-party systems.

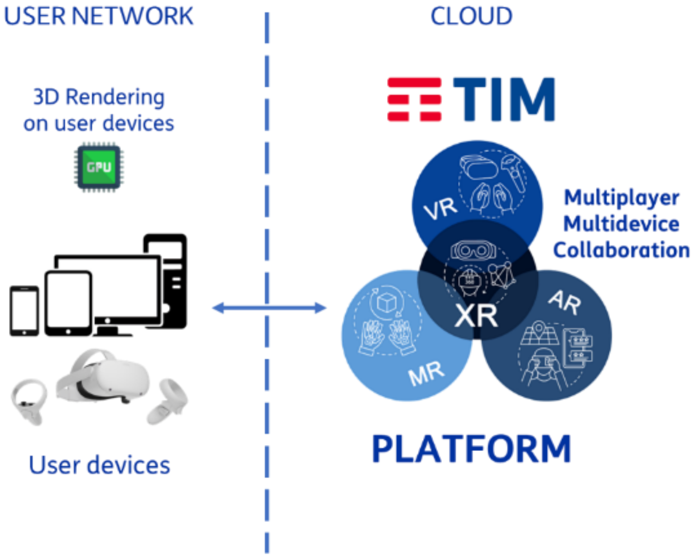


Figure 26 High-level architecture of TIM XR Platform.

The TIM eXtended Reality Platform consists of two main functional components that deals with the AR and VR respectively and that are described in the following.

The main AR platform components mapped with functional components are shown in Figure 27.

- **AR Composer:** A Web tool to create and manage AR experiences by defining the contents to be displayed (such as info panels, videos, images, audios, 3D models, way finders, live data, etc.) through simple templates.
- **AR SDK:** Android/iOS SDK which, integrated into third-party apps, allows you to enjoy AR experiences created using the AR Web Composer and refined through the AR Mapper.
- **AR Mapper:** Android/iOS app that allows you to set the spatial anchors as well as refine the positioning of the augmentation defined through the AR Web Composer.
- **AR Backend:** Multi-tenant platform for the management of AR experiences and their fruition by users.

Both AR Mapper and AR SDK components leverage on and ARCore, which are respectively the frameworks provided by iOS and Android to develop AR apps. With this platform is easy and fast to build an AR experience, it is a 3-steps procedure as follows:

- **Create**: creation of the structure of AR experience using the AR Composer.
- **Define**: it consists of i) **Set-up** in terms of definition of 2D and 3D anchors by scanning the environments and upload of augmentations, and ii) **Refine & test** as enhancement of augmentations by refining their size/placement and testing using the AR Mapper.
- **Publish**: AR experience publishing and fruition by users.

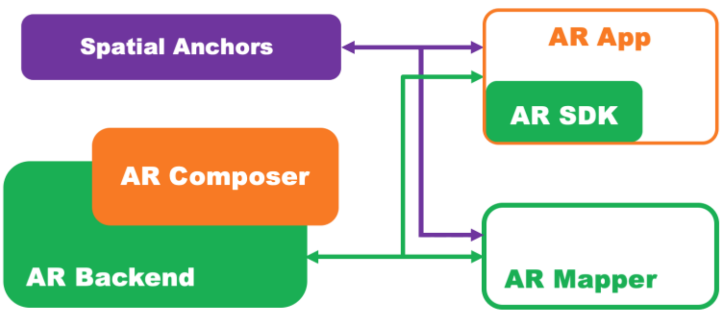


Figure 27. AR Functional Components.

The main VR platform components mapped with functional components are shown in Figure 28.

- **Photon services:** cloud services used for multi-player management (such as synchronization events, VoIP sessions, etc.).
- **Photon services:** cloud services used for multi-player management (such 'Manager': a web tool that allows the creation and management of multi-user sessions and the enabling of specific features that users can use.
- **VR Backend:** multi-tenant platform that creates and manages VR experiences and enables their fruition by users.
- **VR Package SDK** (for Android, iOS and Windows): Unity3D package that enables multi-player functionality. It offers a customizable lobby where the user (depending on settings) creates, searches for, or joins a multi-player session. Besides, the package manages the following:
  - VR sessions
  - Avatar replication
  - Spatial voice replication
  - Objects replication
  - Laser, teleport and grab functionalities.
  - Events and call-backs
  - Hierarchical distinction between users (guide/visitor, instructor/learner)

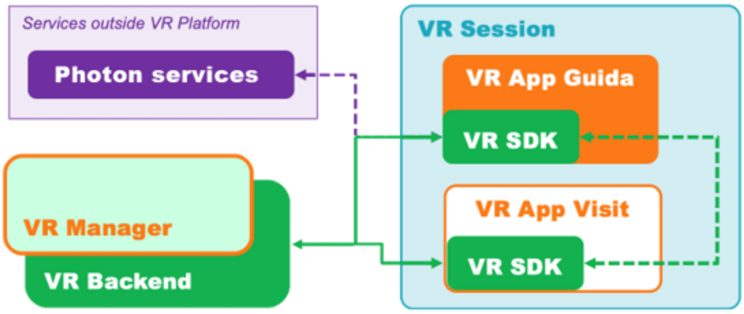


Figure 28. VR Functional Components.

With this platform it is easy and fast to build a VR multi-player experience, it is a 3-steps procedure:

- **Create:** the VR Web Manager defines and manages the VR sessions and registers the users.
- **Integrate:** Unity developer creates the VR project and integrates the package enabling multi-player functionality offered by the TIM XR Platform.
- **Publish:** VR experience is published, and end-users can make use of it.

In Figure 29 there are shown some AR and VR experiences built within the TIM XR Platform.

Figure 29. VR enabled scenarios with TIM XR Platform.

3.4.3.3 TIM XR Streaming Platform

This platform has already been described in section 3.3.3.2. The TIM XR platforms will be used, along with the applications and virtual environments developed for other museums. This is a significant step towards democratizing access to cutting-edge technology. By extending its reach to other museums, the benefits of TIM's platform and applications can be shared with a wider audience, enhancing the cultural and educational experience for all and test the performances of the beyond 5G network.

3.4.3.4 5G network infrastructure

As per all the other use case that will be implemented in the Turin site, the 5G connectivity will be provided by the 5G commercial network deployment of TIM providing high data transfer rates, improved reliability, and reduced latency. These benefits will enable the application to provide users with a more seamless and immersive experience, allowing for real-time updates and a more dynamic user experience. At the same time, sensors will transfer data in real time to the IoT platform running at the Edge cloud and will enable the generation of the digital twin of the people in an area within the XR platform. Nevertheless, for this specific use case, the 5G indoor coverages that were deployed by 5G-TOURS at Palazzo Madama and GAM will be exploited. Details about this infrastructure will be provided in D2.1 of WP2.

