Co-funded by the European Union

TrialsNet: TRials supported by Smart Networks beyond 5G

Open Call

Sites and Use Cases description

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1 Introduction

TrialsNet project aims to deploy full large-scale trials to implement a heterogenous and comprehensive set of innovative 6G applications based on various technologies and covering three relevant domains of the urban ecosystems in Europe identified as i) *Infrastructure, Transportation, Security & Safety*, ii) *eHealth & Emergency*, and iii) *Culture, Tourism & Entertainment*. In the context of these domains, TrialsNet is going to design and implement 13 innovative use cases that will be developed over wide coverage areas with the involvement of extended sets of real users in 4 geographical clusters, located in Italy, Spain, Greece and Romania respectively:

- **Infrastructure, Transportation, Security & Safety**
  - Use Case 1 “Smart Crowd Monitoring” (Madrid)
  - Use Case 1 “Smart Crowd Monitoring” (Iasi)
  - Use Case 2 “Public Infrastructure Assets Management” (Athens)
  - Use Case 3 “Autonomous APRON” (Athens)
  - Use Case 4 “Smart Traffic Management” (Iasi):
  - Use Case 5 “Control Room in Metaverse” (Turin)
- **eHealth & Emergency**
  - Use Case 6 “Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area” (Athens/Madrid)
  - Use Case 7 “Remote Proctoring” (Pisa)
  - Use Case 8 “Smart Ambulance” (Pisa)
  - Use Case 9 “Adaptive Control of Hannes Prosthetic Device” (Pisa)
- **Culture, Tourism & Entertainment**
  - Use Case 10 “Immersive Fan Engagement” (Madrid)
  - Use Case 11 “Service Robots for Enhanced Passenger's Experience” (Athens)
  - Use Case 12 “City Parks in Metaverse” (Turin)
  - Use Case 13 “Extended Reality (XR) Museum Experience” (Turin)
  - Use Case 13 “Extended Reality (XR) Museum Experience” (Athens)

Additional and more detailed information about the use cases and the infrastructures of TrialsNet can be found in the public deliverables D3.1 “Use Cases definition for Infrastructure, Transportation, and Security & Safety (ITSS) domain” [1], D4.1 “Use Cases definition for eHealth and Emergency (eHE) domain” [2], D5.1 “Use Cases definition for Culture, Tourism, and Entertainment (CTE) domain” [3], and D2.1 “Preliminary design aspects for Platforms and Networks solutions” [4] available for download on the project’s site [5].

In the following sections, the document provides the description of the sites and related infrastructures that are going to be deployed by TrilasNet in support of its large-scale trials’ activities. In addition, the document also describes the use cases that will be developed and implemented throughout the course of the project. For both infrastructures and use cases, the document provides a set of challenges that could be addressed to further extend or enhance the solutions provided by the project.

As such, this document can serve as a particularly useful source for the Open Call candidate applicants, to learn on one hand precisely about the activities of the project and this way to assist them in submitting a competitive proposal in terms of innovation and technology implementation, and on the other hand to be informed about the available infrastructures and the use cases there implemented in the different sites in case they wish to make use and integrate them within their proposal.

2 Description of TrialsNet sites

This section provides an overview of the TrialsNet's platform and network solutions designed, deployed, and integrated for the implementation of the trials in the four clusters located in Italy, Spain, Romania and Greece. More in detail, the Italian cluster consists of two different sites located in Turin (see sub-section 2.1) and Pisa (see sub-section 2.2), while the Spanish, Romanian and Greek clusters (described in sub-sections 2.3, 2.4, and 2.6, respectively) will consist of one site each. It should be highlighted that the Romanian cluster will also relay on an ad-hoc experimental infrastructure that will be initially deployed in IMEC premises in Belgium (see sub-section 2.5) and then moved to the trial site in Romania. Overall, the cluster framework provided by TrialsNet is going to address both commercial and experimental domains providing a complete package of trials activities which results will be evaluated to validate further the benefits of B5G system and deriving the requirements towards 6G.

2.1 Italian cluster (Turin site)

This section describes the main infrastructure components of the Turin site in which UC5 "Control Room in Metaverse", UC12 "City Parks in Metaverse", and UC13 "Extended XR Museum Experience" will be implemented. The Turin site in the Italian cluster includes a very extensive set of technologies, that will leverage on the previously gathered experience in the 5G EVE projects as well as other available software component such as the XR platforms provided by TIM.

2.1.1 Short description

The mobile connectivity in the Turin site will be essentially provided by the 5G commercial network deployment of TIM. Taking advantage of the different products releases that will become available during the project's lifetime, the development of large-scale trials covering very extended areas and reaching a multitude of end-users with 5G enabled devices (phones, tablets, Virtual Reality (VR) visors, etc.) will be therefore possible. In terms of network infrastructure equipment, the Turin site is deployed on commercial products from Ericsson. The current network deployment is based on the 5G NSA (Non-Standalone) architecture imple-mented with Option 3 as per 3GPP Rel-15 using the 3.7 GHz band in which TIM owns 80 MHz. During the lifetime of the project, the TIM commercial network will evolve to the 5G Standalone (SA) architecture based on Rel-16 products.

2.1.2 Services offered by the infrastructure

The Turin site will make use of the facilities deployed in the context of the 5G EVE project. In particular, the 5G EVE platform in Turin offers different radio environments for testing with dedicated CNs, including commercial 5G network that can be used with commercial Access Point Name (APN) for internet access and/or via private APN (5geve.tim.it, available with enabled SIM cards) to access the 5G EVE facilities. Radio and CN are based on Ericsson equipment. The facility is multi-location, interconnected by high performance links (via TIM transport network or dark fiber), as depicted in Figure 1.

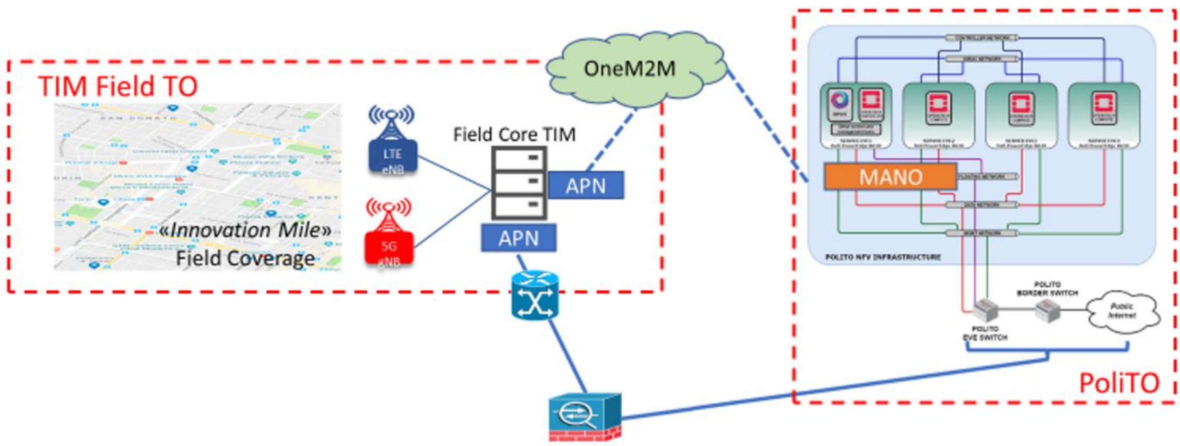


Figure 1. 5G EVE Turin site architecture.

Between the several functionalities that the 5G EVE platform can provide, TrialsNet will mostly make use of the service cloud infrastructure hosted by CNIT at Politecnico di Torino premises and managed by NextWorks. This infrastructure is based on Openstack and it can onboard both Virtual Network Functions (VNFs) and Physical Network Functions (PNFs) and consists of three physical servers. The first one is acting as service server container, where all the services related to the 5G EVE infrastructure are instantiated. The other two servers are configured as OpenStack Compute nodes, where the VNFs are executed based on a Management and Orchestration (MANO) operating at service/ Virtual Machines (VMs) layer.

2.1.3 Main assets of the infrastructure

The TIM eXtended Reality solutions are a set of platforms, developed by TIM that offer the possibility to build Augmented Reality e Virtual Reality digital services in various fields such as culture, retail, entertainment, education. The two main platforms, here described, are the **XR Platform** and **XR Streaming Platform** that will be used in the project to support the development of UC12 and UC13.

As said, both platforms are used to develop Augmented Reality (AR)/VR or more in general Mixed Reality digital services but with a substantial difference related to the rendering functionality, i.e., the capability to show digital content on the screen/device of the user starting from a 2D/3D Model.

In the case of XR Platform, this rendering functionality is performed directly by the end user device meaning that the user equipment must have the computational ability to perform this graphical functionality.

In the case of XR Streaming Platform, the rendering functionality is moved on the cloud (or telco edge cloud), it means that the user device could be “thin”, less performant and with smaller computational ability than the ones that are expected to be used with the XR Platform. The rendering functionality is done by a server with the render application, and through the network the user device receives a video stream that contains the digital content related to the XR experience. In this way, the user can experience a very high quality of detail of the 3D content regardless of the device.

In this case, an important role is played by the network since high bandwidth and low latency are needed to allow the user device to send to the server-side components some parameters, e.g., head-mounted display (HMD) tracking data, controllers input, sensors input data such as gyroscope, accelerometer, etc., that are required to select the right stream to be sent back to the user device in real time.

With the XR Streaming platform, the difference between an AR and VR experience lies simply in transmitting a video with or without transparency. If the video content (always related to a 3D content processed by the server) has a transparent background, it is possible to overlay it on the image of the smartphone/tablet webcam to obtain an AR experience. If the content of the surrounding 3D environment is also added, it can simply transform the service experience into a more immersive VR.

By separating the 3D surrounding environment from the scene objects (digital twins), it is possible to dynamically switch between an AR and VR experience (on devices where AR is possible), as well as having multiple users involved in the same experience with different visual options (AR or VR). For example, with two users connected to the same experience using a tablet and a VR headset, the user with the tablet can see and interact with different digital twins in their real environment, while the user with the VR headset can do the same but immersed in a virtual 3D environment. The interaction between avatars and VoIP session (to naturally speak each other) completes the experience for both users.

It is important to emphasize that the two platforms are not mutually exclusive. In cases where devices are powerful enough or where user-side device control is possible, or even where high details in the experience are not essential, it is possible to use the XR Platform, which still has lower costs on the server side.

The XR Platform is a TIM Software as a Service (SaaS) product already commercially available to its customers with different offers for various application areas, while the XR Streaming platform is currently being experimented in TIM Innovation Labs in Turin and Rome. The servers that manage the XR Platform are available in the cloud, while the servers of the XR Streaming platform are physically located between the two laboratories. Moe details about the two platforms, including information on the Software Development Kits in support to the creation of AR/VR applications are reported in D2.1 [4].

2.1.4 Extensions and new features

As previously reported, the 5G commercial network of TIM will evolve to the 5G SA architecture based on Rel-16 products during the lifetime of the project.

2.2 Italian cluster (Pisa site)

The Pisa site will serve for the deployment and validation of three use cases reported in D4.1 [2]: UC7 “Remote Proctoring”, UC8 “Smart Ambulance”, and UC9 “Adaptive Control of Hannes Prosthetic Device”.

2.2.1 Short description

The three use cases will be supported by a 5G network at 26 GHz covering the indoor and outdoor experimental areas in the CNR campus in Pisa. The Fondazione Monasterio hospital in Massa will host the training surgical room for UC7 and the emergency unit for UC8. The TIM site in Turin will house part of the 5G Core Network (CN) and the Ericsson Orchestration system. The initial deployment of UC9 will take place in the Ericsson 5G laboratory in Genoa, and later it will be moved to Pisa.

2.2.2 Services offered by the infrastructure

The infrastructure to support the use cases in under deployment so no services are currently offered by the network.

2.2.3 Main assets of the infrastructure

Figure 2 depicts the main assets for the of the Pisa site infrastructure. The RAN will comprise a BB system located in a dedicated room inside the CNR Building A and two antennas: an indoor antenna system (Ericsson Radio Dot) for UC7 and UC9, and an outdoor antenna system (micro cell) for UC8. The Core Network (CN) will be divided between TIM premises in Turin and Pisa. These sites will be connected through a VPN using specific packet gateways. The 5G infrastructure will be supported by the commercial Ericsson Orchestrator located in TIM's premises in Turin. Additionally, there will be an "ER Innovative Orchestrator" co-located with the BB system in Pisa. This second orchestration module is designed to manage vertical use cases with more complex end-to-end QoS requirements and optimal utilization of infrastructure resources. The infrastructure components are orchestrated dynamically and automatically to accommodate each specific service, including those that demand guaranteed and deterministic performance levels. The mapping of resources is based on actual traffic behavior to ensure effective service delivery.

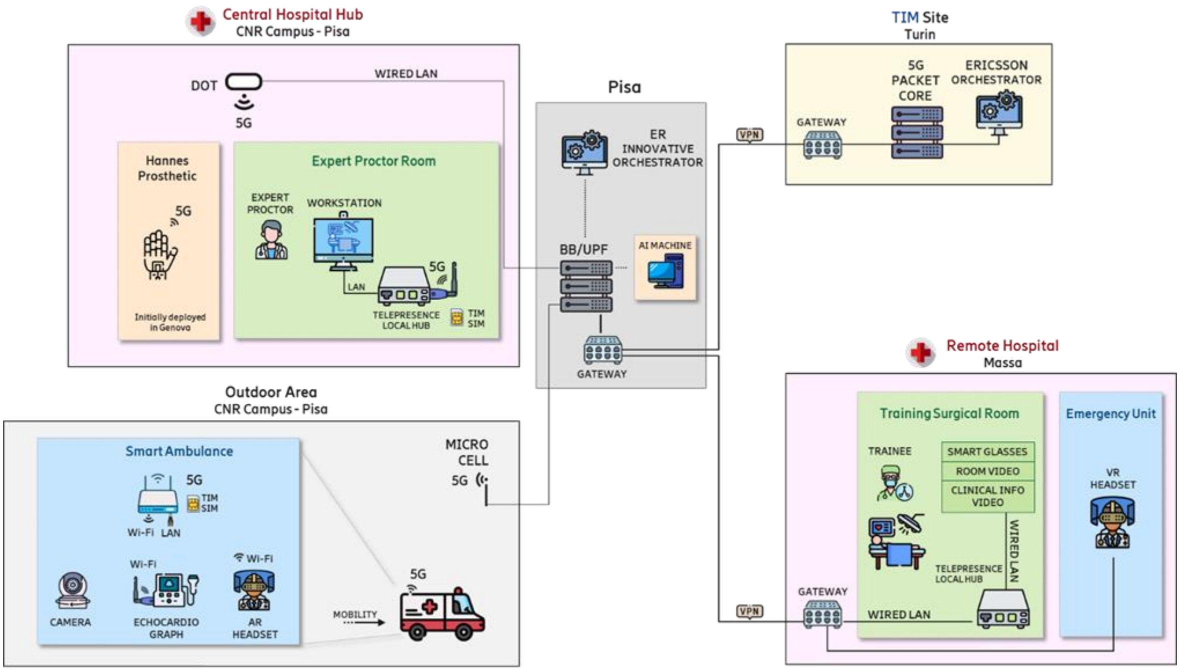


Figure 2. Main assets of the Pisa site infrastructure.

