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TrialsNet: TRials supported by Smart Networks beyond 5G

Deliverable D4.1

Use Cases definition for eHealth and Emergency (eHE) domain

Project Details

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

Deliverable Details

Deliverable WP:	WP4
Deliverable Task:	T4.1, T4.2, T4.3, T4.4, T4.5
Deliverable Identifier:	TrialsNet D4.1
Deliverable Title:	Use Cases definition for eHealth and Emergency (eHE) domain
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Contractual Date of Delivery:	30/04/2023
Submission Date:	28/04/2023
Dissemination Level:	PU
Status:	Final
Version:	1.0
File Name:	2023-04-30_TrialsNet_D4.1_Use Cases definition for eHealth and Emergency (eHE) domain.doc

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Deliverable History

Version	Date	Modification
V1.0	*28/04/2023*	*Final version, submitted to EC through SyGMa*

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List of Acronyms and Abbreviations

Acronym	*Description*
ACS	Acute Coronary Syndromes
AI	Artificial Intelligence
AR	Augmented Reality
B5G	Beyond 5G mobile network
CERTH	Center for Research and Technology Hellas
CN	Core Network
CNN	Convolutional Neural Network
CNR	Consiglio Nazionale delle Ricerche
CP	Control Plane
CPE	Customer Premises Equipment
CROSSM	Crossmedia Belgique
CS	Control Session
DAEM	Dimos Athinaion Epicheirisi Michanografisis
DoF	Degrees of Freedom
DL	Deep Learning
E2E	End-to-end
eHE	eHealth and Emergency
EMG	Electromyography
EMS	Emergency Medical Services
EPC	Evolved Packet Core
EPG	Evolved Packet Gateway
ES	Experimental Session
FTGM	Fondazione Toscana Gabriele Monasterio
5G	Fifth generation of mobile communications
GPS	Global Positioning System
HD	High Definition
HSS	Home Subscriber Server
HW	Hardware
IIT	Fondazione Istituto Italiano Di Tecnologia
IMU	Inertial Measurement Unit
KPI	Key Performance Indicator
KVI	Key Value Indicator
LE	Law Enforcement
MCI	Mass Casualty Incident
ML	Machine Learning
MS	Milestone
NN	Neural Network
NSA	Non-Standalone Architecture
PCI	Percutaneous Coronary Intervention
QoS	Quality of Service
ORO	Orange Romania Sa
PNI-NPN	Public Network Integrated Non-Public Network
RAN	Radio Access Network
SA	Standalone Architecture
SNPN	Stand-alone Non-Public Network
STEMI	ST-segment elevation myocardial infarction
TEI	Ericsson Telecomunicazioni Spa
TIM	Telecom Italia Spa
UI	User Interface
UC	Use Case
UC3M	Universidad Carlos III de Madrid
UDM	Unified Data Management
UP	User Plane
UPF	User Plane Function
VPN	Virtual Private Network
VR	Virtual Reality
WINGS	Wings Ict Solutions
WP	Work Package
XR	Extended Reality
USB	Universal Serial Bus

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Executive Summary

Deliverable D4.1 of TrialsNet project [1] provides baseline information for use cases (UCs) of Work Package (WP) 4 related to the eHealth and Emergency domains that would be enabled by the beyond-5G mobile network (B5G) technology. It contains key information for each use case regarding their definitions, implementation, technical requirements, and trials.

The activities of WP4 will be carried out in the overall project framework described in D1.1 "Management Handbook" [2] and will mainly address the objectives 1 and 3 that have been defined for the project. In particular, objective 1 is to demonstrate the large-scale trialling of the B5G technology specifically devoted to eHealth and Emergency domains, by supporting the B5G applications in large-scale environments (e.g. hospitals) and bringing novel applications (e.g. Remote Proctoring and Smart Ambulance). The objective 3 is to introduce societal benefits in eHealth and Emergency areas through the development of innovative B5G/6G applications.

The use cases related to eHealth and Emergency (eHE) domain that will be implemented in the context of WP4 are briefly described hereafter:

Use Case 6 "Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area" (Athens/Madrid): The UC6 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. 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.

Use Case 7 "Remote Proctoring" (Pisa): 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.

Use Case 8 "Smart Ambulance" (Pisa): 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.

Use Case 9 "Adaptive Control of Hannes Prosthetic Device" (Pisa): This use case will focus on designing advanced control capabilities for prostheses using Artificial Intelligence (AI) methods and deployment on the Hannes arm. The main aim of UC9 is to improve the user experience, leveraging radio 5G connectivity to provide sufficient computing power to the prosthesis to deploy AI methods with high reliability and minimal latency.

WP4 will provide the requirements arising from the use case definition to WP2 "Platforms & Network Solutions" to properly design the platforms and network solutions. The validation activities of WP4 are going to be performed in connection with WP6 "Validation & Dissemination". The WP4 activities will also be related to

the implementation of the additional use cases in the eHealth and Emergency domain by WP7 “Open Call and support to third parties”. Ethics aspects of WP4 will be considered in interaction with WP8 “Ethics requirements” including the input already provided to the deliverables D8.1 “H - Requirement No. 1” [3] and in line with D1.2 “Ethics Assessment Plan” [4].