3.4.4 Trial description

The trial will take place in the selected museums, or in an area in front of them according to the strength of the local 5G signal. The participants of the UC will be representatives from the museums as well as the students that have been involved in the Design Thinking+ process. In the pre-trial phase, only staff of the participants organizations will be engaged. The trial activites will be articulated in the following phases.

Phase 1: Preliminary Analysis

- Create an inventory of existing digital contents regarding selected museums and cultural points of interest.
- Collect and analyse data regarding visitors' appreciation of past digital exhibitions.
- Carry out an analysis of the main existing metaverse platforms to identify at least two possible candidates for the trial.
- Perform a verification of the current 5G coverage in all the target locations.

Phase 2: Design Thinking+ and Master Plan

- Start of Design Thinking+ activities with a relevant sample of local representatives, final user representatives, technology providers and artistic and cultural experts to co-design the trial.
- Select material that could be re-used from previous projects (e.g., 5G-TOURS, 5G-EVE, AI4Museums).
- Select museums for initial trials Prepare a Master Plan.
- Brainstorm about new possible App.

Phase 3: Implementation

- Design of the experience, its objectives, contents and functionalities based on the Master Plan.
- Build the metaverse platform. This includes creating 3D models, designing the virtual space, and coding any interactive elements.
- Develop a 1new Apps with original content.
- Draft a captivating storytelling to integrate the material.
- Test and refine the project: Before launching the metaverse project, it's important to test and refine it to ensure that it meets the museums' goals and objectives. This includes testing for usability, accessibility, and user engagement in line with Design Thinking+.
- Integration and Implementation of the Apps, platform, devices and network.

Phase 4: Trial

- The trial will include the deployment and test of the integrated system in different scenarios and targets. The experiences could be organized outdoor as an introductory attractive for tourists and dwellers; or indoor in the main halls to act as informative or immersive experiences to lead the user into the very heart of the museum; or be linked to a specific set of artworks/collection to enhance its knowledge or experience about them.
- The duration, methodology and target group of the trial will be specified after the Design Thinking+ phase.
- In principle, the system could be first tested among a volunteer group of practitioners, selected from the Design Thinking+ group. This may be linked to possible new applications developed via the open calls. The test field experience would be open for one month or more.

The following Table 9 describes the trials for Extended XR Museums Experience in the Turin Cluster.

Table 9. UC13 (Turin) trial description.

Trial ID / Name	Trial 13.1 / Extended XR Museums Experience	
Infrastructure / Venue	**5G commercial network / Museums in the city of Turin**	
Description	Description of the test case, and high-level purpose	
Components and Configuration	Components	• Advanced all-in-one VR headset. • AR glasses. • Mobile devices. • Sensors. • PC. • Metaverse Platforms. • 5G Network.
	Configuration	• The sensors are connected to the IoT platform running at the Edge cloud.
Test procedure	Pre-conditions	• Inventory of existing digital contents regarding selected museums. • Data regarding visitors' appreciation of past digital exhibitions. • Analysis of the main existing metaverse platforms. • Verification of the current 5G coverage in all the target locations.
	Test Case steps	• Deployment and testing of the integrated system in different scenarios and target museums both indoor and outdoor. • First test among a volunteer group of practitioners. • Test of possible new applications developed via the open call. • Test field experience open for one month or more.
Measurements	Methodology	Acceptable values for the monitoring time, the iterations required, the monitoring frequency, etc. This will be defined in the Design Thinking+ phase which involves all partners and stakeholders.

	Complementary measurements	A secondary list of metrics/KVIs useful to interpret the values of the target metric/KVI. Getting these measurements is not mandatory for the test case. • Engagement: This KVI measures how much time visitors spend in the VR experience and how many interactive features they engage with. It can help museum curators understand what content is most engaging to visitors and adjust the experience accordingly. • Retention: This KVI measures how many visitors return to the VR experience after their initial visit. It can help museum curators evaluate the overall satisfaction of the experience and the likelihood of visitors recommending it to others. • Learning outcomes: This KVI measures how well visitors absorb and retain information presented in the VR experience. It can help museum curators evaluate the effectiveness of the VR experience as an educational tool. • Social sharing: This KVI measures how many visitors share their experiences on social media or other platforms. It can help museum curators evaluate the overall reach and impact of the VR experience. • Conversion rates: This KVI measures how many visitors purchase tickets or merchandise related to the VR experience. It can help museum curators evaluate the ROI of the VR experience and determine whether it is worth investing in similar experiences in the future.
	Calculation process	• Engagement: The engagement metric can be calculated by measuring the time spent by visitors in the VR experience, the number of interactive features engaged with, and the frequency of revisits. These metrics can be tracked through VR analytics tools that capture visitor data such as session duration, click-through rates, and the number of interactions. • Retention: The retention metric can be calculated by tracking the number of return visitors to the VR experience over a given time period. This can be done through visitor tracking tools or by offering incentives such as discounts or rewards for returning visitors. • Learning outcomes: The learning outcomes metric can be calculated through pre- and post-visit surveys, quizzes or assessments that measure the visitor's knowledge acquisition, and retention of information presented in the VR experience. • Social sharing: The social sharing metric can be calculated by tracking the number of shares, likes, and comments on social media platforms using social media analytics tools. • Conversion rates: The conversion rates metric can be calculated by dividing the number of conversions (e.g., ticket sales, merchandise purchases, etc.) by the total number of visitors to the VR experience, and then multiplying by 100 to get a percentage. This can be

		tracked using visitor tracking tools that capture conversion data.
Expected Result	• Increased accessibility and fruition of the Museums also for visitors who live at long-distance or are unable to travel physically), including of non-accessible areas. • Enhanced the quality of the experience for real and virtual visitors, through interaction (engaging in social activities like playing games, having virtual picnics, or simply chatting with friends), customization (by choosing avatars, selecting clothing, changing the environment, etc). • Increased educational and cultural opportunities for students, teachers and individuals, through an immersive artistic and cultural experience.	

The trial descriptions reported in Table 9 is complemented with the KPIs/KVIs definition and measurement of the specific use case reported in section 4.4.2.

3.5 UC13: Extended XR museum experience (Athens)

In parallel to the experience in Turin, a second trial for UC13 will take place in Athens, Greece.

3.5.1 Use case definition

In the Athens site, AR-based technologies will be used to leverage on content that elaborates on culture/historic aspects, which will be expanded and be updated. In addition to the content, there will be scope for optimizing the itineraries, to enhance the user experience (and safety when needed). The areas of interest are museums and pathways of historical importance in Athens, Greece (with a possibility to extend in other areas).

In the framework of 5G-TOURS project, WINGS has developed an innovative AR application that showcases the history of the Athenian girl, Myrtida, from the 5th century BC (Figure 30). The applicatoin presents a virtual museum experience, allowing users to interact with exhibits via pre-set buttons and touchscreen gestures. The application utilizes target images that are recognised by the user's mobile camera and are then enhanced by 3D virtual objects. These objects provide visual and audio information about the exhibits, including the scientific reconstruction of Myrtida's skull and facial features. With this AR application, users can explore history in an engaging and immersive way, experiencing the past like never before.