2.2.4 Extensions and new features

Since the network solution is going to be deployed from scratch, the primary goal is to develop a working solution according to the requirements of the current use cases. Possible enhancements will be considered if the experimentation of use cases identifies specific needs.

2.3 Spanish cluster

The Spanish cluster will support the implementation of UC1 "Smart Crowd monitoring" [1], UC6 "Mass Casualty Incident (MCI) and Emergency Rescue in Populated area" [2], and UC10 "Immersive Fan Engagement" [3].

2.3.1 Short description

The Spanish cluster is based on 5Tonic laboratory in Leganés (Community of Madrid) for the setup of the uses cases applications with 5G/B5G infrastructure. 5Tonic is an open laboratory for research and innovation that focus on 5G technologies. The 5Tonic co-creation laboratory was established to provide an open environment where members from business, industry and academia could collaborate with the telecoms innovation projects. The aim is to support innovation and help organizations work together to develop applications and business ventures. Ericsson provides the 5G System that supports the experimentation with the key objective of fostering 5G research and development and strengthening the competitiveness of European industry in the areas of 5G and innovation.

Uses cases of the Spanish cluster will be tested in real-life environment, so remote location deployment would be needed in addition to the laboratory part. For that purpose, Ericsson have developed a flight rack that contains the infrastructure with Radio Access equipment and User plane function that could support these uses cases in the events planned by the stakeholders. The overall scenario for the Spanish cluster, with the different locations of the equipment and how to support the uses cases in the lab and in remote location is depicted in Figure 3.

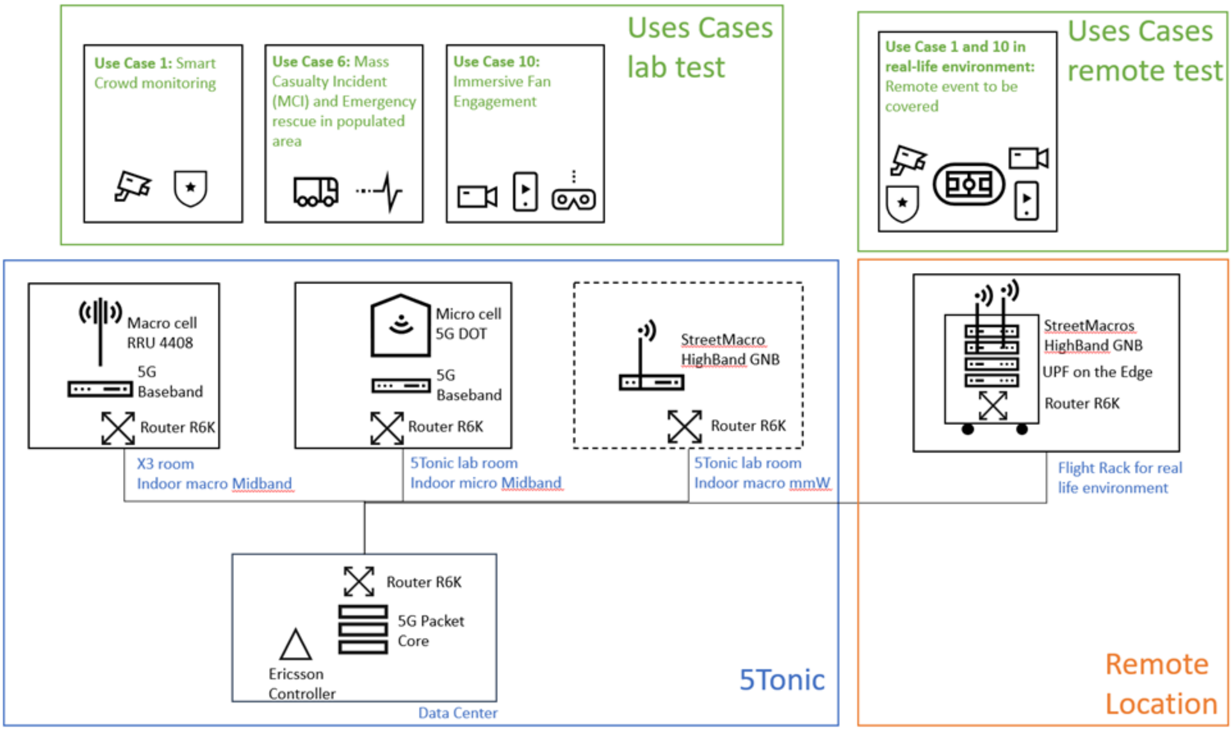


Figure 3. Spanish cluster overall scenario.

5Tonic infrastructure is in a continuous process of improvement and evolution, by incorporating new technologies that allows to experiment with new business cases where 5G technology is key for innovation. In the following sections the detailed infrastructure provided by Ericsson in the 5Tonic laboratory that will support the project is described.

2.3.2 Services offered by the infrastructure

5Tonic has two main areas of RAN coverage called X3 room and 5Tonic lab room respectively, with 5GC CP centralized in the data center (DC). It is also planned a future deployment with high-band node based on the StreetMacro gNB, that will be located also in the 5Tonic lab room. To support the remote tests in real-life environment, a flight rack with high-band antennas and UPF on the Edge will be used.

The actual infrastructure implemented uses 5G RAN equipment in mid-band (n78 - 3,5 GHz) and Stand-alone (SA) technology. Software installed in RAN and CN components are 3GPP Release-16 compliant and support projects with QoS/QoE guaranteed in the concurrent services implementation. As RAN configuration and spectrum available is limited due to commercial agreement by operator, actual network could serve eMBB (700Mbps DL/150MBps UL) or URLLC (E2E RTT <20 ms).

2.3.3 Main assets of the infrastructure

2.3.3.1 RAN X3 room coverage

The main area of coverage, also called X3 room, is the experimentation room and is shown in Figure 4. This main experimentation facility of 5Tonic is where the concurrent experiments are executed. The goal of this area is not only to have access to 5G technology but also to have access to the experimentation tools like for example the KPI framework or the graphical dashboard of the experiments.

Figure 4. X3 room coverage area.

This experimentation room has 5G mid-band outdoor antenna deployed for covering the experimentation facility as well as the outdoor space of 5Tonic. The Figure 5 shows a diagram of the RAN equipment used in the the X3 room coverage area.

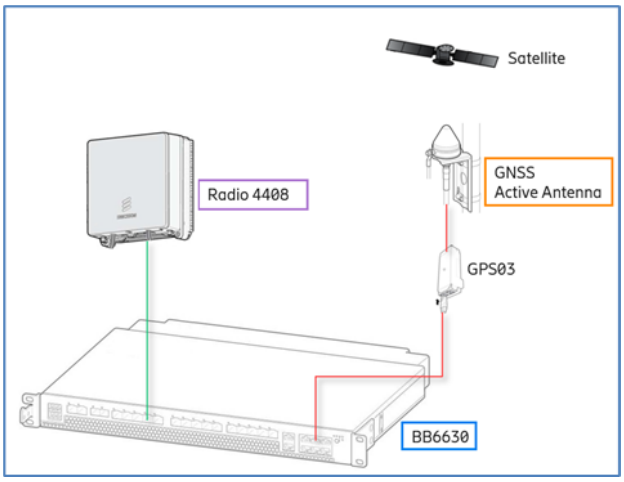


Figure 5. RAN equipment diagram for the X3 room area.

This RAN deployment is composed by the following equipment:

- **RRU 4408 n78L (B43):** Micro radio designed for more flexible and easier deployments and still efficient single and multiband. It consists in a four duplex Transmit (TX)/Receive (RX) branches supporting up to 4 x 5 W output power
- **Baseband 6630:** This equipment provides switching, traffic management, timing, baseband processing, and radio interfacing. It has the capability to be configured in mixed mode (more than one Radio Access Technology (RAT)).
- **Router 6675:** High-capacity access router, designed to provide high density 10 interfaces. It supports VPN services over Internet Protocol (IP)/Multi-Protocol Label Switching (MPLS) networks, service provider Software Defined Networking (SDN), service exposure using Network Configuration Protocol (NETCONF)/Yet Another Next Generation (YANG), extensive QoS and precise synchronization features.
- **Global Positioning System (GPS) receiver (Rx):** This component consists of a Global Navigation Satellite System (GNSS) Active antenna and a GPS signal is needed to have a time and phase synchronization required for 5G with Time-Division Duplexing (TDD) strategy. Precise signal is needed to synch the Download Link (DL) and Upload Link (UL) frames and to synch between the node B sites.

Figure 6 shows the RRU 4408 used for this deployment. Note that is the small antenna below the big antenna that is in the back that was the AIR6488 used in the first 5G deployments.

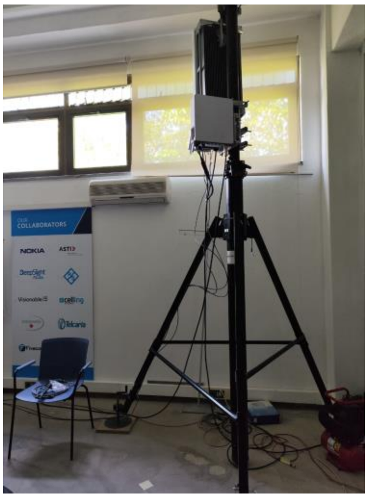


Figure 6. X3 RRU 4408 n78L (B43) antenna.

2.3.3.2 RAN 5Tonic laboratory

5Tonic also provides coverage to the 5Tonic laboratory room. This coverage is provided using DOTs antennas (small cells) that works in mid-range bands (same n78 band) for 5G NR and has indoor coverage purpose. Figure 7 is a picture of this room, with the DOT antennas installed on the roof.

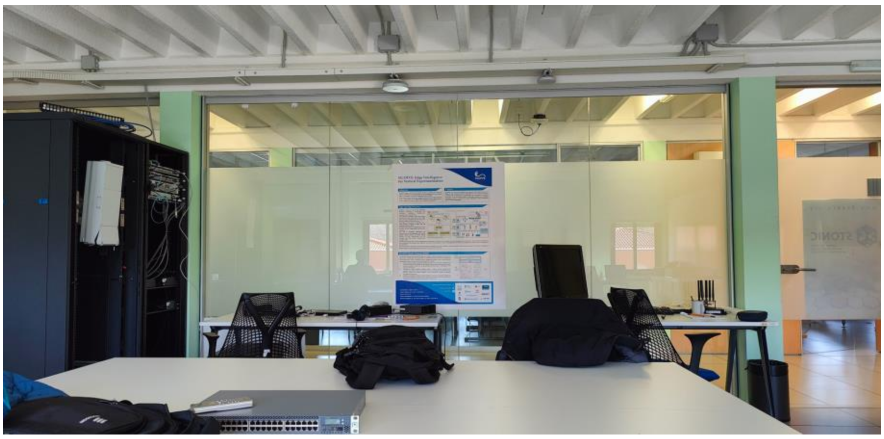


Figure 7. 5Tonic laboratory coverage.

The Figure 8 shows a diagram of the RAN equipment used in the 5Tonic laboratory coverage area:

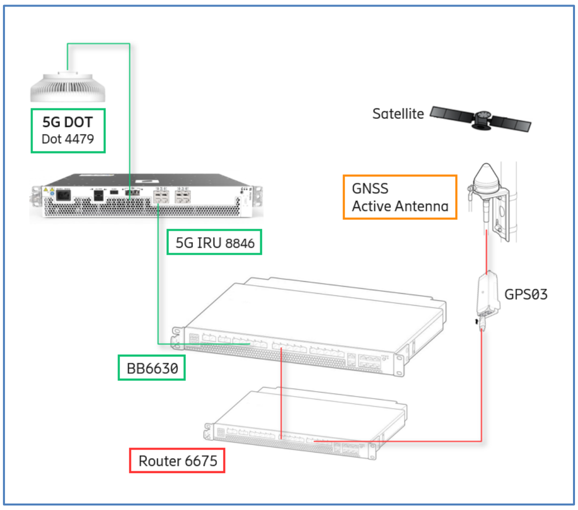


Figure 8. RAN equipment diagram for 5Tonic laboratory area.

This RAN deployment is composed by the following equipment:

- **5G DOT:** Smallest Ericsson’s radio used to cover indoor areas for NR 5G purpose. Is a 4x4 MIMO antenna that offers an innovative and high performing solution that effectively connects indoor users to the whole mobile eco-system.
- **5G IRU:** This equipment has the transmission of signals as main purpose. It provides an interface to the Radio DOTs (RDs) through the Radio Dot Interface (RDI) and supplies power to the RDs through the RDI.
- **Baseband 6630:** Equipment that provides switching, traffic management, timing, baseband processing, and radio interfacing. Ithas the capability to be configured in mixed mode (more than one RAT).
- **Router 6675:** High-capacity access router, designed to provide high density 10 interfaces. It supports VPN services over IP/MPLS networks, service provider SDN, service exposure using NETCONF/YANG, extensive QoS and precise synchronization features.
- **GPS receiver:** As was already mentioned in the previous sections, it is used for time and phase synchronization in TDD.

Figure 9 shows the 5G DOT antenna used for this deployment with the IRU and the Baseband in the Rack in the back. This 5G DOT covers the area of the experiments performed in the desk below, as this mechanic arm.

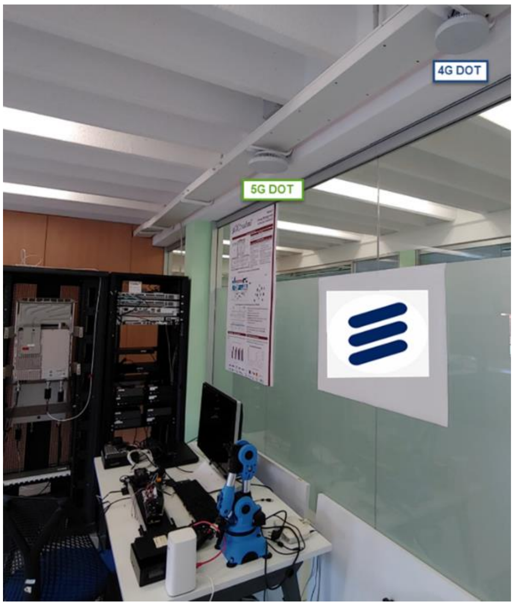


Figure 9. 5G DOT antenna, IRU and Baseband.

2.3.3.3 5G Core

The 5GC is deployed at the 5Tonic DC and it contains the basic NFs required for supporting the 5G System:

- **Basic NF:** NRF, Network Slice Selection Function (NSSF).
- **Subscriber NF:** UDM, UDR.
- **Control NF:** AMF, SMF, Policy Control Function (PCF).
- **User Plane NF:** UPF.
- **Exposing:** Network Exposure Function (NEF).