It should be highlighted that the use cases defined in this deliverable might be further refined and integrated according to the progress of the activities (e.g. first implementations, pre-trial phases, deployed infrastructures, etc.) and eventual input provided by the other WPs.

1 Introduction

The WP4 of TrialsNet project is focused on the design and implementation of the UCs in the domain of eHE for the Greek, Spanish, and Italian clusters. In more details, the specific objectives addressed by WP4 are i) to implement large-scale trials of the B5G technologies in the eHE domain and ii) to introduce societal benefits in eHE areas, thanks to B5G/6G applications.

The WP4 is structured into four tasks (T4.1-T4.4) specifically related to different use cases. This document interacts with D8.1 for the possible Ethics implications and with D1.2 that provides the procedures to be followed for the protection of the ethical rights of the users participating or providing real data during the trials.

This first deliverable of WP4, D4.1, aims at detailing use case definitions for eHealth and Emergency domain. D4.1 can be considered as a preliminary document related to UC configuration, infrastructure and application and trial execution. Some information reported in the present version of D4.1 may be adapted or integrated during the project lifetime, considering the evolution of needs of the project and requirements from other WPs. The structure of this document is reported below.

Section 2 describes the relevance of eHE in the context of SNS (Smart Networks and Services) and beyond 5G systems as well as from the societal point of view.

Section 3 defines and describes the four use cases of WP4 and related trials from a high-level perspective identifying the context, the targeted users, the implementation aspects and the infrastructure components and functionalities. This section introduces the design aspects related to the development and implementation of the trial that will be used in each case. Finally, this section describes the initial assumptions about the trial description, parameters, and procedure are reported.

Section 4 details the technical requirements and the evaluation methodologies that will be addressed by each use case of WP4. The details include functional requirements and non-functional requirements (i.e., performance, scalability, and security). In this section, the Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) for each use case are defined.

Section 5 describes the time plan for each use case by defining the main activities and specific milestones (MS) related to their implementation phases.

A final section (Section 6) of conclusions highlights the main achieved results of the activities related to D4.1. This section also introduces the next steps related to the use cases implementation including the interactions with the other WPs of the project.

2 eHealth and Emergency (eHE) domain overview

eHealth is certainly one of the most promising fields in which new technologies will play a fundamental role. Impacts are expected to be essentially in three main areas reported hereafter:

- **Data transmission:** increasingly performing technologies in terms of bitrate, latency, security, and resilience enable previously unfeasible use cases.
- **Peripheral devices:** These are innovative viewers for augmented reality/virtual reality (AR/VR) or ever more innovative prostheses.
- **Software solutions:** mainly based on innovative techniques of machine learning (ML) and AI.

2.1 SNS and B5G system benefits for eHE domain

In the following sections it is reported how SNS and future network technologies can benefit eHE domain and that will be deployed as part of the trials performed by TrialsNet.

2.1.1 eHealth

Telemedicine: SNS and 5G/B5G systems consisting in high-speed, low-latency connections allow for medical images and other data to be transmitted quickly and accurately. So, it is possible to transmit data about a patient's health to healthcare professionals in real time, even in mobility situations, permitting pre-hospital identification of the correct diagnosis and management strategy in chest pain patients may lead to a better disease outcome.

Remote Monitoring: SNS and 5G/B5G systems, together with AR/VR and telepresence technologies can represent a revolution in remote monitoring and proctoring in the interventional cardiology sector. In this way it may be possible, even in areas not equipped with departments for certain medical specializations, to be assisted by the specialised medical doctors', especially in the surgical field.

Control of Prothesis: A smart prosthesis is an application product that combines cognitive imaging and control technology, enabled by radio connectivity to allow a prosthetic device control system with AI technologies for reducing the need for explicit control by the user and thus their cognitive load for driving it. This type of prosthesis control makes the movements of the wearer more natural.

2.1.2 Emergency

SNS and 5G/B5G systems open a new possibility to mass causality incidents. In fact, currently, emergency services in case of accidents are based on predefined Emergency Action Plans, lacking the flexibility to address different dynamic plans and guidelines. Moreover, even though a massive number of sensors and connected devices such as smartphones, tablets, wearables, etc., are available on market, they are not currently used in emergencies. Where demand for medical assistance and resources is greater than that available, the priority must be to identify those who are most in need of medical attention. Strengthening health system preparedness for MCI has become a priority for the European Strategy, therefore preparedness, management, and minimisation of the consequences of MCI will be investigated in this use case. Similar concepts apply when rescuing a patient in a densely crowded area, where it is paramount to achieve very fast reaction times which can improve substantially the survival rate in these contexts.

2.2 TrialsNet cluster overview

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

2.2.1 Greek cluster

In Athens, the area of Technopolis has been selected. The Technopolis of the city of Athens (Figure 1 and Figure 2) hosts large cultural events in both its opened and closed area spaces with a large audience. Dimos Athinaion

Epicheirisi Michanografisis (DAEM) is the IT Company of the Municipality of Athens aimed at providing e-Governance systems to the city. As it is operating as a body of the city, DAEM's involvement in the project ensures the smooth collaboration with other municipal agencies that will be engaged for some use-cases, e.g., the agency for roads maintenance, the agency for buildings maintenance, the Technopolis of Athens complex etc. Hence, DAEM will provide all necessary public infrastructures for the trials.