Figure 30. UC13 Model integration in the AR app developed by WINGS.

As part of the TrialsNet project, the AR application developed by WINGS for the 5G-TOURS project will be utilized to enhance the visitor experience by providing additional information on the art exhibits. Furthermore, the application will be expanded to cover other subjects and areas of interest, such as the Acropolis, the historical triangle of Athens city, and the Corinth canal. This will allow visitors to explore and learn about more exhibits and sightseeing areas in an engaging and immersive way.

In addition, the possibility of expanding the capabilities of the application to include VR technology will be explored. This would allow for the creation of a virtual museum space that can be accessed by multiple users, such as families exploring together. The VR space could provide a more interactive and realistic experience for visitors to explore historical artifacts and learn about the rich history of the world.

3.5.2 Implementation aspects

3.5.2.1 Application design

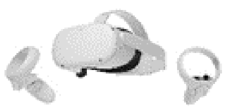
The application provided by WINGS comprises parts in UEs (User Equipment) and in the cloud (and can expand to the Edge if available). The application will have a user-friendly GUI that will allow users to navigate through different sections of the museum, select different artifacts, and access additional information. It may include buttons, icons, and other graphical elements to guide the visitor through the experience. As for the VR capabilities of the application, it will allow visitors to explore a virtual museum space and interact with historical artifacts in a more immersive way. Visitors may be able to pick up and manipulate objects, walk around the museum space, and interact with other visitors in real-time. The main modules of the AR/VR app are summarized below:

- **Image recognition module**: This module will use computer vision algorithms to analyse the images captured by the camera module and identify objects and patterns within them. It will then match these objects and patterns with a pre-existing database of images to provide additional information about the objects or to trigger the display of augmented content.
- **Content management module**: This module will manage the storage and organization of the AR/VR application's content. It will store all the images, videos, and 3D models that the application uses for its augmented content, and it will provide an interface for developers to add, remove, or modify content.

3.5.2.2 Equipment and devices

The equipment and devices for the UC3 in Athens are presented in Table 10.

Table 10. Equipment and devices for UC13 (Athens).

Equipment	Item	Description	Quantity
	META QUEST 2 256 GB	Oculus Quest 2 is a standalone virtual reality (VR) headset developed by Facebook Technologies. It offers an all-in-one VR experience with no PC or console required, allowing users to easily enter immersive virtual environments. • Display: Fast-switch LCD display with a resolution of 1832 x 1920 pixels per eye • Refresh rate: 90Hz • Field of view: 100 degrees • Processor: Qualcomm Snapdragon XR2 Platform • RAM: 6GB • Storage: 256GB internal storage • Tracking: 6DoF inside-out tracking for head and hand movements	1

		• Audio: Built-in speakers and microphone, 3.5mm headphone jack • Battery life: Up to 2-3 hours of gameplay, up to 2 hours of video playback	
	Lenovo Tab P11 5G [50]	The Lenovo Tab P11 5G is a powerful Tablet that runs on the Android 11 operating system and is powered by a Qualcomm Snapdragon 750G processor with 5G connectivity. It features an 11-inch IPS LCD display, 6GB of RAM, and 128GB of internal storage (expandable up to 1TB via microSD card). The Tablet also comes with an 8MP front-facing camera, a 13MP rear-facing camera with autofocus, and dual front-facing speakers tuned by Dolby Atmos for an immersive audio experience.	1
	Samsung Galaxy S20 [51]	The Samsung Galaxy S20 is a high-end smartphone with a 6.2-inch 120Hz display, Qualcomm Snapdragon 865 chipset, 8GB RAM, and 128GB internal storage. It has a triple rear camera setup, 10-megapixel front camera, 4000mAh battery, and 5G connectivity. Other features include under-display fingerprint sensor, IP68 water and dust resistance, and AKG-tuned stereo speakers. The phone runs on Android 10 with Samsung's One UI 2.5 on top.	2

3.5.3 Infrastructure components and functionalities

The AR/VR application that will be developed follows a typical Unity application architecture. It consists of a client-side application running on an Android device and a backend server with a database that provides data and processing services (Figure 31).

The client-side application will utilize the Unity engine for rendering the AR/VR environment and handling user interactions. Unity offers a range of built-in tools for creating 3D models, animations, and interactions, making it an ideal choice for developing AR/VR applications.

The backend server will be responsible for processing data, user authentication, and other server-side functionality. To store and retrieve data, a database will be used, which can be accessed through APIs. The backend will also provide asset bundle downloads for the client-side app.

Asset bundles will be used to improve performance and reduce the initial download size of the application, as they allow for dynamic loading of application assets and can be downloaded from a server. These bundles can be built for different platforms and can be deployed to a server for downloading by the client application.

To allow the application to communicate with the cloud XR server, the public 5G network and WINGS testbed (section 3.2.3) will be utilized. In the case of the AR application, requests will be sent to the XR platform based on the AR targets. The platform will respond with asset bundles, which the application will use to create images. The VR application will also obtain virtual content from the platform.

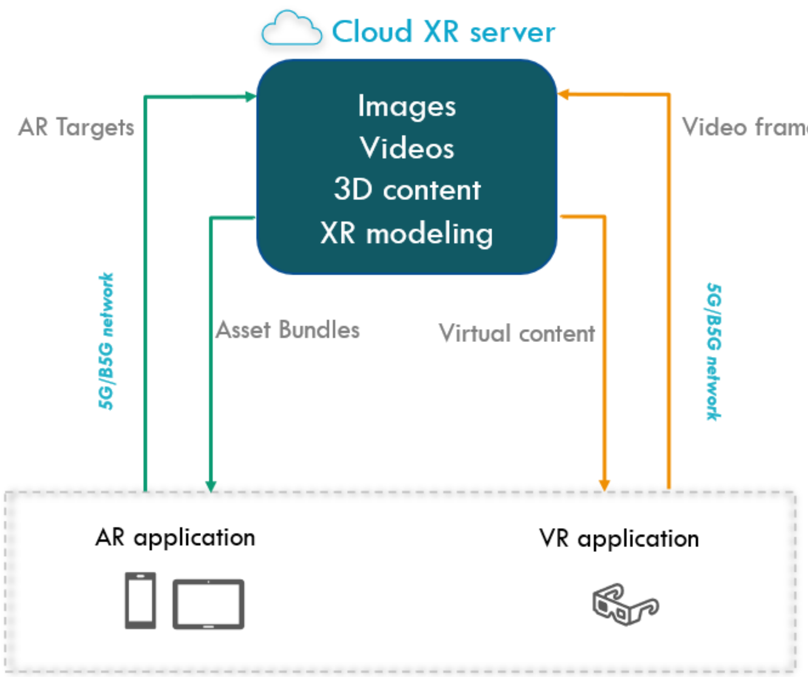


Figure 31. High-level AR/VR application architecture for UC13 (Athens).