The 5GC is the cloud-native version of Ericsson and runs on top of a Kubernetes deployment. The Kubernetes-based solution is a container as a service (CaaS) platform that runs directly on the underlying HW, this provides the support for cloud-native applications as the fastest and most cost-efficient way:

- Automation of a Kubernetes over bare-metal cloud infrastructure is easier to achieve since the lack of a virtualization layer significantly simplifies the architecture, with fewer products and components to maintain, and fewer people needed to operate the technology,
- A Kubernetes over bare-metal infrastructure is more suitable for distributed cloud infrastructure deployments to provide edge solutions, where 5GC or Cloud RAN applications are needed,
- The introduction of new acceleration technologies (smart Network Interface Controller (NIC), etc.,) becomes easier for new 5G UCs,
- APP performance is better and more deterministic,
- Savings in the magnitude of 30 percent are possible, including costs for energy, operations and maintenance, software licenses, and HW.

The 5GC running on top Kubernetes over bare-metal infrastructure delivers a simplified architecture compared to running containers in VMs, and greater efficiency, performance, and automation can be achieved. The solution is simpler stack and makes better use of the underlying HW compared to virtualized infrastructure, enabling more efficient continuous integration and continuous deployment capabilities.

2.3.3.4 Portable system

Ericsson developed at 5Tonic a portable system, based on the concept of Non-Public Network (NPN), which is able to provide 5G NR coverage to sites outside 5Tonic premises but using the 5GC and the experimental infrastructure of 5Tonic. This portable infrastructure could support UCs implementation in remote locations.

The design of the NPN deployment shown in Figure 10 takes the advantage of the new capabilities provided by 5G, such as Control User Plane Separation (CUPS) and UP flexibility, to deploy at vertical premises only the equipment required for providing the access network (gNB) and the local break-out of the UP (UPF, transmission routers).

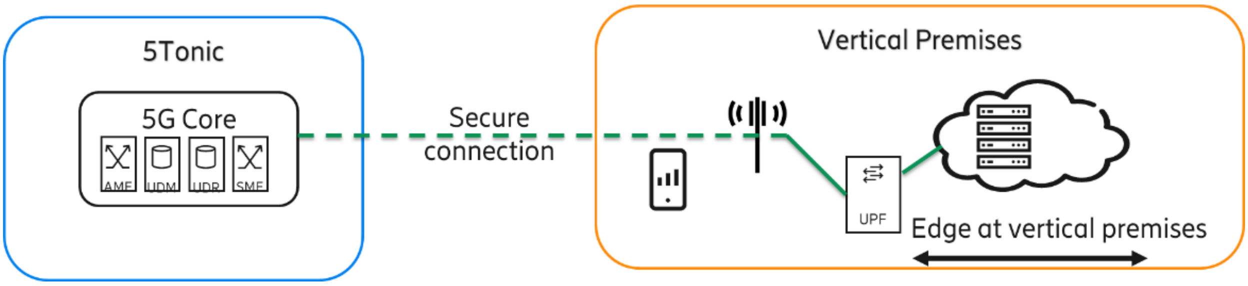


Figure 10. Diagram of NPN deployment.

The on-premises equipment uses a secure connection towards 5Tonic facilities in order to get access to the CP part of the 5GC. The secure connection used is Internet Protocol Security (IPSEC), a secure network protocol suite that authenticates and encrypts packets of data to provide secure encrypted communication between 5GC and 5G RAN. With this on-premises equipment, the 5Tonic 5G coverage can be extended to external premises and hence provide the same capabilities that 5Tonic has, including all the experimentation infrastructure.

2.3.3.5 Controller

Ericsson has a system that is used to orchestrate elements from the network deployed. This element is an open application that is developed to be able, at the RAN side, to collect the configuration of the gNB and counters information related to network behaviour. This system could also make changes in the network configuration and even change RAN features on real-time, but this feature would not be available in the context of the UCs implementation. The system could also operate over the UPF with the same purpose.

2.3.4 Extensions and new features

The actual 5G infrastructure deployed in 5Tonic has supported many UCs related to industry, gaming as the requirements is aligned with what is achievable by the network. However, the analysis of the needs from actual UCs, in terms of high user data rate with small jitter experience, requires the network setup evolves to be feasible.

With this objective, Ericsson and terminals manufacturers roadmap have been studied and conclude the deployment of high band frequencies in combination with Stand-alone technology will the best solution.

High-band have the advantages of:

- Having wider bandwidth and could aggregate more carriers.
- There is a latency reduction in high-band compares with mid-band due to numerology.
- High-band is not largely deployed in Spain compared to mid-band, so it will be easier to deploy in real-life scenarios with not affective operator’s user traffic.

Actual Software does not support the combination of high-band with SA, however high-band equipment exists and is supported in a NSA. When Software will be available to support SA case, the network will be updated.

The Figure 11 shows a diagram of the RAN equipment for high band that will be used in the 5Tonic, which is composed by:

- **StreetMacro 6701:** This equipment is for high-band frequency (n257) and includes baseband, RU and antenna.
- **GPS receiver:** As was already mentioned in the previous sections, it is used for time and phase synchronization in TDD.

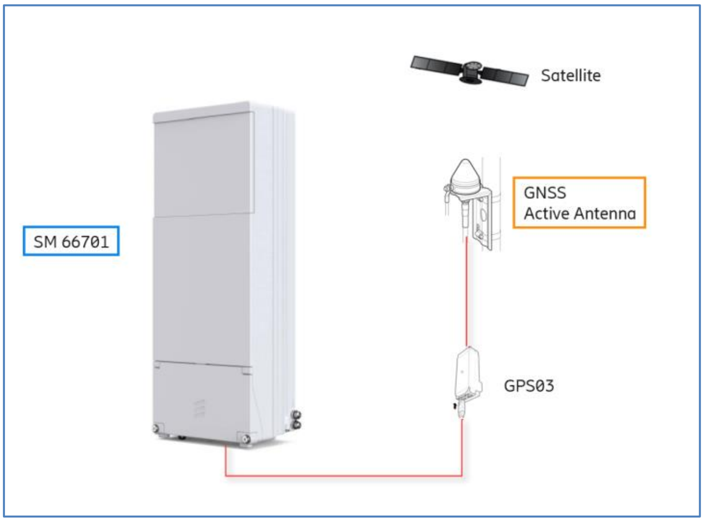


Figure 11. RAN equipment diagram for high-band solution.

Figure 12 shows a picture of the Highband equipment and the installation in the 5Tonic lab coverage area. This equipment is the Ericsson solution for a massive deployment in big cities (is known as StreetMacro), and when the software will support SA technology, will be the B5G solution in the road to achieve demanding requisites of the UCs.

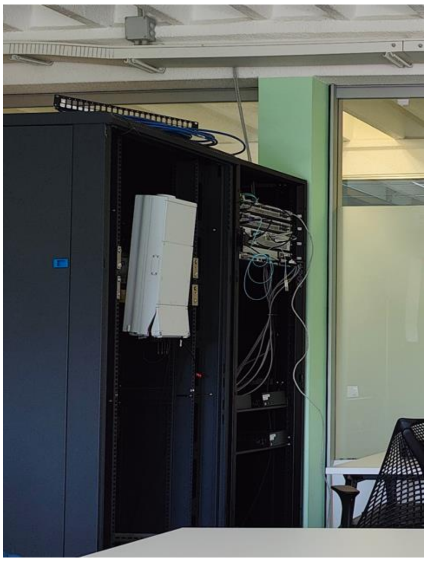


Figure 12. 5G StreetMacro 66701 for high band frequency located in 5Tonic laboratory.

2.4 Romanian cluster

This section describes the main infrastructure components of the Iași site in which UC1 "Smart Crowd Monitoring" and UC4 "Smart Traffic Management" [1] will be implemented and the testbed sibling from Bucharest.

2.4.1 Short description

The ORO 5G Labs, from both Bucharest and Iasi, are the primary locations for hosting the infrastructure for this use-case and will be the desired places for testing and validation of the related applications. The Bucharest 5G Lab is located within the CAMPUS Research Center of the Polytechnic University from Bucharest (UPB) and currently implements a full 5G SA infrastructure. The Iasi 5G Lab, depicted in Figure 13, is ORO's main testbed for the project and is located within the Iasi Technical University (TUIASI) and currently hosts only indoor 5G SA radio connectivity. In the next months it will be prepared so that it will have similar capabilities to the Bucharest laboratory and in the medium term the RAN will be extended so that the use-cases areas will be covered with 5G SA connectivity. However, the commercial 5G NSA network, with existent coverage on the use-cases areas, will be used initially for piloting and testing of the developed solutions.

Figure 13. Iasi Orange 5G Lab 5G Experimentation Area.

2.4.2 Services offered by the infrastructure

The testbed, with the architecture represented in Figure 14, is capable to provide multi-slices implementations, with QoS/QoE guarantee in the concurrent services implementation, as eMBB (1500Mbps DL/150MBps UL) or URLLC (E2E one way delay <4 ms), based in 3GPP NSSAI parameters.

Use case developers and also potential 3rd party experimenters currently have access to the Edge-Compute facility from the Bucharest 5G Lab that implements virtualization and orchestration features. The deployment of network applications on this infrastructure will be performed through a project dedicated onboarding and instantiation platform that will require minimal inputs from the developer's side.

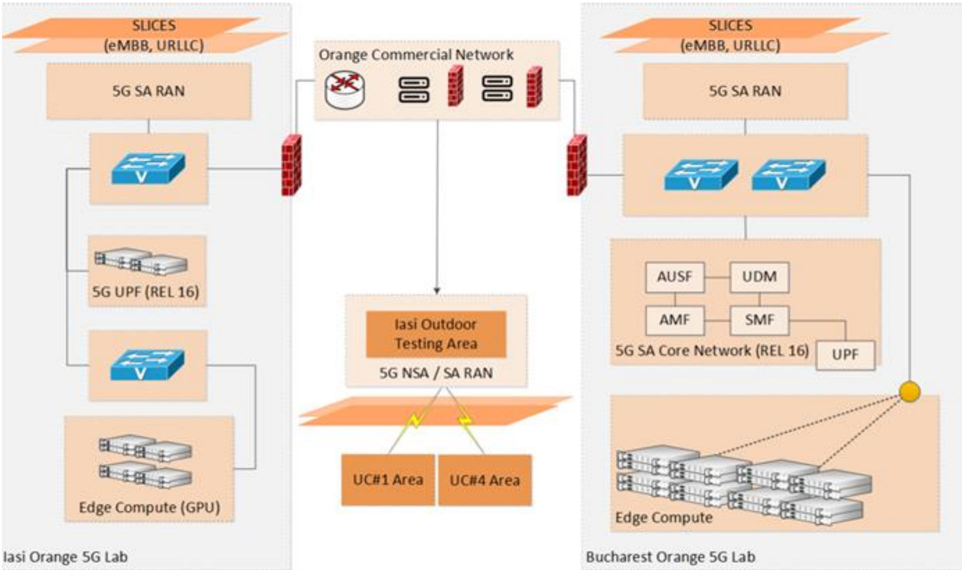


Figure 14. Orange 5G Labs architecture.

The Romanian testbed will pilot the envisioned use cass within two different phases, looking at first at the preliminary results using the current commercial 5G NSA network and then evaluating the applications performance when running on a 5G SA private network:

- **Phase 1:** Testbed deployment started with a commercial 5G NSA implementation in Iasi, for early trials, with the 5G NSA RAN and Core Option 3x (virtualized core solution). In the scope of the project, a private APN will be created, so that all the traffic from the surveillance cameras installed in the use-case areas, as described in D3.1 [1], will be directed to the edge-compute facility from the Bucharest 5G Lab or the one that will be deployed on the premises of the Iasi 5G Lab. The 1st phase will also include testing and validation activities that will be performed indoors, in the Orange 5G Labs from Iasi and Bucharest, through a private 5G SA 3GPP Release 16 network.
- **Phase 2:** In the 2nd phase, ORO's testbed is expected to implement an outdoor 5G service over SA network in a private mobile network concept, that is integrated in the Bucharest 5G Lab testbed from Control Plane and a local UPF in Iasi (Control Plane/User Plane separation) that is 3GPP Release 16 compliant. The 5G is running on dedicated virtualized infrastructure, 5G SA option 2 implementations.

2.4.3 Main assets of the infrastructure

2.4.3.1 Outdoor 5G NSA coverage

As described, for Phase 1, the commercial 5G NSA network will be used for the development and large-scale trial of the envisioned use-cases in the designated areas as well as the private 5G SA network from the 5G Labs indoor premises. For UC1, that will take place on the Stefan cel Mare pedestrian alley, as well as for the UC4, that will run in the Podu Ros intersection area, the 5G NSA coverage is provided as seen in Figure 15 and Figure 16 respectively.

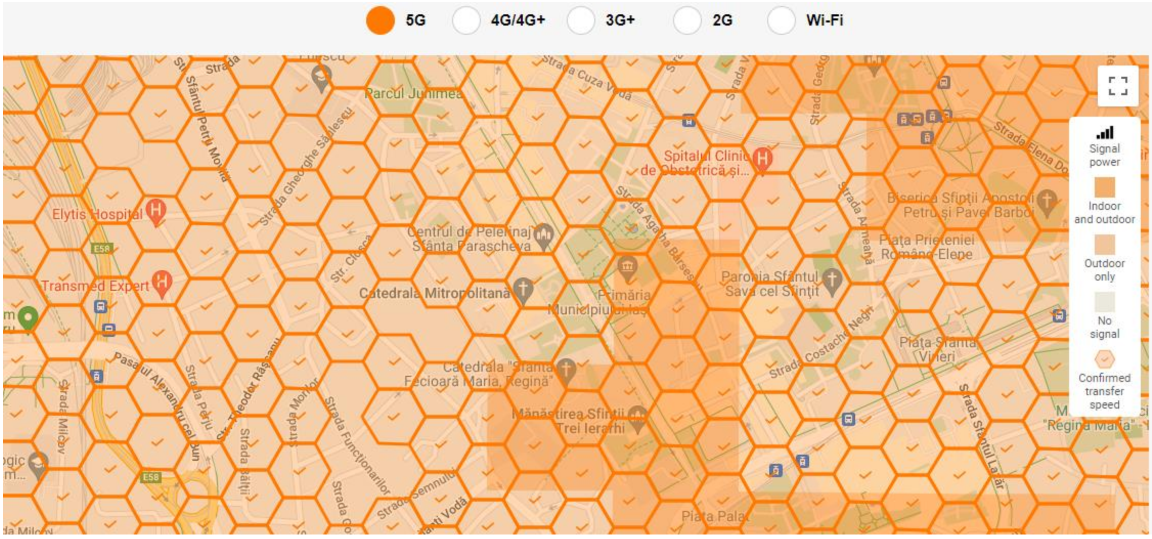


Figure 15. 5G NSA Stefan cel Mare pedestrian alley coverage simulation map.