3.5.4 Trial description

The trial will take place in a museum or a historical site in Greece. The participants of the use case will be staff of the participants organizations. The trial activities will be organized in the following phases.

Phase 1: Preliminary Analysis

- Create an inventory of existing digital contents regarding selected historical site and cultural points of interest.
- Perform a verification of the current 5G coverage in the target locations.
- Design thinking+ methodology to be examined.

Phase 2: Implementation

- Design of the solution, its objectives, contents and functionalities.
- Enhancement of the existing AR app and developing a new VR app.
- Testing and refining the solution before its launch, in order to verify that it satisfies the intended aims and objectives.
- Integration and Implementation of the apps, platform, devices and network.
- Deployment and test of the integrated system.

Phase 3: Trial

- The trial will include the scenario described below.
- Initial tests for the AR/VR app will be carried out in WINGS offices, to examine its functionality.

The following Table 11 describes the trials for Extended XR Museums Experience in the Athens site.

Table 11. UC13 (Athens) trial description.

Testbed ID / Name	Trial 13.2 / Extended XR Museums Experience
Infrastructure / Venue	The trial site will be defined in cooperation with the other Greek partners
Description	The AR/VR app for XR museums experience test case aims to verify the functionality and performance of an AR/VR application that provides a virtual tour

	of a museum using XR technologies. The test case will focus on various aspects of the application, such as user interface, navigation, 3D objects rendering, audio, and video playback.	
Components and Configuration	Components	• VR headset. • Mobile devices. • Tablet. • AR/VR platform. • 5G Network.
	Configuration	• All devices should be configured to access the 5G network. • Monitoring tool should be installed on the devices, to measure latency and throughput. • The AR/VR app should be installed on the device.
Test procedure	Pre-conditions	• The relevant content for the selected museum/sightseeing area should be available and accessible to the users conducting the test case. • Verification of the current 5G coverage in the target locations.
	Test Case steps	• The user opens the AR/VR app on their device. • The app loads the main menu, and the user selects the museum they wish to visit. • The app displays the virtual map of the museum. • In the AR case, the user points their device's camera at a designated marker and the app superimposes the virtual exhibits and artefacts over the real-world view of the museum. • In the VR case, the user puts on a compatible VR headset and the app provides an immersive experience of the museum in a virtual environment. • The user can move around the museum and view the exhibits from different angles, zoom in or out, or rotate the virtual objects. • The user can click on the exhibits and artefacts to access information about them. • The app provides additional features such as a search function, favourites list, or audio commentary to enhance the user's experience.
	Methodology	• The speed of rendering AR elements on the screen and the presence of latency in the VR application will be assessed. • Other metrics such as user satisfaction and ease of use may also be evaluated during the testing.
	Complementary measurements	• Screen resolution: the number of pixels that the app can render on the screen without compromising the image quality. • Tracking accuracy: the accuracy of the app's tracking system in detecting the user's location and movements. • Load time: the time it takes for the app to launch and load the necessary data and resources.

		• User engagement: the level of interest and engagement exhibited by the users during the test, measured through user feedback and interaction data.
	Calculation process	Performance monitoring software will be used to measure some of the above parameters. User engagement can be measured through surveys.
Expected Result	• The AR/VR app for museums provides an immersive and engaging experience to users. • The user interface is intuitive and easy to use. • The graphics are high-quality and visually appealing. • The audio is clear and enhances the overall experience.	

The trial descriptions reported in Table 11 is complemented with the KPIs/KVIs definition and measurement of the specific use case reported in section 4.5.2.

4 Technical requirements and evaluation methodology

This section provides the initial technical requirements and the evaluation methodologies that will be addressed by each use case. Each technical requirement can be reassessed (or new ones defined) based on the tests that will be performed in laboratory and/or on-field contexts, in different cycles, according to the TrialsNet's methodology defined in D1.1 [3].

4.1 UC10: Immersive fan engagement

4.1.1 Preliminary technical requirements

In this use case, two scenarios have been defined, including specific requirements for the 5G network. For the UC assessment, some priorities linked to the advantages received by the UC application have been established for each scenario. The diagrams reported in Figure 32 and Figure 33 compile these needs and priorities.

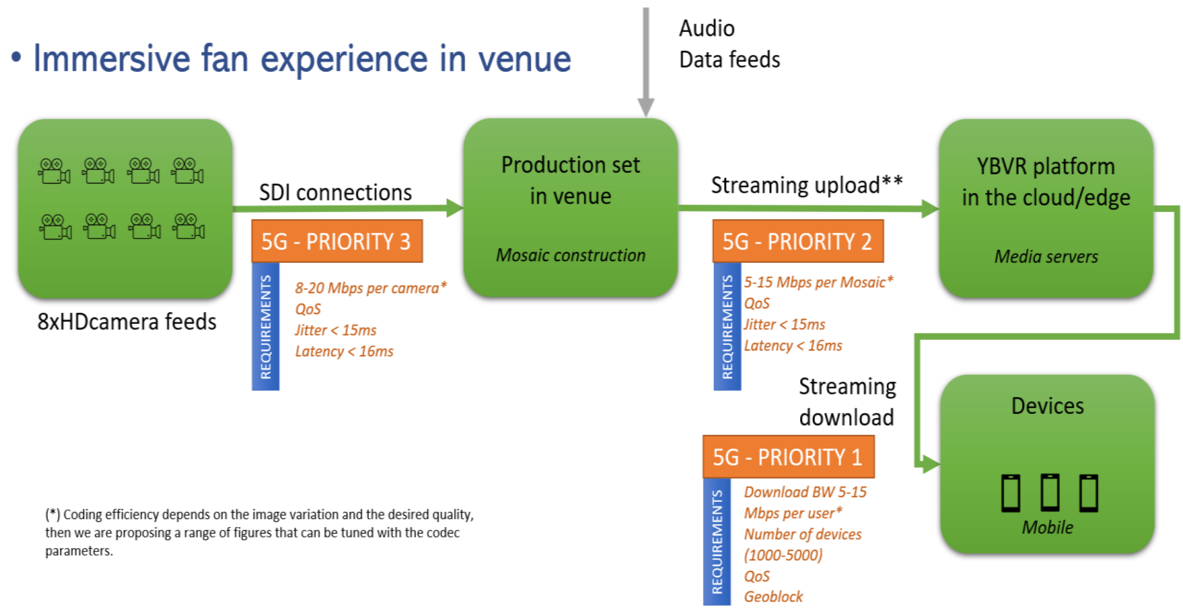


Figure 32. UC10 requirements for In-venue scenario.