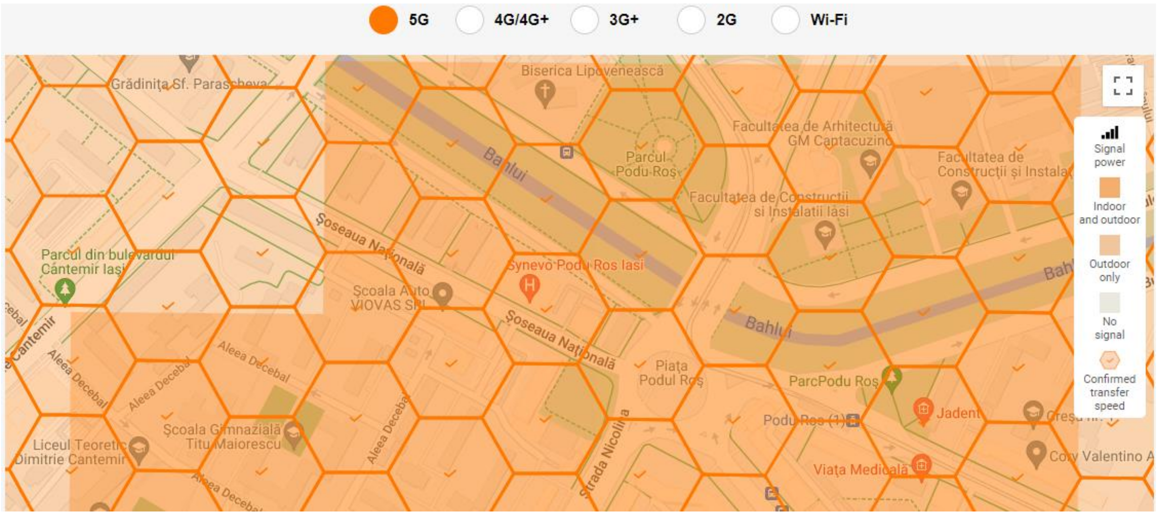


Figure 16. 5G NSA Podu Ros Intersection coverage simulation map.

2.4.3.2 Network and management functions

In the testbed, OSMv12 is ORO's orchestrator that is compliant with ETSI MANO architecture and is offering an orchestrator tool that integrates with infrastructure controllers and can build different VNFs and Network Slices across all the platforms inside the lab. It will act as an umbrella deployment and management tool for different slice networking deployment, 5G ready use cases. Ansible and Terraform are the automation core tools triggered from CI/CD managers that create the automation back bone of the 5G lab used for provisioning and configurations of any applications. All these tools are facilitating automation in TrialsNet and make the environment ready for any integration oriented in 5G SA present and future use cases that will come through the open-call program.

2.4.3.3 Edge-Compute facility

The edge-compute facility that will be used in the Romanian testbed will be hosted in the Iasi 5G Lab datacenter and can be extended to the Bucharest 5G Lab datacenter if needed. It will feature two HPE servers of which one will be fitted with a NVIDIA GPU for Machine Learning acceleration tasks. This testbed infrastructure will be ready to host and accommodate applications and services in both bare metal and containerized forms by leveraging both classical virtualization software as well as containers orchestration tools.

2.4.3.4 Applications onboarding platform

In the context of unitary Applications onboarding steps, the Romanian testbed onboarding platform, developed in the context of H2020 VITAL-5G project (GA #101016567, 2021-2023, 5GPPP), will be implemented as a flexible platform, which can be adapted to serve and streamline the specific needs of the UC#1&4 application developers and 3rd party experimenters, being focused on the creation, deployment, management and validation of applications, including service & network monitoring, slice inventories, service and testing capabilities and orchestration. By setting up an integrated web portal, where the Application developers can select the needed resources from the service catalogue, ORO aims to ease the integration of applications that require novel 5G services.

2.4.3.5 Secure access to the TrialsNet platform for developers

In the scope of the TrialsNet project, ORO will install in the premises of the Iasi 5G Lab Datacenter a security solution designed to alleviate the issues and concerns that may appear in the open-call experimenters onboarding and operation phases. A firewall deployment will streamline the access procedure to the testbed for the experimenters and will assure the proper isolation between different network applications and services.

2.4.3.6 Equipment for experimentation

Orange Romania is able to provide to interested 3rd parties a set of devices that are compatible to both 5G SA and NSA networks and are able to support the development of novel 5G-enabled use cases. The devices are depicted in Table 1.

Table 1. Orange Romania devices for 3rd party experimenters.

Equipment	Item	Description
	Milesight MS-C8266-X4GPC	The Milesight MS-C8266-X4GPC is a 5G SA/NSA surveillance camera that can record 4K footage. This camera will be used for 2K/4K video capturing in the area defined for the use-case. This video stream will be transmitted directly to an Edge-compute facility via the 5G SA/NSA network, this way eliminating the security risks involved with the transmission of sensitive data through publicly accessible switches.
	Nokia FastMile 5G14-B	The Nokia FastMile 5G14-B is a 5G SA/NSA outdoor CPE that can connect simultaneously to multiple slices, with different IPs and different Package Data Unit (PDU) sessions, with a single SIM card specifically provisioned to support 2 or more DNN profiles. The CPE splits the traffic into separate VLANs and ends the connection into a switch that allows devices to access different slices. This Nokia CPE is also able to connect to a TR-069 Automatic Configuring Server (ACS), this way being able to transmit real-time metrics about the UL and DL traffic values for the connected slices and the radio signal parameters. The CPE will be configured to connect to both an eMBB slice and an URLLC slice. This way, the non-cellular cameras and the sensors will use the eMBB for data transmission, while the VRUs will be notified by the security system through the URLLC slice.
	Quectel 5G M2 EVB and RM500Q-GL	The Quectel 5G M2 EVB is a development board on top of which we can place the Quectel RM500Q-GL, this way being able to connect to both 5G SA and NSA and pilot different use cases and devices. The board is fitted with USB C and Ethernet connectivity.

2.4.4 Extensions and new features

In the scope of the project, in order to improve the E2E system latency for UC#1 and UC#4, the 5G network architecture will be further developed in a Distributed Cloud/MEC type of approach with the deployment of a virtualized UPF in the Iasi 5G Lab Datacenter. This UPF will be integrated in the 5G SA CN from Bucharest (Control Plane), will be connected to the Iasi gNBs and the local edge-compute facility and will have direct access to several DNNs (including Internet).

The proposed design, highlighted in Figure 17, is taking into consideration all the network segments and transmission characteristics, for latency between UE and base station (LLC slice) ≈ 3ms, gNB to 5GCN ≈ 1.5ms and 5GCN to MEC less than 0.5ms, as they are collocated and fiber links interconnected, offering the E2E delay budget of ≈ 4.5ms, under analysis from the Network Application perspective for the UC1 and UC4 envisioned developments based on video feeds from surveillance cameras.

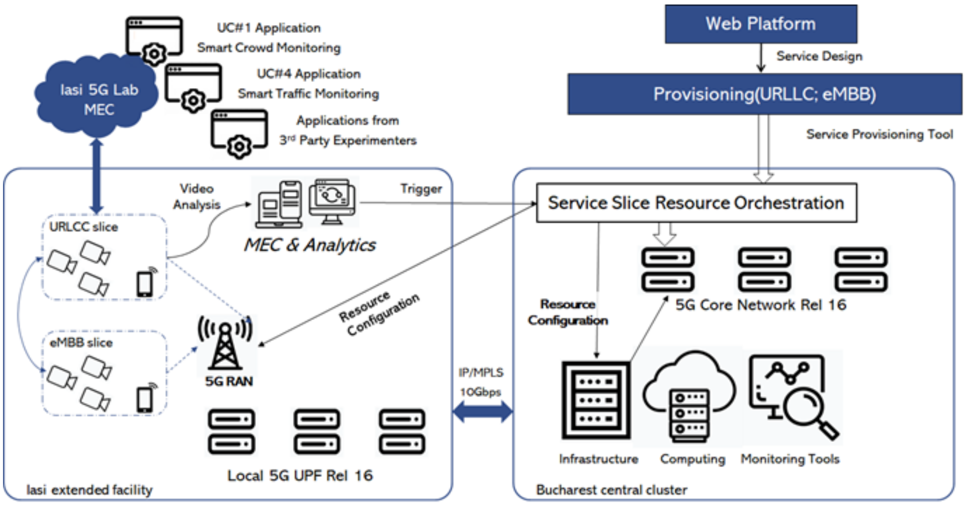


Figure 17. Romanian testbed MEC implementation.

2.5 Romanian cluster (experimental facilities in Belgium)

The IMEC testbed ecosystem located in Belgium provide an experimentation setup based on real-life testbeds such as CityLab, Smart Highway, and 5GOpen. Although in the TrialsNet project, this experimental site is defined as a supporting trial site for the Romanian cluster use cases, for the Open Call, it will be used as a completely standalone (i.e. independent from the Romanian cluster) testing setup with network and virtualized infrastructure resources to support the implementation and trials of third parties use cases.

2.5.1 Short description

This ecosystem provides an extensive experimentation setup based on real-life testbeds such as CityLab Smart City, Smart Highway, 5GOpen, and portable 5G. As such, the overall setup is being used as supporting trial site for the Romanian cluster and use case Smart Traffic Management, where IMEC is using both network and virtualized infrastructure resources to build and test the 5G and beyond enablers such as zero-touch network and service management, flexible and autonomous radio resource management, and creation of flexible and virtualized vertical service deployments following the design of Edge Network Applications.

2.5.2 Services offered by the infrastructure

The IMEC testbed ecosystem provides the following services:

- **Edge computing capabilities**: various distributed edge computing nodes deployed within CityLab and Smart Highway testbed, offering computing capabilities for sensor data fusion & large-scale analytics, as well as deployment of latency-sensitive services close to the end users (e.g., vehicles and vulnerable road users)

- **Real-time monitoring of resources and services**: tools for monitoring performance of services and their resource usage are available on the testbeds described in the following subsection, offering dashboards to monitor performance, but also databases and APIs to collect real-time and historical data potentially useful for training AI/ML models
- **Smart orchestration of edge services**: open-source orchestration tools such as Open-Source MANO and Kubernetes are used on all testbeds to perform orchestration of edge services, including necessary extensions in terms of intelligent decision-making algorithms that improve the overall decision-making taking into account service requirements and real-time network performance
- **Flexible radio resource management**: O-RAN-based frameworks that facilitate the use cases in terms of optimal configuration of available wireless technologies (5G and Wi-Fi) based on the data traffic requirements and the wireless environment conditions.

2.5.3 Main assets of the infrastructure

2.5.3.1 CityLab testbed

The CityLab testbed is intended for large-scale wireless networking and edge computing experimentation in a highly realistic environment in an area of 0.5km by 0.5km in the city of Antwerp. The 50 CityLab IoT gateways work as edge nodes for sensor data fusion and large-scale data analytics.

2.5.3.2 Smart Highway

The Smart Highway test site is built on top of the E313 highway, and it consists of a highway strip of 4 km equipped with Roadside Units (RSUs). The testbed concerns various application domains such as Smart Mobility, Cooperative, Connected and Automated Mobility (CCAM), and Autonomous Driving. As such, it is designed for Vehicle-to-Everything (V2X) communication & distributed/edge computing research, thereby providing means for creating scalable and reliable V2X system, with opportunities to validate automotive requirements for automated driving with industry in real-life trials. Besides the RSUs that are deployed along the highway, there are three Onboard Units (OBUs) which are either in-vehicle or rooftop units. The important feature of such OBUs is their flexibility and adjustability, as they can be easily mounted on any regular car. In addition to that, testbed is equipped with two testing vehicles that can be used in experimentation activities. The Smart Highway testbed consists of seven RSUs in total, and they are deployed on top of the gantries along the E313 highway in Antwerp. Each of those RSUs is fully managed remotely, which facilitates the federation of testbed resources and resource usage by external experimenters. The testing car is a BMW X5 with automatic gearbox from 2014 that is provided by the University of Antwerp. The car is equipped with an OBU, power system, and communication hardware. Both in-vehicle and rooftop OBU are equipped with computing capabilities as well, with Intel NUC7iDNKE and Nvidia AGX Xavier, respectively. This car can be driven and used as a mobile node in a 6G V2X context. The Smart Highway architecture empowers researchers and external experimenters to place functions at different computational locations ranging from the OBU up to the cloud, leveraging RSUs as distributed edge computing units. Latency, network load and processing time can be further reduced by dynamically selecting the location of the data processing and the used communication links.

2.5.3.3 5GOpen testbed

The 5GOpen testbed is located in Antwerp offering indoor and temporarily outdoor 5G connectivity based on two gNodeBs and a 5G Core Stand Alone deployment where different combinations of Open RAN combinations can be tested. IMEC has obtained a Belgisch Instituut voor postdiensten en telecommunication (BIPT) test license, which is valid for the 3800-4200MHz frequency range (N77 upper) and the stretch on the road covered by the above-mentioned Smart Highway testbed. One of the planned activities is to extend this license to the CityLab locations where gNodeBs are scheduled for deployment. Currently, 5GOpen testbed is deployed as a testbed in a box, containing both radio and core capabilities, offering tools to pursue 5G validation, integration and testing, in both office and open environments. On the Core side, we have OpenAirInterface (OAI), Open5GS, and Free5GC. The 5G New Radio (NR) is based on OAI and srsRAN. Further, for User Equipment (UE), we use Commercial Off-The-Shelf (COTS) implementation (Intel NUC with 32GB RAM, and Intel i7-10710U processor) with Quectel modules (RM500Q). Finally, to enable computing capabilities of the testbed, we enabled Proxmox enabled Supermicro servers suitable for provisioning virtualized resources, 128GB RAM, two Intel Xeon E5-2620 CPUs (8 Cores, 16 Threads each), and one USRP X310 over 10GB link to passthrough to VMs where application services and AI/ML models are running.

2.5.3.4 Portable 5G testbed

The portable 5G testbed is located in Ghent, offering a transportable 5G standalone network in a box solution that can be used for 5G network testing, experimentation and novel research on 5G and beyond network technologies. The testbed consists of two portable 5G units including both commercial off-the-shelf (COTS) and software defined radio (SDR) equipment enabling flexibility for extensions and customization beyond features offered in 3GPP releases and capability for end-to-end experimentation involving business-critical and/or mission-critical applications with demanding QoS requirements in dynamic wireless environments.

2.5.4 Extensions and new features

The integration of 5GOpen testbed with CityLab and Smart Highway testbeds is ongoing and planned to be finalized during 2023, for the purpose of providing 5G connectivity in all test sites within IMEC testbed ecosystem, and to ease the integration of zero-touch mechanism into the Romanian cluster. In addition, testing vehicles are part of the Smart Highway testbed and as such will be equipped with corresponding 5G modems and additional testing equipment. Also, some of the planned upgrades for both CityLab and Smart Highway testbed are related to the sensors (air quality, lidar) are planned for purchase and installation in order to enrich the testbed capabilities for testing smart city and automotive applications, AI/ML capabilities at the network edge, among others.

The deployment and validation of capabilities for advanced zero-touch service management and flexible and autonomous radio resource management is going to be performed within the IMEC testbed ecosystem, focusing on the Smart Traffic Management use case. Such or similar use cases can be deployed and demonstrated to validate the effectiveness of intelligent traffic management within a robust zero-touch management of edge services.

2.6 Greek cluster

This section describes the main infrastructure components of the Athens site in which UC2 “Proactive Public Infrastructure Assets Management” [1], UC3 “Autonomous Apron” [1], UC6 “Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area” [2], UC11 “Service Robots for Enhanced Passengers' Experience” [3], and UC13 “Extended XR museum experience” [3] will be implemented.

2.6.1 Short description

Use cases of the Greek cluster will be trialed at the Athens airport (AIA) and at public area in the city of Athens such as Technopolis venue. At these locations the Greek cluster will mostly rely on the commercial 5G network. In addition, WINGS private network infrastructures will be also utilized for leveraging its high-speed connectivity, low latency, and wide coverage to support the data-intensive applications required by the use case, to conduct testing activities, validation and demonstration, prior to the deployment on the field but also to allow for greater flexibility in the experimentation.

2.6.2 Services offered by the infrastructure

The public, commercial 5G network uses NSA architecture and operates 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 cases.

The WINGS testbed provides E2E 5G/B5G functionality, along with extensive cloud and edge computing capabilities, leveraging the 3GPP (Release-16 and beyond) Public Network Integrated Non Public Network (PNI-NPN) with shared CP (at a first phase) and isolated, Stand-alone Non-Public Network (SNPN), with all NFs (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 HW, software, and configurations to enable the testbed to handle these UCs. WINGS testbed serves as a testing ground for services, equipment, and new features before they are commercially released. Figure 18 reports the WINGS testbed high-level architecture.

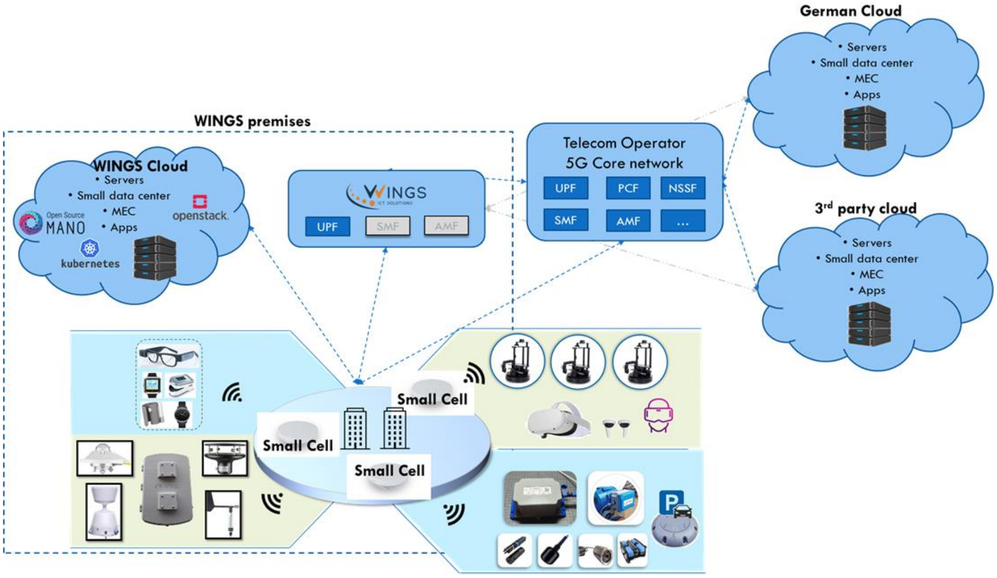


Figure 18. WINGS testbed architecture for experiments

WINGS has progressively extended the existing software, HW, and network functionality to support Cloud, Mobile Edge Computing (MEC), Extreme Edge and IoT functionalities. WINGS has demonstrated advanced UCs on DTs, Collaborative Robots with native-AI B5G/6G capabilities of the system. Also, the required frameworks to build, test, and validate innovative 6G applications are part of the overall infrastructure.

The WINGS testbed utilizes AI mechanisms to support diagnostics, intelligent management, and orchestration. The management of the facility is done using a combination of existing and new software, covering DevOps, AI/MLOps, monitoring, profiling, diagnosis, and service-aware resource allocation and orchestration. An AI-enhanced MANO component inherited from 5G-TOURS project is used to enable advanced automation and optimization. Monitoring, profiling, and diagnostic components provide information on available resources and network capabilities to help find the optimal deployment of a vertical service.

The WINGS testbed utilizes open-source software such as Openstack, Kubernetes and OSM MANO to provide a flexible and scalable infrastructure for verticals, as well as other open-source tools like Kafka, MQ Telemetry Transport (MQTT) and Robot Operating System (ROS). These components can support VMs, containers, and serverless execution of code from cloud to extreme edge devices such as raspberry pi.

The WINGS testbed prioritizes protection and privacy-preserving mechanisms to ensure reliability, security, privacy, confidentiality, and integrity of data. Open-source tools like Keycloak or Blockchain technology may be used where appropriate, and OpenNAC for Network Access Control. Strong authentication, user management, and secure services will be provided with minimum effort from the verticals. The solutions selected will comply with General Data Protection Regulation (GDPR) article 5 to ensure appropriate security and protection against unauthorized or unlawful processing, accidental loss, destruction, or damage. They will employ consolidated Public Key Infrastructure (PKI) certificate-based cryptographic systems for critical communications to encrypt personal data during transmission.

2.6.3 Main assets of the infrastructure

2.6.3.1 WINGSPARK++

The WINGSPARK++ platform (see Figure 19) 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. WINGSPARK++ utilizes advanced monitoring, fault detection, performance optimization, security, and configuration capabilities in the areas of infrastructure, parking, and stations. As part of the TrialsNet project, data collected from multiple sources will be transmitted through the 5G network, enabling further data extraction, and processing. The resulting data will be ingested into a highly scalable datastore, which will serve as input for AI processing. WINGSPARK++ will leverage advanced AI technologies to analyse data and provide insights, such as infrastructure faults. In addition, the platform will enhance its user interfaces with a dashboard that will provide insights and alerts to the remote experts. To further improve accessibility and convenience, mobile apps will also be developed, providing users with easy access to information and insights on the go. WINGSPARK++ will be used in UC2, UC3 and UC11.

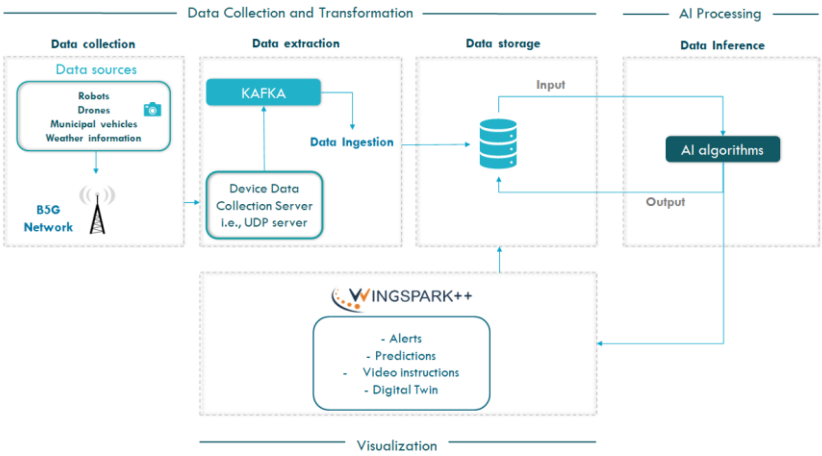


Figure 19. Overview of WINGSPARK++ platform.

2.6.3.2 WINGS STARLIT++

WINGS STARLIT++ (see Figure 20) is a cloud-based platform that will be used for UC6. The services provided will be an extension of the functionalities of the existing STARLIT platform (https://www.wings-ict-solutions.eu/startlit/). STARLIT++ will exploit devices such as cameras, drones and robots to develop an electronic triage monitoring APP to handle victims' health data, triage status, and its dynamic development through secondary and transport phase, current location, while support for evacuation operations will also be provided. The devices capture images, video, and other data, which are transmitted over 5G networks to a central platform for processing and analysis using AI models and techniques. For the MCI case, devices, will also comprise wearable devices for monitoring of vital signs, such as heart rate, oxygen saturation, body temperature, blood pressure, etc. The platform comprises AI powered mechanisms for providing insights on a range of factors (e.g., estimated number of victims, potential issues for first responders to address in the field, estimated location of users, user's vital signs evolution, forecasting of future issues and health emergencies, notification for designated doctors and first responders, etc). In addition, the routing algorithms to be developed (adapted to the particular needs of the project) for the calculation of the optimal evacuation routes, will be connected as a service to the STARLIT platform. This way, a direct and continuous transfer of data is to be utilised, to make use of the latest updated information collected and to channel the generated information through the common applications/interfaces to be decided and defined for each scenario (e.g., a smart device or XR glasses, tec.).

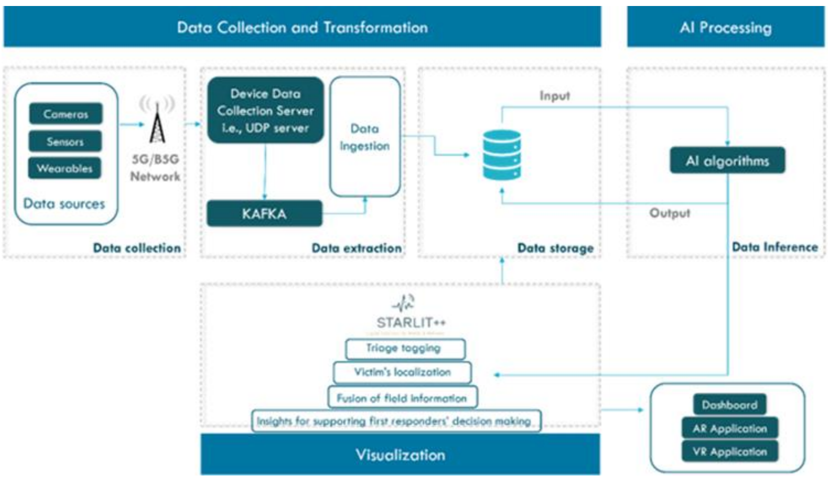


Figure 20. Overview of STARLIT++ platform.

The current list of equipment and devices used in the Greek cluster for the supported use cases is presented in Table 2. It should be noted that the list may be augmented as the implementation of the use cases progresses.

Table 2. Equipment and devices for Greek cluster.

Equipment	Item	Description
	Clearpath Robotics Jackal Unmanned Ground Vehicle	Clearpath Robotics Jackal Unmanned Ground Vehicle/UGV is a small, fast, entry-level field robotics research platform. It has an onboard computer, GPS, 3D LIDAR, camera and IMU fully integrated with ROS. Jackal's chassis is made entirely from welded aluminium and provides IP65 protection rated to operate from -20 Celsius or +45 Celsius. The high torque 4x4 drive train gives Jackal maximum traction, with enough on-board power available to traverse obstacles or unconsolidated terrain.
	Tarot Quadcopter Custom Drone + PixHawk controller	A custom-made quadcopter with a PixHawk flight controller and carbon ultra-light weight body can be an excellent tool for aerial photography, mapping, and surveying applications. The PixHawk is a popular open-source autopilot system that provides advanced control algorithms for stabilization, navigation, and mission planning. The PixHawk flight controller provides stable and reliable flight performance, thanks to its advanced sensor fusion algorithms that combine data from multiple sensors, including accelerometers, gyroscopes, and magnetometers. This ensures that the quadcopter remains stable and responsive, even in challenging environments.
	Rasberry pi 4	The Raspberry Pi 4 is a powerful single-board computer that can be used for a wide range of applications, including drone technology. Its quad-core ARM Cortex-A72 CPU running at 1.5GHz, combined with its high RAM options, makes it a suitable choice for drone technology. With its small form factor, low power consumption, and various connectivity options, the Raspberry Pi 4 can be integrated into a drone's flight control system, providing real-time data processing, image and video capture, and even remote-control capabilities. Additionally, the Raspberry Pi 4's multimedia capabilities can be used to enhance a drone's camera and video streaming capabilities.
	Ouster OS1	Some of the sensors that will be used are the Ouster OS1 which is a type of LIDAR sensor used for 3D imaging applications. LIDAR stands for "light detection and ranging" and it uses lasers to generate a 3D map of the surrounding environment. The Ouster OS1 is designed for use in robotics and autonomous vehicles like the Jackal robot. The sensor has up to 128 laser beams that emit light in a 360-degree pattern, allowing it to capture a comprehensive image of the surrounding environment. It has a range of up to 200 meters and can generate up to 5.2 million points per second. In this robotic use case, the Ouster OS1 can be mounted on a robot/autonomous vehicle to provide a real-time map of the surrounding environment. The LIDAR data can be used to help the robot navigate and avoid obstacles, such as walls, people, or other vehicles delivering a clean, dense data across its entire field of view for accurate perception and crisp mapping.

	Intel RealSense Depth Camera D455	Intel RealSense Depth Cameras will be integrated into the robots, to capture images of faults and other defects. By using these cameras, the robots will be able to more accurately and efficiently identify and address issues within the area. The high-resolution capabilities and depth sensing based on stereo camera array of these cameras will provide a level of detail and precision that would not be possible with traditional inspection methods. The cameras can capture full HD video to up to 10 meters combining depth information with a wide field of view making it the preferred solution for applications such as robotic navigation and object recognition even in low-light areas allowing robots to navigate spaces in dark environments.
	Vision RTK 2	GPS devices will also be incorporated into the robotic assets to facilitate easy tracking of their location. This integration will enable the system to monitor and control the movement of the robots with greater accuracy and precision, avoiding potential hazards and obstacles. The selected GPS receivers use GNSS technology to provide location solutions that are 100 times more accurate (centimetre-level positioning) than traditional GNSS solutions. The combination of GPS and camera data will be used to train AI/ML algorithms for analysing the environment. This analysis will run on specific GPUs like the NVIDIA's GeForce RTX 3070 GPUs or newer for a better and faster analysis of the collected data. With tensor and cuda cores the system will be optimized for parallel computing or accelerated deep learning and AI workloads that this use case needs.
	Samsung Galaxy S10 5G	This Smartphone will be used for the mobile applications, including the XR application that will be provided for the evacuation case.
	Smart watch (A16) Aitaer Technology Co., Ltd	This smartwatch will be used as a device for monitoring of vital signs of the injured people in order to be analysed in real time in the STARLIT++ platform.
	LoCoBot WX250	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.

	Intel® RealSense Depth Camera D435	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.
	RPLIDAR A2M8 360° lidar	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.
	Quectel RM500Q-AE wireless module	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 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	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.

2.6.4 Extensions and new features

As part of the effort to support the envisaged KPI target values, work in the scope of the project will focus on the enhancement of the WINGS private network infrastructure with the small cells and the 5GCN functions. Further enhancements include adaptation of the WINGSPARK++ platform for UCs 2, 3 and 11 and of the STARLIT++ platform for UC6. Initial testing will take place in Q1 of 2024. Further testing will take place at the Q1 of 2025 with execution of the final trials towards the end of the project (Q3 of 2025).