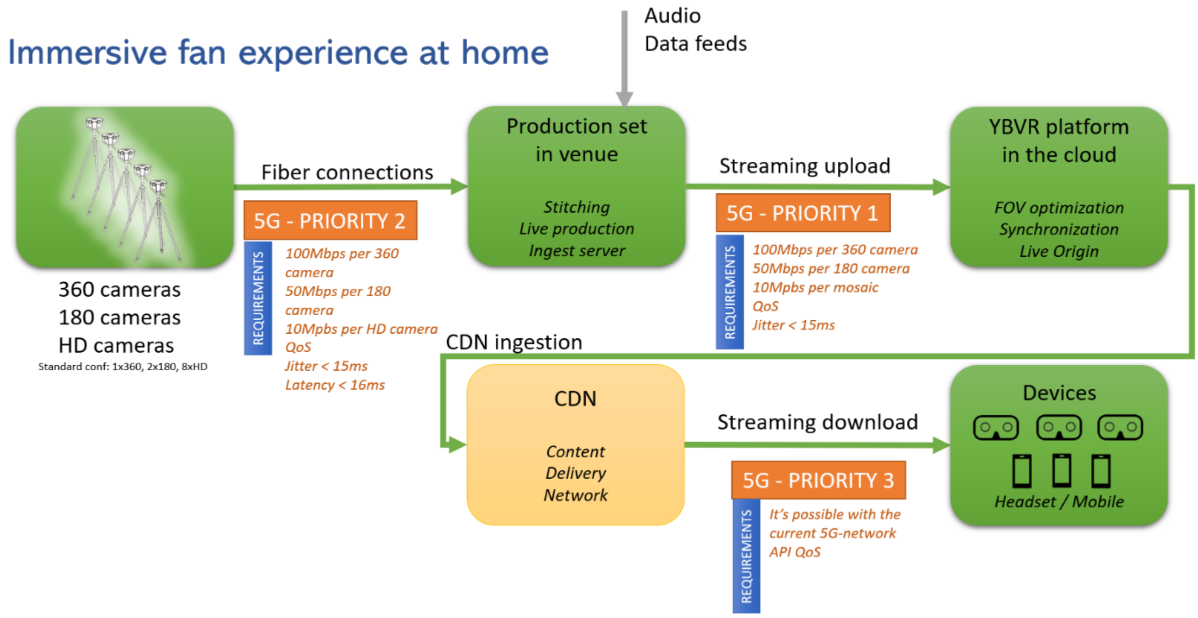


Figure 33. UC10 requirements for At-home scenario.

The preliminary technical requirements for UC10 are listed in Table 12 below.

Table 12. Preliminary technical requirements for UC10.

Device Type	Requirements	Target
App at-home	Upload per 360deg. camera	100Mbps
App at-home	Upload per 180deg. camera	50Mbps
Both App	Upload per HD camera	5-15Mbps
Both App	Upload per Mosaic	10Mbps
Both App	QoS to avoid congestion	API or ad-hoc configuration
Both App	Network Jitter	<15ms
Both App	Network Latency	<30ms
App in-venue	Download per user	10Mbps
App in-venue	Simultaneous users	Up to 5,000
App in-venue	Geo-blocking in the venue	<5 meters

4.1.2 KPIs/KVIs definition and measurement

KPIs for this use case are defined now as aspirational values, trying to get the best with the available technology and, if it's not affordable now, to define a target for future network evolutions (Table 13).

Table 13. KPIs of UC10.

KPI name	Description/KPI definition	KPI target
Downlink throughput per user	Sustained throughput in a file transfer of a user	20Mbps (at-home), 10Mbps (in-venue)
Uplink throughput per user	Sustained throughput in a file transfer of a user	Up to 100Mbps
Downlink throughput per application	Sustained throughput for the aggregation of users in the venue	5000 users @ 10Mbps (in-venue)
Uplink throughput per application	Sustained throughput for the aggregation of the camera feeds (2x180d + 1x360d + 8xmosaic)	280 Mbps
Application-level latency (glass to glass)	Amount of time it takes for a user device to display the image captured by the camera. It is a measure of the delay that the user experiences when interacting with an application	800 ms
Location accuracy	Accuracy in the positioning of the device	5 meters

Downlink and uplink throughput will be measured by a speed network application. Glass to glass latency will be measured comparing a chrono image streamed with the YBVR application. Location accuracy will be measured testing blocking in the borders of the venue. Additionally, with reference to Figure 8, network metrics will be collected by means of two software probes on N3 and N6 interfaces. The N3 interface is responsible for providing connectivity between the 5G RAN and the 5G Core and N6 is the Interface between UPF and the Edge computing.

KVIs are also defined as a measurement of the easiness and acceptability of the fan engagement with this application and technology (Table 14). At least, 10 users per scenario (in-venue and at-home) are required to validate the trial.

Table 14. KVIs of UC10.

KVI name	Description/KVI definition	Value
User experience in the venue	Perceived easiness, enjoyment and emotional quality of the experience in the venue	70% of users expressing positive evaluation
User experience at home	Perceived easiness, enjoyment and emotional quality of the experience at home	70% of users expressing positive evaluation
Accessibility	Perceived acceptability, ease of use and comfort of the experience	70% of users expressing positive evaluation

4.2 UC11: Service Robots for Enhanced Passengers' experience

4.2.1 Preliminary technical requirements

The preliminary technical requirements for UC11 are presented in Table 15.

Table 15. Preliminary technical requirements for UC11.

Device Type	Requirements	Target
Robotics	Maximum latency	100 ms
Robotics	Maximum number of packages lost	0.5%
Robotics	Throughput min (up and down)	10 Mbps & 50Mbps
Robotics	Throughput recommended (up and down)	30Mbps & 150 Mbps
Mobile Devices	Throughput recommended (up and down) of tablets/smartphones	10Mbps & 100Mbps
Robotics	Cybersecurity	VPN tunnel is required (ideal VPN IPSec)
Robotic Mobility	Speed at which a service robot can move while maintaining a stable network connection	At least 2m/s
Robotic Energy Efficiency	The amount of energy required to transmit data, analyse data, and move inside the airport area of the service robots, measured in time	At least 6 hours continuously
Cameras	Throughput minimum	30 fps or 1.5 Mbps

4.2.2 KPIs/KVIs definition and measurement

The evaluation methodology is described in the Table 16 and Table 17, regarding both KPIs and KVIs. Throughput measurements will be collected via probes, iPerf [57] and Ookla [58]. Latency measurements will be collected at the application layer by adding timestamps to requests between functional entities/service components of the overall application. Then the difference in time will be calculated between the request from one entity (e.g., client) and the response from the other entity (e.g., server). Additional measurements will also be collected e.g., with the use of iPerf. Location accuracy will be measured as the difference between the position to which a device (e.g. robot) is directed and the actual position where it ends up and the difference between the position of a device estimated by the overall system and the actual position.

Table 16. KPIs of UC11.

KPI name	Description/KPI definition	KPI target
Downlink throughput per device	The amount of data that can be transmitted over the network in a certain amount of time	50Mbps (min), 150Mbps (recommended)
Uplink throughput per device	The amount of data that can be transmitted over the network in a certain amount of time	10Mbps (min), 30 (recommended)
App latency (glass to glass)	Delay between the image captured by the camera and it showed in the screen of the user device	800 ms
Location accuracy	Accuracy in the positioning of the device	5 meters

Table 17. KVIs of UC11.

KVI name	Description/KVI definition	Value
Accessibility	Perceived acceptability, ease of use and comfort of the experience	70% of users expressing positive evaluation (to be reviewed in WP6)
User experience	Perceived easiness, enjoyment and emotional quality of the experience	70% of users expressing positive evaluation (to be reviewed in WP6)
Trustworthiness	The extent to which a system is reliable, secure and safe, and inspires confidence in its users	70% of users expressing positive evaluation (to be reviewed in WP6)
Digital Inclusion	The ability of a system to provide equal access to digital technologies and services, regardless of income, gender, end-user equipment or other factors	70% of users able to access the services or interact with the robot (to be reviewed in WP6

KVIs will be measured by *ad hoc* questionnaires or an online survey through our application with responses on a Likert scale [59]. Percentages of users expressing positive evaluation on each KVI will be assessed.

4.3 UC12 City Park in the metaverse

4.3.1 Preliminary technical requirements

The preliminary technical requirements for UC12 are presented in Table 18.

Table 18. Preliminary technical requirements for UC12.

Device Type	Requirements	Target
Devices	Maximum latency	100 ms
Devices	Maximum number of packets lost	0.5%
Devices	Throughput min (up and down)	10Mbps
Devices	Throughput recommended	40+ Mbps
Devices	Number of users active in the metaverse	24-50 per room

4.3.2 KPIs/KVIs definition and measurement

KPIs for this use case are defined now as aspirational values, trying to get the best with the available technology and, if it's not affordable now, to define a target for future network evolutions (Table 19).

Table 19. KPIs for UC12.

KPI name	Description/KPI definition	KPI target
Downlink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100Mbps
Uplink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100 Mbps
Downlink throughput per application	Sustained throughput for the aggregation of users in the venue	25-50 users @ min 20 Mbps up to 100Mbs
App latency	Delay before the transfer of data begins following an instruction for its transfer	< 100 ms

Download and upload throughput will be measured by a speed network freely available on Internet such as Speedtest Custom [60].

Use case KVIs are defined as the percentage of visitors expressing a positive evaluation (scores 1 to 3 on a 6 points scale) on the accessibility, user experience, edutainment experience and social connection enabled by the technology during the trial. Both on-site and at-home visitors will be involved in the evaluation (Table 20). Where it applies, KVIs will be also assessed as a measure of the improvement of the visitor experience with the proposed technology, compared to standard (not technologically enhanced) visits.

Table 20. KVIs of UC12.

KVI name	Description/KVI definition	Value
Accessibility	Perceived acceptability, ease of use and comfort of the experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)
User experience	Perceived engagement, enjoyment and emotional quality of the experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)
Edutainment	Perceived usefulness in enhancing educational experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)
Social connection	Perceived quality of social interactions, social connectedness and sense of community	70% of visitors expressing positive evaluation (to be reviewed in WP6)

KVIs will be measured by *ad hoc* questionnaires with responses on a Likert scale. Percentages of users expressing positive evaluation on each KVI will be assessed. If feasible, *Happy or not* [61] devices will also be used to measure general satisfaction of users on the trial site.

4.4 UC13: Extended XR museum experience (Turin)

4.4.1 Preliminary technical requirements

The preliminary technical requirements for UC13 in Turin are presented in Table 21.

Table 21. Preliminary technical requirements for UC13 (Turin).

Device Type	Requirements	Target
Devices	Maximum latency	100 ms

Devices	Maximum number of packets lost	0.5%
Devices	Throughput min. (up and down)	10Mbps/ user
Devices	Throughput recommended	50 Mbps /user
Devices	Number of users active in the metaverse	24-50 per room

4.4.2 KPIs/KVIs definition and measurement

KPIs for this use case are defined now as aspirational values, trying to get the best with the available technology and, if it's not affordable now, to review them later on (Table 22). The description of the trial is found in section 3.4.4.

Table 22. KPIs for UC13 (Turin).

KPI name	Description/KPI definition	KPI target
Downlink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100+Mbps
Uplink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100+ Mbps
Downlink throughput per application	Sustained throughput for the aggregation of users in the venue	25-50 users @ min 20 Mbps up to 100Mbs
App latency	Delay before the transfer of data begins following an instruction for its transfer	< 100 msec

Download and upload throughput will be measured by the speed network application as in Turin Cluster [see comment in Table 19].

Use case KVIs are defined as the percentage of visitors expressing a positive evaluation (scores 1 to 3 on a 6 points scale) on the accessibility, user experience, edutainment experience and social connection enabled by the technology during the trial (Table 23). Both on-site and at-home visitors will be involved in the evaluation. Where it applies, KVIs will be also assessed as a measure of the improvement of the visitor experience with the proposed technology, compared to standard (not technologically enhanced) visits.

Table 23. KVIs for UC13 (Turin).

KVI name	Description/KVI definition	KVI target
Accessibility	Perceived acceptability, ease of use and comfort of the experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)
User experience Engagement	Perceived engagement, enjoyment and emotional quality of the experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)
Edutainment	Perceived usefulness in enhancing educational experience	70% of visitors expressing positive evaluation (to be reviewed in WP6)

Social connection/social sharing	Perceived quality of social interactions, social connectedness and sense of community	70% of visitors expressing positive evaluation (to be reviewed in WP6)
Retention	how many visitors would like to return to VR experience after their initial visit	50% of visitors expressing positive evaluation (to be reviewed in WP6)

KVIs will be measured by *ad-hoc* questionnaires with responses on a Likert scale. Percentages of users expressing positive evaluation on each KVI will be assessed. If feasible, *Happy or not* devices will also be used to measure general satisfaction of users in the trial site.

4.5 UC13: Extended XR museum experience (Athens)

4.5.1 Preliminary technical requirements

The preliminary technical requirements for UC13 in Athens are presented in Table 24.

Table 24. Preliminary technical requirements for UC13 (Athens).

Device Type	Requirements	Target
Devices	Maximum latency	100 ms
Devices	Maximum number of packets lost	0.5%
Devices	Throughput min. (up and down)	10Mbps/ user
Devices	Throughput recommended	50 Mbps /user
Devices	Number of users active in the metaverse	24-50 per room

4.5.2 KPIs/KVIs definition and measurement

The KPIs in Table 25 for this use case are aimed at achieving optimal performance with the current technology available or to set a benchmark for future network advancements. Throughput measurements will be collected via probes, iPerf and Ookla. Latency measurements will be collected at the application layer by adding timestamps to requests between functional entities/service components of the overall application. Then the difference in time will be calculated between the request from one entity (e.g., client) and the response from the other entity (e.g., server). Additional measurements will also be collected e.g., with the use of iPerf. The description of the trial is found in section 3.5.4.