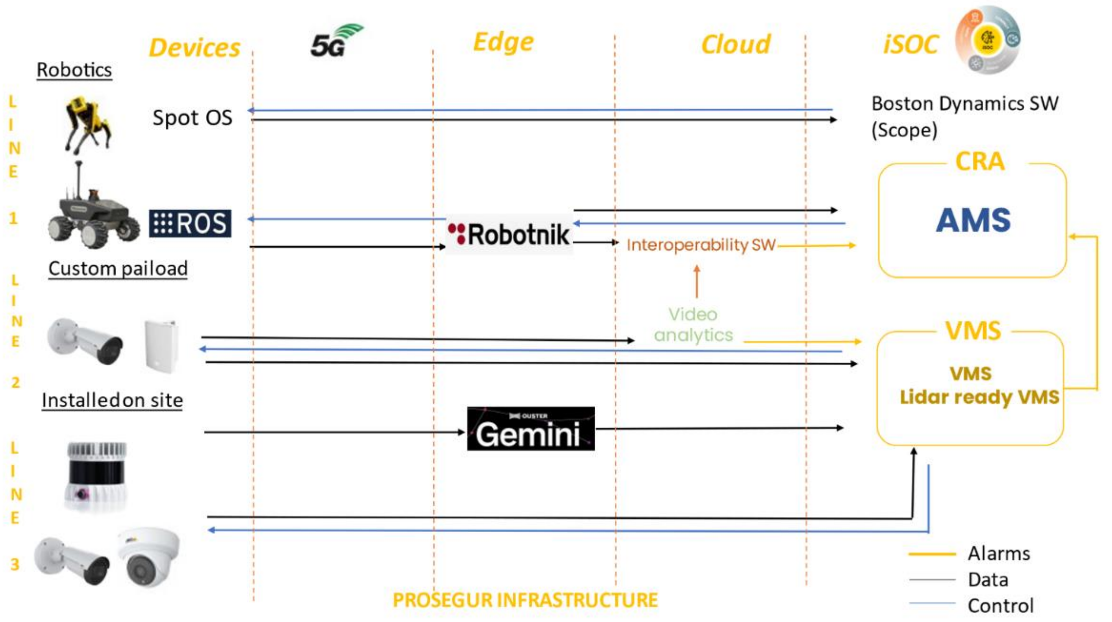
2.7 Challenges of the TrialsNet infrastructures

In the following some examples of challenges that could be addressed in order further extended the TrialsNet's infrastructures and functionalities are reported:

- Expanding the TrialsNet sites with new platform and network solutions in support of the use cases implementation
- Adding new clusters in the TrialsNet project, including new infrastructures in terms of experimental, private and/or commercial networks
- Unification of the TrialsNet infrastructures with common platforms for network monitoring and edge applications deployment
- Adding Network Exposure Functions capabilities to the TrialsNet infrastructures
- Integrating network sensing capabilities in the TrialsNet infrastructures to save energy
- Expanding the TrialsNet infrastructures with O-RAN compliant solutions, including RAN infrastructure, RICs and xApps
- Expanding the TrialsNet infrastructures that host traffic-heavy applications with Content Distribution Networks for improved QoE

3 Description of TrialsNet use cases

This section provides an overview of the 13 use cases that will be implemented in the context of the TrialsNet large-scale trial activities. For each use case a short description and main objectives are reported, main implementation aspects (including equipment and devices) are described, and examples of challenges that could be addressed to enhance the use case are also listed.

UC1 – Smart Crowd Monitoring (Madrid)
Use case description and main objectives
The use case is oriented to deploy several technology solutions that enable to ensure the security and safety of people at highly busy areas whether they are concentrated in one area or moving from one area to another. The use of surveillance cameras and LIDARs together with artificial vision algorithms will be applied to support in the following tasks: crowds prevent free access to the facility, violent activity such as people fighting or riots, vandalism, weapons, suspicious activities such as loitering, or person running and abandoned bags. Fixed and robot-based cameras will send the video streams to the cloud where different AI algorithms will help to detect the above-mentioned risky situations. Moreover, two terrestrial robots will circulate around the environment facilitating vision through its onboard cameras. The communication between the devices deployed at the facility towards its control Software (SW) deployed in the Edge will use the 5G network for the communication.  **Application architecture**
Implementation aspects, equipment, and devices
Two robots' models will be used. The first is Yellow, a robot that will be teleoperated by a trained operator by Boston Dynamics software. The second robot, Kiiro, will move completely autonomously. This robot will send its status and malfunctions to its proprietary software (Robotnik-KMI). The Robots have an onboard payload, this is, a backpack with the electronic components necessary for the security service. It includes cameras, intercom, computers for artificial intelligence, etc. The video and audio streams are sent to the iSOC VMS (Video Management System). Cameras and LIDARs will also be used and will send data to VMS and Gemini software. AMS (Alarm Management Systems) is an advanced alarm management system that allows users to monitor and manage alarms from multiple locations in real-time. The network infrastructure to be deployed for this use case will be a 5G/B5G Ericsson Non-Public Network (NPN).

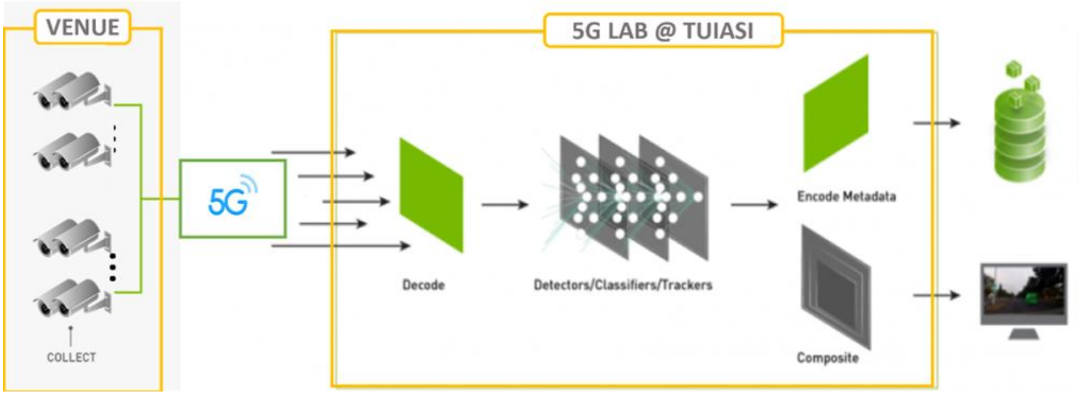
Challenges
• Extend the classes of situations to be detected by the application, including the onset of fires, falling people, lost pets. • Implement prediction algorithms to estimate crowd dynamics. • Monitoring the status of infrastructure (sport venue, public spaces etc). Potentially new sensors to be used connected by the B5G network. • Address pedestrians' safety at street crossings or other areas of interest.

UC1 – Smart Crowd Monitoring (Iasi)

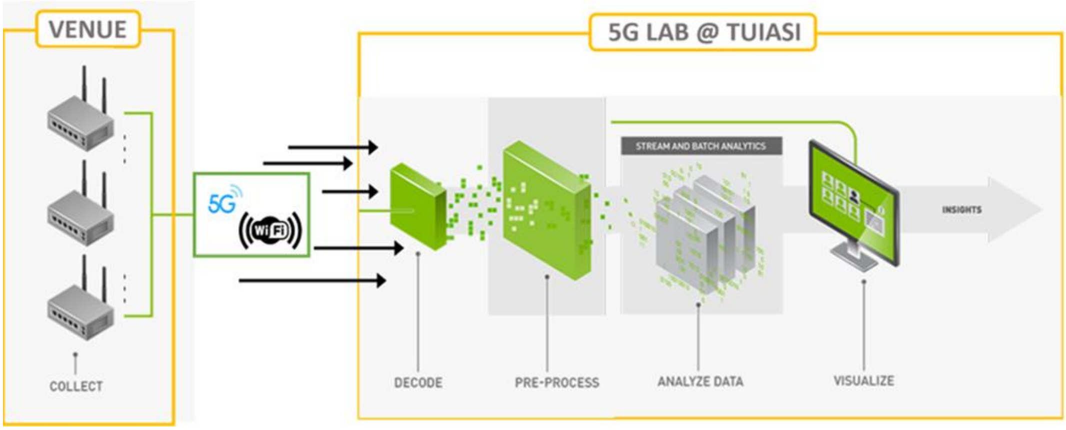
Use case description and main objectives

The use case will aim for improving the protection of people in crowded public spaces. The information provided by the use case will help the authorities to better plan public events and to efficiently react in case abnormal situations occur. Two scenarios will be followed for implementation: i) crowd characterization in terms of people counting, density, and dynamics of large numbers of persons (flow directions, spread, speed) during outdoor public events and ii) detecting special situations during normal traffic scenarios (e.g., presence of various objects such as cars, trucks, motorcycles, etc. in restricted access areas).

Several cameras will be installed on poles already available on the premises, along with Wi-Fi Access Points (AP's). Video streams and information related to the number of Wi-Fi enabled devices present in the region under study will be sent (through the 5G communication infrastructure put in place by ORO) to a server located in the 5G Lab facility within the "Gheorghe Asachi" Technical University of Iasi. Specific (AI-oriented) algorithms will run on the server side, aiming at reliably estimating the number, density, and dynamics of large crowds, along with the identification of special events of interest (e.g., cars entering restricted access areas or people falling on the street). Analytics results provided by the algorithms will be transmitted to the relevant stakeholders and made visible through appropriate interfaces.



Smart crowd-monitoring use case in Iasi with cameras



Smart crowd-monitoring use case in Iasi with Wi-Fi

Implementation aspects, equipment, and devices

The camera-based solution will consider the acquisition and transmission of video streams from the devices on place to a server installed in the “Gheorghe Asachi” Technical University of Iasi. The video stream will subsequently be the subject of video analytics algorithms aiming at providing statistical information to be further sent to interested third parties (city administration, 112 emergency service, etc.). The video processing flow will be based on the (free) DeepStream SDK package provided by Nvidia that integrates continuous acquisition, AI-based algorithms implementation, and decision-making.

Initially the commercial 5G NSA network, integrated with the Iasi Edge-compute facility, will be used for piloting and testing of the developed solutions. In the second stage the RAN will be extended so that the use-case area will be covered with 5G SA connectivity.

5G enabled cameras and Wi-Fi Access Points will be used in order to implement smart crowd management.

Challenges

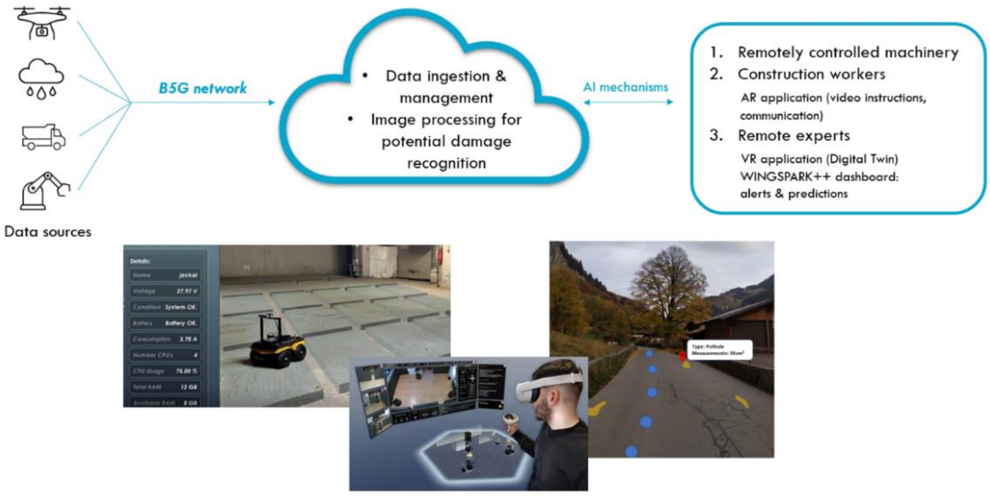
- Extend the classes of situations to be detected by the application, including the onset of fires, falling people, lost pets.
- Implement prediction algorithms to estimate crowd dynamics.
- Monitoring the status of infrastructure (sport venue, public spaces etc). Potentially new sensors to be used connected by the B5G network.
- Address pedestrians' safety at street crossings or other areas of interest.

UC2 – Public Infrastructure Assets Management

Use case description and main objectives

This case will be implemented in two areas within the Greek Cluster: the Athens International Airport and public infrastructure provided by DAEM in the Municipality of Athens. The solution will utilize data from various sources, such as municipal vehicles, weather information, security cameras drones and robots, to assess the structural health of buildings, pavements, and roads. The data collected will allow for more efficient and effective proactive management of public infrastructure assets, leading to cost savings and improved operations and services.

The use of Augmented Reality (AR) will allow construction workers to have an on-site view of buildings or other assets blueprints and receive live bidirectional communications with remote experts who can provide assistance and video instructions. Remotely controlled or unmanned vehicles will be used to reduce risk and accelerate the building process. AI techniques, such as Neural Networks (NN) and Deep Learning (DL), will be used to assess the state of public infrastructure assets, produce alerts and suggestions for city authorities, improve workers’ safety, and schedule predictive maintenance. Digital Twins of public construction sites will be used to validate complicated technical plans without wasting physical resources.



Proactive public infrastructure assets management

Implementation aspects, equipment, and devices
The proposed application design depicted in Figure UC2 involves the deployment of autonomous devices such as drones and robots for real-time monitoring of public infrastructure and critical assets. The devices capture images and other data, which are transmitted over 5G/B5G networks to a central platform for processing and analysis using AI techniques. The WINGSPARK++ enables users to view and analyze the data collected by the devices. Users can access various features such as data visualization, anomaly detection, and predictive analytics. Additionally, there is a Digital Twin module that provides a detailed virtual representation of the airport and its infrastructure. To support the operation of advanced technologies, robots, drones, and other devices, a public 5G network will be used, leveraging its high-speed connectivity, low latency, and wide coverage. In addition, a WINGS owned, private network infrastructure will be utilised, to conduct testing activities, validation, and demonstration, prior to the deployment in the field.
Challenges
• Extension with additional robots and devices to enhance visual surveillance and context awareness. • Development of a system for predictive maintenance of additional public infrastructure assets such as lighting or solar panels (e.g with the use of drones). High-quality cameras and sensors may be used to detect any damage or issues. • AI mechanisms to predict and prevent network failures and security breaches with a consequent improvement of security and trustworthiness of data and traffic flows. • Address the industrial transport and logistics domain with novel 5G applications.

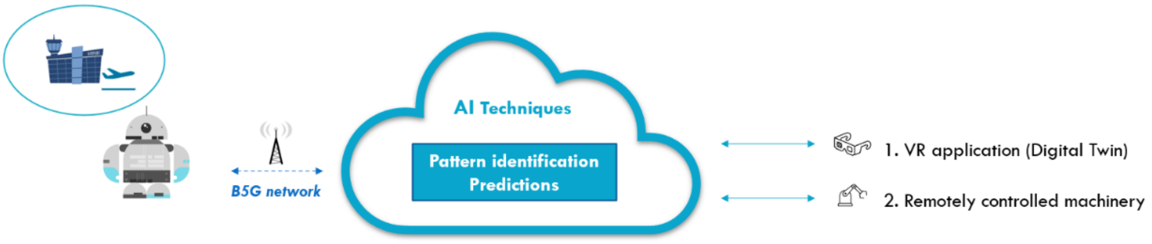
UC3 – Autonomous APRON

Use case description and main objectives

The use case focuses on showcasing how autonomous and smart systems can perform typical ground handling operations at the APRON such as passenger handling, in-flight catering, aircraft fuelling, potable water & aircraft toilet servicing, baggage and cargo handling, and Foreign Object Damage (FOD) prevention. This will be achieved using remotely controlled or unmanned vehicles, such as collaborative robots. The Digital Twins of the APRON will be accessed by VR headsets, enabling a real-time depiction of the physical world inside the virtual one. Digital Twins have a significant impact in optimizing the operations of the staff supervising APRON, ensuring safer and incident-free operations. Operators can intervene remotely and take control of vehicles in critical situations.