Table 25. KPIs of UC13 (Athens).

KPI name	Description/KPI definition	KPI target
Downlink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100+Mbps
Uplink throughput per user	Sustained throughput in a file transfer of a user	Min 20Mbps up to 100+ Mbps
Downlink throughput per application	Sustained throughput for the aggregation of users in the venue	25-50 users @ min 20 Mbps up to 100Mbs
App latency	Delay before the transfer of data begins following an instruction for its transfer	< 100 msec

Download and upload throughput will be measured by a speed network application such as Ookla.

Use case KVIs are defined as the percentage of users expressing a positive evaluation (scores 1 to 3 on a 6 points scale) on the accessibility, user experience, edutainment experience and social connection enabled by the technology during the trial (see Table 26).

Table 26. KVIs of UC13 (Athens).

KVI name	Description/KVI definition	KVI target
Accessibility	Perceived acceptability, ease of use and comfort of the experience:	70% of users expressing positive evaluation (to be reviewed in WP6)
User experience	Perceived engagement, enjoyment and emotional quality of the experience:	70% of users expressing positive evaluation (to be reviewed in WP6)
Edutainment	Perceived usefulness in enhancing educational experience:	70% of users expressing positive evaluation (to be reviewed in WP6)
Social connection	Perceived quality of social interactions, social connectedness and sense of community:	70% of users expressing positive evaluation (to be reviewed in WP6)

5 Implementation time plan

The time plan of the trials sets out the specific steps and milestones that need to be achieved to successfully perform the objectives of the project within the expected time frame. This includes a breakdown of the different phases of the project, such as planning, implementation, testing, and evaluation, as well as the specific tasks and deliverables that need to be completed within each phase. The Table 27 summarizes the overall WP5 time plan in terms of the milestones that are defined for each use case in the following sub-sections.

Table 27. Overall WP5 time plan for use cases implementation.

	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
UC10		MS1		MS2			MS3				MS4	
UC11			MS1		MS2				MS3		MS4	
UC12			MS1			MS2			MS3		MS4	
UC13.1			MS1			MS2			MS3		MS4	
UC13.2			MS1			MS2		MS3			MS4	

5.1 UC10: Immersive Fan Engagement

Table 28 describes in detail the milestones of UC10.

Table 28. Time plan for UC10.

	Activities	Description	Use Case Milestone	Time plan
1	UC definition	Use Case definition, initial platforms and network solutions and venue selection	MS1	Q2 2023
2	Infrastructure and devices creation and deployment	Pre-trial review and detailed planning		
3	Pre-trial development	Development of software for network, servers and players for pre-trial	MS2	Q4 2023
4	Pre-trial deployment	Network deployment, servers, devices and player updates in 5Tonic lab		
5	Testing pre-trial	Testing the UC10 elements in the pretrial environment, gathering KPIs and KVIs	MS3	Q3 2024
6	Review and redesign	Analysis of results and review if the trial design		
7	Trial development	Review the development of software for network, servers and players for the trial		
8	Trial deployment	Network deployment, servers, devices and player updates in the venue	MS4	Q3 2025
9	Testing trial	Testing the UC10 elements in the trial environment, gathering KPIs and KVIs		

10	Review and disseminate	Review of the trial results and elaboration of conclusions		

The milestones of UC10 are:

- **MS1** (Q2 2023): This milestone involves the definition of the user needs, technical requirements, and trials design for the activities/tasks related to the implementation of UC10.
- **MS2** (Q4 2023): This milestone is related to the performance of the pre-trial at Ericsson 5Tonic testing laboratory in Madrid.
- **MS3** (Q3 2024): This milestone involves the design of the technical setup needed to implement the trial for UC10. It aims at configuring the infrastructure (sensing, communicating, processing, acting) and identifying the hardware/software tools to be used.
- **MS4** (Q3 2025): This milestone is related to the deployment of the trial in the venue and the acquisition of the KPIs and KVIs during the trial

5.2 UC11: Service Robots for Enhanced Passengers' Experience

Table 29 describes in detail the milestones of UC11.

Table 29. Time plan for UC11.

	Activities	Description	Use Case Milestone	Time plan
1	UC definition	The initial phase to lay the foundations of the activities and the definition of UC	MS1	Q3 2023
2	Infrastructure and devices creation and deployment	Extend Network UCs in Athens		
3	Application development	Development of application for UC11		
4	Network connections	Identify the need for connecting different devices, equipment and sensors.		
5	Masterplan	Prepare a masterplan for project implementation		
6	Start trial phases	UC progress and Platforms and Network solutions intermediate phase	MS2	Q1 2024
7	Pre-trial execution	Uses case test cases scenario deployment		
8	Initial performance analysis	KPIs and KVIs collection		
9	Additional UC analysis	Additional Use Case analysis trough Open Call		
10	Additional UC application development	Development of application for the new use cases		
11	Additional UC integration and testing	New applications integration in Athens infrastructure		
12	Trial execution	Uses case test cases scenario deployment	MS3	Q1 2025

13	Collecting data and reporting	Preliminary UC execution results		
14	Final performance analysis	KPIs, KVIs collection		
15	Completion trial execution	Execution of the final trial	MS4	Q3 2025

The milestones of UC11 are:

- **MS1** (Q3 2023). This milestone involves the definition of the user needs, technical requirements, network connections, and trials design for the activities/tasks related to the implementation of UC11 (including a masterplan detailing tasks, timeline, resources and costs), the development of an App, and the execution of the pre-trial.
- **MS2** (Q1 2024). This milestone involves the start of the control and experimental sessions of the trial at the Athens airport. It tests platforms and network solutions, KPI and KVIs collection, additional UC analysis, additional development integration & testing.
- **MS3** (Q1 2025). This milestone reports on the preliminary execution results including KPIs and KVIs collection for UC11.
- **MS4** (Q3 2025). This milestone coincides with the reports of the execution of the final trial of UC11.

5.3 UC12: City Parks in Metaverse

Table 30 describes in detail the milestones of UC12.

Table 30. Time plan for UC12.