Data will be collected from vehicles in the airport APRON and robots using a variety of sensors, including LIDAR and GPS, as well as images and videos from security cameras. Advanced AI techniques will be employed to analyze the data, identify patterns, and make accurate predictions, allowing for continuous monitoring and analysis of airport operations. Based on these analyses, alerts and suggestions will be generated to improve operations and enhance overall airport efficiency.

The integration of a distributed monitoring system will enable the continuous monitoring of unmanned vehicles, collaborative robots, and relevant resources. This system can collect data across the Edge and far Edge resources, and traffic profiling will be conducted to detect network anomalies and predict/prevent failures and security breaches. Automated mitigation procedures will be applied to address any issues that arise.



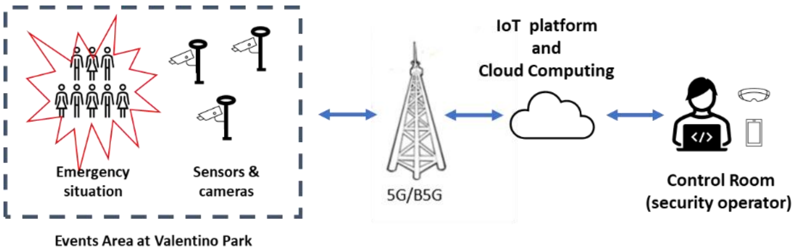
high level architecture

Implementation aspects, equipment, and devices
For the implementation of the use case, the Jackal unmanned ground vehicle will be utilized. Given the robots capabilities, it will be able to perform a range of APRON operations, such as baggage transport and cargo, debris clearing, or other related tasks. Its agile mobility and advanced autonomous capabilities will allow it to navigate the APRON's terrain quickly and efficiently while ensuring the safety of nearby personnel. This will enable the robot to perform more substantial tasks and increase overall operational efficiency. The use of LIDAR sensors will also be explored as part of the project. LIDAR is a remote sensing method that uses laser light to measure distances and generate precise, high-resolution 3D maps of environments. The data collected from cameras and robots will be sent by a public 5G network to the cloud for further analysis. The autonomous APRON application design will also involve the creation of a Digital Twin of the airport APRON area that will provide a virtual representation of the physical environment.
Challenges
• Extension with robots acting as companions for supporting APRON maintenance staff in everyday tasks. This includes the development of components that enable the robots to respond to individual questions and behaviours through a naturalistic dialogue. • Development of IoT solutions for autonomous APRON operations that includes devices embedded in the ground, on the equipment or even on personnel. These IoT devices may use sensors to detect vibrations, pressures, and other environmental factors to ensure safe operations. The system will be designed to alert ground crews and equipment operators of any potential hazards or malfunctions, such as fire or equipment failure. • AI mechanisms to predict and prevent network failures and security breaches with a consequent improvement of security and trustworthiness of data and traffic flows. • Network Monitoring System to simplify and automate the monitoring of unmanned vehicles and collaborative robots from a network point of view, including the automated execution of mitigation procedures in case of detected network issues.

UC4 – Smart Traffic Monitoring
Use case description and main objectives
The use case aims to improve traffic management in a very crowded intersection in Iasi and to detect and prevent potentially dangerous situations. The traffic flow will be monitored to create predictive models and suggest intersection rules adaptation to reduce congestion. Safety will be increased especially by protecting Vulnerable Road Users (VRUs) by creating a traffic digital model, capable of identifying hazardous traffic situations. In addition, an air quality heat map will be created by collecting data from the IoT sensors for Environmental Monitoring. Two additional enablers will be trialed, thereby measuring their impact on the service performance. The first one is zero-touch management, Edge resources and RAN optimizations, which will be tested and validated in trialing activities along with the use case-related scenarios with traffic management and enhancements for VRUs. The second one is related to the framework for designing and developing vertical applications for B5G systems, i.e., Edge Network Applications.

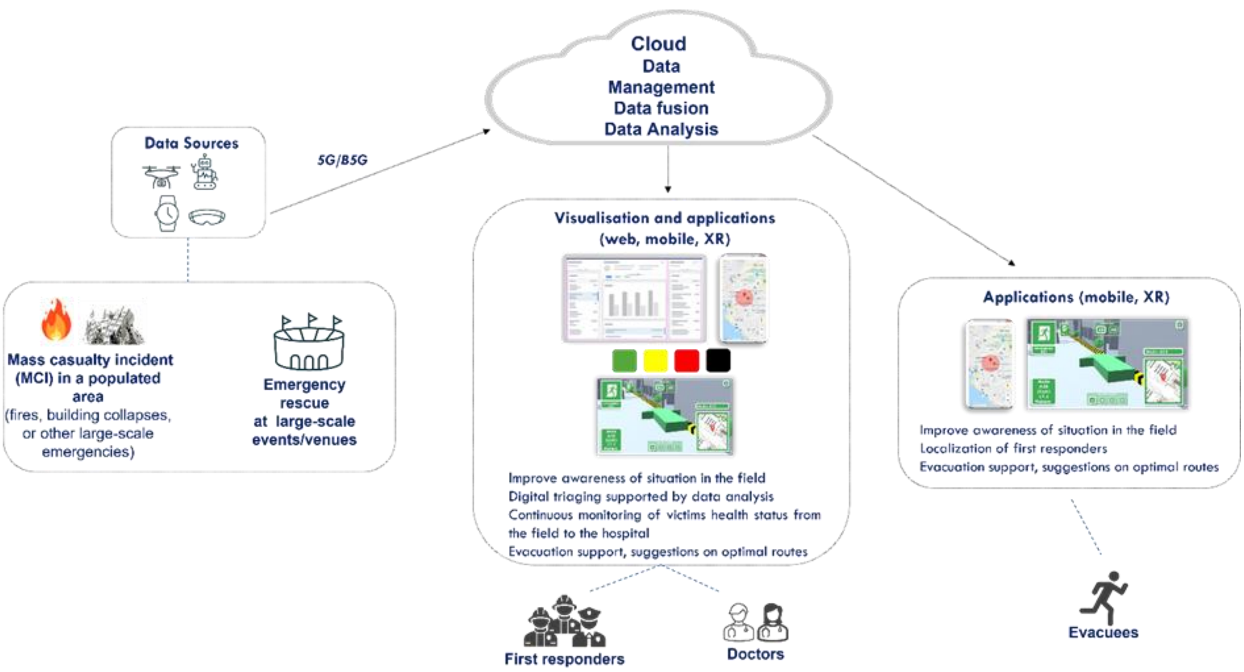
Application design

Implementation aspects, equipment, and devices
The Platform will ingest available data from arrays of Sensors and Cameras deployed through the city, communicating over reliable B5G and Wi-Fi networks and outputting insights and actionable intelligence on Traffic Monitoring. Initially the commercial 5G NSA network, integrated with the Iasi Edge-compute facility, will be used for piloting and testing of the developed solutions. In the second stage the RAN will be extended so that the use-case area will be covered with 5G SA connectivity. The application design presented in Figure UC4 will use and follow the principles of B5G/6G Network Edge Applications (EdgeApps), which are considered as building blocks of Edge application services that boost network performance with data-driven insights for enhancing situation awareness. EdgeApps are designed to be programmable, modular, and configurable, based on specific service requirements (e.g., URLLC for sending prioritized notifications to VRUs, or eMBB for collecting data from distributed sensors, such as cameras). 5G enabled cameras and Wi-Fi Air Quality sensors will be used in order to implement smart traffic management.
Challenges
• Development of tracking and prediction algorithms to predict traffic incidents, advanced traffic analytics and advanced safety applications for VRU protection. • Development of a fused digital traffic model based on different types of sensors (e.g., cameras and radars), using digital traffic model based on more intersections and generate corridor-type traffic analytics. • Use data collected from a drone to enhance the digital traffic model. • Address pedestrians' safety at street crossings. • Address smart city mobility with car sharing, e-bikes and scooters management and optimization applications based on 5G. • Address road users' compliance with the traffic laws with monitoring applications based on 5G. • Address the industrial transport and logistics domain with novel 5G applications.

UC5 – Control Room in Metaverse
Use case description and main objectives
The purpose of this use case is to employ XR, Metaverse and IoT technologies for remote, multi-agency and environment tailored XR training and real-time visualization of behavioral anomalies/movement patterns. UC5 enhances the management of large events and situations of panic by contributing to improved decision-making and reduced intervention times in the event of an emergency on the side of emergency responders. By already knowing elements such as the planimetry of the intervention area and the exact location of people, including those in need of urgent assistance (e.g., injured, wounded), emergency responders can save precious time and increase expediency. The control room will thus enable emergency responders to: • Undertake immersive remote, environment-tailored, inter-agency XR training for mission planning, intervention protocol testing, real-time communications exchange, and mission debriefing. • Access real-time analytics from sensors and cameras-detected data on movement patterns and behavioural anomalies.  **High-level description**

Implementation aspects, equipment, and devices
The 5G connectivity for the use case implementation will be provided by the commercial network deployed by TIM in Torino. Two main platforms will be used to implement the use case control room in metaverse, namely Mozilla Hubs for the implementation of the metaverse component, and Symphony, for the management of IoT devices and transmission of analytics directly into the control room in metaverse which will both be deployed in the Cloud. The main components that will be available locally are 5G solar-powered cameras a set of sensors (Wi-Fi sniffers, mm-waves), smartphones, tablets and VR headsets.
Challenges
• Development of more environment tailored XR training modules scenarios such as panicking crowds, street accidents, fires, floods, and other potential emergencies for the control room in metaverse to provide more context based coaching and real operational solutions. • Development of solutions to provide authorities with a smart-navigation system for smart route identification, avoiding closed roads and traffic jams and to connect with trapped people and redirect them towards safe areas. • Development of a scalable model, that can be applied, after a process involving precision photogrammetry and 3D modelling and rendering, to other venues of the city.

UC6 – Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area
Use case description and main objectives
This use case aims to offer cutting-edge technological solutions created by TrialsNet for the most effective coordination for first-case responders in the context of i) triage and coordination of resources at the scene of mass casualty incidents, which could be building collapses, earthquakes, fires, or other large-scale emergencies, and ii) an emergency evacuation in the context of a crowded sporting or cultural event. This use case has the ambition to demonstrate the viability of a coordinated response in a densely populated area as well as more effective and digitally traceable pre-hospital care by first responders in the event of MCI. Through this use case, cutting-edge (and 5G/B5G/6G) technologies will be shown off in a large-scale field exercise for more effective first responder communication, quicker and more efficient triage, and pre-hospital treatment, and they will be compared to the baseline approach using conventional approaches.



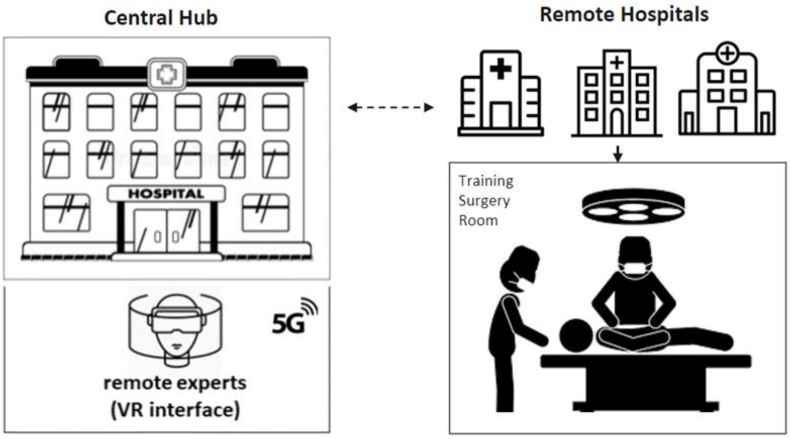
MCI and Emergency Rescue in populated area

Implementation aspects, equipment, and devices
The evacuation part of the use case will be implemented both in Athens and in Spain with the use of a different Fifth generation of mobile communications (5G) infrastructures. In Athens the network will use Non-Standalone architecture (NSA) 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. In Madrid, the network infrastructure to be deployed for the implementation of the emergency evacuation scenario will be a 5G/B5G Ericsson Non-Public Network (NPN). The proposed application design is based on the STARLIT++ platform and involves the deployment of devices such as robots or drones with the appropriate equipment (thermal cameras, sensors, etc.) Devices will also comprise wearable devices for monitoring of vital signs, such as heart rate, oxygen saturation, body temperature, blood pressure, etc. The platform comprises AI powered mechanisms for providing insights on a range of factors.
Challenges
• Address individuals' health tracking with smart devices that leverage the 5G technology (partially covered) • Solutions for dynamic management of network resources including but not linted to solutions supported by flex topologies and orchestration mechanisms over the network continuum to ensure 100% reliability of communications in the case of emergencies.

UC7 – Remote Proctoring

Use case description and main objectives

This use case aims to support remote proctoring activities in the field of interventional cardiology, offering innovative solutions based on smart tools for telepresence in the surgical field to connect expert proctors and remote hospitals. UC7 will be deployed by connecting two sites at a geographical distance, via a dedicated Virtual Private Network (VPN), and equipping with tailored 5G coverage the site where the proctor is located. This allows increasing the number of remote hospitals that can leverage the support of remote experts and improve the entire eHealth workflow of interventional cardiology.



Remote proctoring use case concept.

Implementation aspects, equipment, and devices

The RAN, which is based on Ericsson systems, consists of two main components. The first component is the baseband unit, the second component is an indoor radio antenna that covers the experimental area. Part of the CN is hosted in Pisa and part in Turin. More specifically: Unified Data Management (UDM) module is hosted in the TIM Innovation site located in Turin and UPF module is hosted in Pisa. Turin and Pisa are connected through a VPN which is active between two specific packet gateways. The overall 5G infrastructure is supported by the commercial Ericsson Orchestrator, located at TIM's premises in Turin.

In the UC7, two operational macro-modules will be implemented, one operating in a remote hospital and the second one in the central hospital. The macro-module in the remote hospital for surgery operating room will be constituted by i) a clinical-certified commercial telepresence system, constituted by acquisition tools and connection hub installed in the surgical room, and ii) a local wired LAN provided by the hospital IT service and related gateway. The acquisition tools of the telepresence system will be formed by smart glasses for the same view as the surgeon, a 360-degree camera for the view of the operating room, and a hub for video streaming of clinical monitors to obtain complete monitoring of surgical operations. The macro-module in central hospital for remote expert will be composed by i) a telepresence platform, i.e., a workstation with High Definition (HD) monitors and control interfaces, ii) a VR headset for an immersive telepresence experience, and iii) a 5G indoor network infrastructure.

Challenges

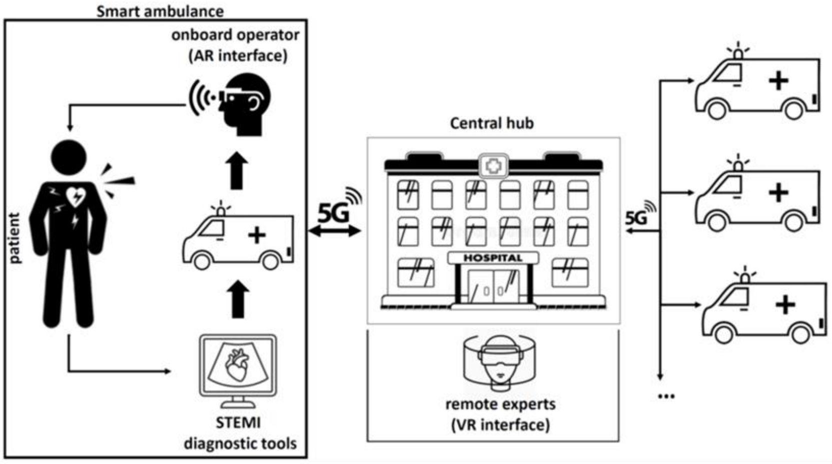
- Intervention radiology use case. The basic idea is to constantly monitor the absorption of radiation due to diagnostic investigations during a surgical operation, both on the patient and on the operators and, consequently, signal excessive radiation and act accordingly in an immediate manner.
- Blockchain technology could potentially be beneficial for UC7. Here are some possible ways in which blockchain could be utilized:
    - Data Security: Blockchain is a very secure technology that can help ensure data is not tampered with or compromised. This could be useful for ensuring the integrity of medical data and patient information.
    - Traceability: Blockchain can provide a detailed audit trail of all transactions, which can be useful for monitoring proctor activities and ensuring accountability.
    - Data Sharing: Blockchain can facilitate secure data sharing across different parties. This could be useful for sharing information between the remote hospital and the proctor.

UC8 – Smart Ambulance

Use case description and main objectives

This use case will propose a 5G-connected smart ambulance operating outdoor in mobility. The use case will develop an infrastructure that will enable ambulances (or small emergency centres) to share diagnostic information with the main centre. The proposed infrastructure will be designed and implemented to equip the ambulance with i) new audio/video communication tools (Augmented Reality – AR - and virtual reality - VR - headsets) between operators on the ambulance and supporting experts in the hospital, ii) diagnostic tools for cardiological pathology and ii) devices to guarantee an efficient and fast 5G connection in remote locations and mobility conditions, including emergency high-speed travel through congested urban areas.

This UC will demonstrate the possibility of sending real-time information to local operators to maximize early intervention and sending information and large data batches (like real-time video and 3D imaging) to a central hub with low latency.



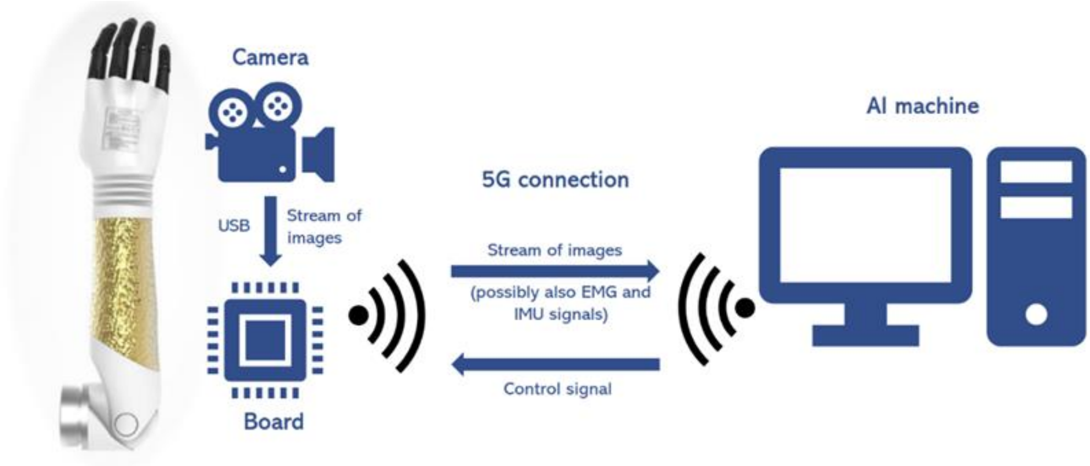
Smart ambulance use case concept

Implementation aspects, equipment, and devices
UC8 trial is served by a 5G network originated by a micro cell covering an outdoor area located in the CNR campus in Pisa. This area is in a vicinity of the "Central Hospital Hub" where the remote proctoring trial (UC7) is deployed. Thus, 5G infrastructure serving UC8 shares most of its components with the infrastructure serving UC7. The main difference is related to the use of an outdoor antenna (micro cell) to provide coverage in the outdoor area where the smart ambulance is planned to operate. The UC8, two operational macro-modules will be implemented, one in the CNR campus area in Pisa and the second one in the hospital in Massa. The macro-module in Pisa will be constituted by: i) an ambulance, ii) commercial echocardiography with real-time stream video functionality, iii) a 5G modem, iv) a commercial AR headset, and v) a 5G-based outdoor network infrastructure. The macro-module in Massa will be constituted by: i) a commercial VR headset, ii) a workstation, and iii) a local wired LAN and related gateway. The remote expert cardiologist in the hospital in Massa will be equipped with the VR headset.
Challenges
• There are no challenges identified.

UC9 – Adaptive Control of Hannes Prosthetic device through Mobile Network

Use case description and main objectives

This use case will focus on designing advanced control capabilities for prostheses, using Artificial Intelligence (AI) methods deployed on the Hannes arm. The main aim of UC9 is to improve the usability of prosthetic hand, leveraging on radio 5G connectivity to provide sufficient computing power to deploy AI methods on Hannes with high reliability and minimal latency.



Architecture of the application for the Use Case 9.

Implementation aspects, equipment, and devices

The Adaptive Control of Hannes Prosthetic trial will be served by a 5G network covering an indoor area located in the CNR campus in Pisa and it is connected via a 5G dongle, which uses a SIM card provided by TIM to ensure access to the network.

From the application point of view, this Use case will rely on infrastructure and functionalities solutions from two groups of the Istituto Italiano di Tecnologia, namely, the Rehab Technology (Rehab) laboratory and the Humanoid Sensing and Perception (HSP) research line. The application that will be developed during the project will require the implementation and integration of both hardware (HW) and software (SW) components.

The full list of components is reported in D4.1, the main are the Hannes arm, an electronic board mounted on Hannes, an embedded video camera placed either into the palm or into the wrist of Hannes and SW modules for signal pre-processing and the control system.

Challenges

- The standard assessment techniques (i.e., Minnesota Manual Dexterity Test - MMDT, Southampton Hand Assessment Procedure – SHAP and Box and Block Test - BBT) are sufficient to evaluate the system performances. However, an in-depth investigation of the system should also include usability, efficacy and embodiment, using the real system, but also virtual reality-based strategies. The latter could improve the evaluation of a wider range of functionalities for multi degrees of freedom prosthetic devices, like Hannes. These techniques can be used during the real clinical trials as an additional source of information, providing more accurate and specific metrics that could not be differently retrieved. Moreover, these novel virtual environments can help training users to drive such prostheses, helping to achieve a higher level of user acceptance.

UC10 – Immersive fan engagement

Use case description and main objectives

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).

Example of camera selection interface.

Implementation aspects, equipment, and devices

The Immersive Fan Engagement use case will be implemented in the Spanish cluster´s Madrid site. This task will include all activities related to the design (equipment selection), and deployment (venue identification and connectivity over a 5G network), of the permanent installation of cameras and equipment in a sports venue, in order to provide an immersive experience to fans in the venue or in a remote location.

Challenges

- To provide every sports fan in the venue the best experience possible, getting live feeds from the venues is crucial. Therefore, it is necessary to place immersive cameras around the venue space, uploading the streaming video to Edge computing video server with the aid of existing connectivity technologies. Currently available fiber solutions can address this issue, but this restricts the placement of cameras to set sites along existing fiber networks. New possibilities are made possible by wireless connectivity, but this requires significant upload bandwidth (between 50 and 100 Mbps per camera), which is not provided by the existing 5G implementations. New technologies are needed to acquire these two innovative capabilities – wireless immersive camera uploading and high-density downloads for spectators inside the venue. Both features go beyond what is currently possible with 5G network. More particularly, it calls for:

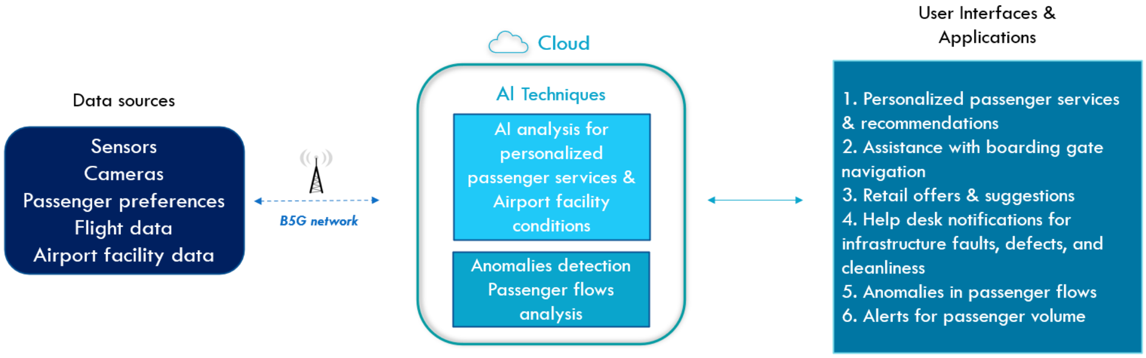
- High-quality camera streams are uploaded around the playing field at a rate of 20 to 100 Mbps per camera.
- The installation of terminals inside the venue for the download of optimal video (15-20-30 Mbps per user, 500-5,000-50,000 users).

- Additionally, edge computing infrastructure is required to process feeds as quickly as possible and redistribute them to both local and remote connected spectators in the stadium.

UC11 – Service Robots for Enhanced Passengers' Experience

Use case description and main objectives

This use case aims at improving passengers' comfort at Athens International Airport, particularly during congested situations. With the use of 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).



High level architecture implementation

Implementation aspects, equipment, and devices

The application design of this use case involves various software modules and functionalities, including AI-powered algorithms, 5G/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 GUI of the solution 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 LoCoBot WX250 will be used for the implementation of the use case. 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. The solution will be supported by a public 5G network and a WINGS owned private network infrastructure.

Challenges

- Extension of the smart services offered to passengers with the use of technology to even more areas within the terminal such as the security screening areas and the passport control areas, but also outside the terminal such as the parking areas in order for airports to achieve a seamless passenger experience.

- Integration with services offered from airport's business partners such as the airlines and/or the handlers in order for travellers to complete the entire airport journey without experiencing delays, disruption or confusion.
- Use of technology capabilities in order for airports to capture more data and leverage of all information gathered in combination with the information available from the community in order to improve in areas such as the Terminal environment i.e. air quality and unexpected situations i.e. terrorist attacks.
- Volumetric holography to improve security and facilitate operations and decisions for enhance passengers experience at the airport. Passengers can walk around the holograms, getting an unparalleled sense of presence. Volumetric video captures will bring human beings into digital, capturing full 3D content that can be seen from any perspective and moves as in reality. The volumetric holograms will communicate the information needed and can perform similar tasks to robots.

UC12 – City Park in the Metaverse

Use case description and main objectives

This use case develops around the social metaverse concept, centered 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.

Example of metaverse of Borgo Medievale

Implementation aspects, equipment, and devices

Multi-player mobile game sandbox applications will be developed with layers of interactive game content onto a virtual space. The 5G connectivity for the use case implementation will be provided by the commercial network deployed by TIM in Torino, with the applications running on the Cloud platform. The main components available locally are a set of sensors (Wi-Fi sniffers, mm-waves), two metaverse platforms (Mozilla Hubs and TIM XR) enabling co-presence, which are connected to different devices (smartphones, tablets and VR headsets).

Challenges

- Integration of innovative educational/gaming Apps/layers into a developed metaverse infrastructure, combined with VR/AR technology, to enhance the visitors experience the Borgo Medievale and Valentino Park, allowing visitors to learn about the history, architecture, and cultural significance of the sites in a fun and engaging manner.

UC13 – Extended XR Museum Experience (Turin)
Use case description and main objectives
The goal of this use case is to create a modular metaverse platform for visiting museums and cultural sites in Turin through portable devices. The use case will entail creating new interactive experiences in collaboration with cultural institutions and will exploit 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.  **Virtual Reality visit at Museo del Risorgimento in Turin**
Implementation aspects, equipment, and devices
The application architecture in Turin is composed by three blocks: the client-side code is built on A-Frame that communicates with the server using Web-Socket and WebRTC protocols; the server-side code is deployed on a Cloud platform; the module-side includes several engines for e.g., 3D rendering, audio, room, avatars, video streaming. The 5G connectivity for the use case implementation will be provided by the commercial network deployed by TIM in Torino. The main components that will be available locally are a set of sensors (Wi-Fi sniffers, mm-waves), two metaverse platforms (Mozilla Hubs and TIM XR) enabling co-presence connected to different devices (smartphones, tablets and VR headsets) with processing in the Cloud.
Challenges
• Development of virtual AI-powered guide(s) within the metaverse that can enhance the visitor experience at museums, both for those physically present and those accessing the museums remotely, with trials at Palazzo Madama and/or Galleria d'Arte Moderna in Turin. These AI-driven guides will offer personalized tours by providing real-time response regarding detailed information about the artworks, historical artifacts, and exhibits. This also applies to the Greek Cluster, as the implementation in additional museums/historical places will be investigated. • Providing new and innovative immersive experiences (e.g., interactive walls, animations, gaming, holograms) in selected museum(s) in Torino, such as Museo del Risorgimento, Polo del 900, Museo dell'Auto) to be integrated in the cultural offer of the city online and in metaverse. This could be also investigated for the Greek Cluster. • Supporting innovative artistic scenarios, online and in the metaverse, combining different disciplines such as music, arts, dance, theatre, marching band, which will take place simultaneously at different city locations both indoor and outdoor, and which are enabled by the low latency and high bitrate of the 5G technology. • Digital signage applications for tourism that take advantage of the 5G technology.

UC13 – Extended XR Museum Experience (Athens)
Use case description and main objectives
In the Athens site, AR-based technologies will be used to leverage on content that elaborates on culture/historic aspects. In addition, there will be scope for optimizing the itineraries, to enhance the user experience (and safety when needed). 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.  **Model integration in the AR application**
Implementation aspects, equipment, and devices
The application in Greek cluster 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. The AR/VR application that will be developed follows a typical Unity application architecture. To allow the application to communicate with the cloud XR server, the public 5G network and WINGS testbed will be utilized.
Challenges
• Extend the cultural proposal provided by the use case with new historical monuments and touristic attractions in Athens.

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References

[1] TrialsNet Deliverable D3.1, "Use Cases definition for Infrastructure, Transportation, and Security & Safety (ITSS) domain", 30 April 2023
[2] TrialsNet Deliverable D4.1, "Use Cases definition for eHealth and Emergency (eHE) domain", 30 April 2023
[3] TrialsNet Deliverable D5.1, "Use Cases definition for Culture, Tourism and Entertainment (CTE) domain", 30 April 2023
[4] TrialsNet Deliverable D2.1, "Preliminary design aspects for Platforms and Networks solutions", 30 June 2023
[5] https://trialsnet.eu