	Activities	Description	Use Case Milestone	Time plan
1	UC definition	Use Cases definition and platforms and network solutions initial phase, Design Thinking+	MS1	Q3 2023
2	Infrastructure and devices creation and deployment	Check 5G Commercial Network UCs in Valentino Park		
3	Application development	Identify suitable metaverse applications		
4	Network connections	Identify the need for connecting different devices, equipment and sensors		
5	Masterplan	Prepare a masterplan for project implementation		
6	Start trial phases	UC progress and Platforms and Network solutions intermediate phase	MS2	Q2 2024
7	Pre-trial execution	Uses case test cases scenario deployment		
8	Initial performance analysis	KPIs, KVIs collection		
9	Additional UC analysis	Additional Use Case analysis trough Open Call		
10	Additional UC application development	Development of application for the new use case		
11	Additional UC integration and testing	New applications integration in Borgo Medievale infrastructure		

12	Trial execution	Uses case test cases scenario deployment	MS3	Q1 2025
13	Collecting data and reporting	Preliminary UC execution results		
14	Final performance analysis	KPIs, KVIs collection		
15	Completion trial execution	Execution of the final trial	MS4	Q3 2025

The milestones of UC12 are:

- **MS1** (Q3 2023). This milestone involves the definition of the user needs, technical requirements, network connections, and trials design for the activities/tasks related to the implementation of UC12 at the Borgo Medievale including a masterplan detailing tasks, timeline, resources and costs.
- **MS2** (Q2 2024). This milestone involves the pre-trial execution, initial performance analysis, additional UC analysis and the start of the trial execution for UC12.
- **MS3** (Q1 2025). This milestone reports on the preliminary execution results and KPIs and KVIs collection for UC12.
- **MS4** (Q3 2025). This milestone involves the execution of control, measurements and experimental sessions of the trial for UC12.

5.4 UC13: Extended XR museum experience (Turin)

Table 31 describes in detail the milestones of UC13 in Turin.

Table 31. Time plan for UC13 (Turin).

	Activities	Description	Use Case Milestone	Time plan
1	UC definition	Use Cases definition and platforms and network solutions initial phase	MS1	Q3 2023
2	Infrastructure and devices creation and deployment	Check 5G Commercial Network UCs in selected museums		
3	Application development	Identify suitable metaverse applications		
4	Network connections	Identify the need for connecting different devices, equipment and sensors		
5	Masterplan	Prepare a masterplan for project implementation		
6	Start trial phases	UC progress and Platforms and Network solutions intermediate phase	MS2	Q2 2024
7	Pre-trial execution	Uses case test cases scenario deployment		
8	Initial performance analysis	KPIs, KVIs collection		
9	Additional UC analysis	Additional Use Case analysis trough Open Call		

10	Additional UC application development	Development of application for the new use case		
11	Additional UC integration and testing	New applications integration in selected museums infrastructure		
12	Trial execution	Uses case test cases scenario deployment	MS3	Q1 2025
13	Collecting data and reporting	Preliminary UC execution results		
14	Final performance analysis	KPIs, KVIs collection		
15	Completion trial execution	Execution of the final trial	MS4	Q3 2025

The milestones of UC13 in Turin are:

- **MS1** (Q3 2023). This milestone involves the definition of the user needs, technical requirements, network connections, and trials design for the activities/tasks related to the implementation of UC13 at the Turin site, including a masterplan detailing tasks, timeline, resources and costs.
- **MS2** (Q2 2024). This milestone involves the pre-trial execution, initial performance analysis, additional UC analysis and the start of the trial execution for UC13 at the Turin site.
- **MS3** (Q1 2025). This milestone reports on the preliminary execution results and KPIs and KVIs collection of UC13 at the Turin site.
- **MS4** (Q3 2025). This milestone involves the execution of control, measurements and experimental sessions of the trial for UC13 at the Turin site.

5.5 UC13: Extended XR museum experience (Athens)

Table 32 describes in detail the milestones of UC13 in Athens.

Table 32. Time plan for UC13 (Athens).

	Activities	Description	Use Case Milestone	Time plan
1	UC definition	Use Cases definition and platforms and network solutions initial phase	MS1	Q3 2023
2	Infrastructure and devices creation and deployment	Check 5G Commercial Network UCs in selected museums or sites		
3	Application development	Development of application for the use case		
4	Network connections	Identify the need for connecting different devices, equipment and sensors		
5	Masterplan	Prepare a masterplan for project implementation		
6	Start trial phases	UC progress and Platforms and Network solutions intermediate phase	MS2	Q2 2024
7	Pre-trial execution	Uses case test cases scenario deployment		
8	Initial performance analysis	KPIs, KVIs collection		

9	Additional UC analysis	Additional Use Case analysis trough Open Call		
10	Additional UC application development	Development of application for the new use case		
11	Additional UC integration and testing	New applications integration in selected museums or sites infrastructure		
12	Trial execution	Uses case test cases scenario deployment	MS3	Q1 2025
13	Collecting data and reporting	Preliminary UC execution results		
14	Final performance analysis	KPIs, KVIs collection		
15	Completion trial execution	Execution of the final trial	MS4	Q3 2025

The milestones of UC13 in Athens are:

- **MS1** (Q3 2023). This milestone involves the definition of the user needs, technical requirements, network connections, and trials design for the activities/tasks related to the implementation of UC13 at the Athens site, including a masterplan detailing tasks, timeline, resources and costs.
- **MS2** (Q2 2024). This milestone involves the pre-trial execution, initial performance analysis, additional UC analysis and the start of the trial execution for UC13 at the Athens site.
- **MS3** (Q1 2025). This milestone reports on the preliminary execution results and KPIs and KVIs collection of UC13 at the Athens site.
- **MS4** (Q3 2025). This milestone involves the execution of control and experimental sessions of the trial for UC13 at the Athens site.

6 Conclusions

This report describes the use cases that TrialsNet will implement in the CTE domain, along with specific requirements provided by the relevant verticals and application developers. The document provides an overview of the application design, infrastructure components and functionalities, trial description, as well as preliminary technical requirements and evaluation methods for each of the use case in the related trial sites (Madrid, Athens, and Turin).

The document aims to provide insights into the network needs for supporting the planned applications, which will serve as input for the platform and network solutions that will be designed and deployed in the context of WP2. The most relevant KPIs and KVIs have been identified for each use case, which will be used in WP6 for the evaluation activity following the measurements that will be performed during the trial phase.

The report also includes an initial time plan and main milestones per use case towards the completion of the trials planning, outlining the various activities to be carried out for each UC progress and associated B5G technology tests.

This document is the first project deliverable of the use case, and their step towards implementation. Following the submission to the EC, the next step will be the completion of the Design Thinking+ process, in order to maximise the relevance of work to the final users. This will be followed by the actual implementation phase of the use cases, whose preliminary results will be captured in the second deliverable, D5.2 "First results of Use cases implementation for CTE domain" due by mid-2024.

Finally, it should be noted that besides implementing the defined use cases, a major objective of the related trials activities will be also to identify the current network technology limits with a view to defining new requirements for their future evolutions. Initial evaluations on such aspects are expected to be carried out during the implementation phase.

Acknowledgment

TrialsNet project has received funding from the European Union's Horizon-JU-SNS-2022 Research and Innovation Programme under Grant Agreement No. 101095871.

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