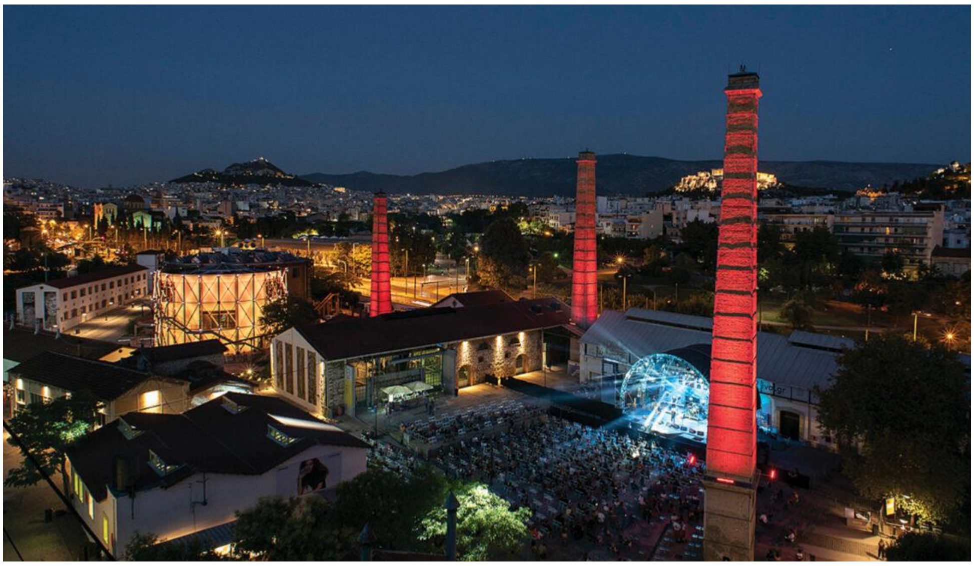

Figure 1. The Technopolis of the city of Athens.

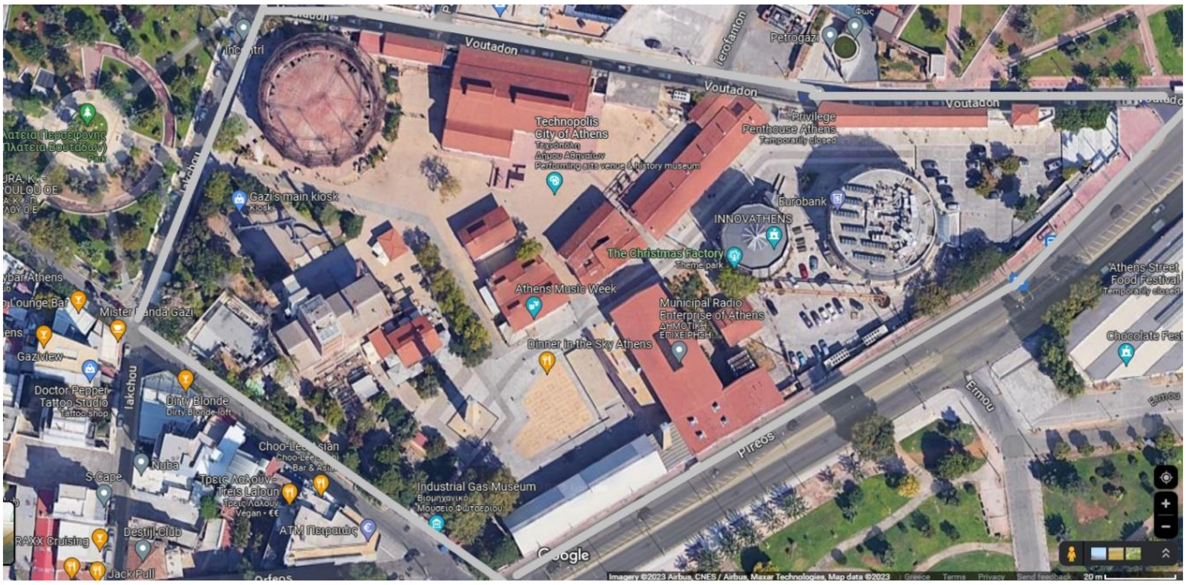

Figure 2. Aerial map of the Technopolis area.

2.2.2 Spanish cluster

The use case will be performed in a context of a large-scale event in a sports venue in which applications provide the users with personalized suggestions aiming to evacuate the area as rapidly as possible while ensuring that the people are safely guided out of the area. As already reported for D3.1 [5] and D5.1 [6], different sports venues in Madrid are being studied as locations for TrialsNet trials activities. Medium sized venues like Basketball arenas such as Wizink Center (Figure 3) or Magariños; tennis courts such as La Caja Mágica; or large venues like Football stadiums such as Bernabeu or Civitas Metropolitano will be prospected for selection as possible options. Small-medium scale venues would fit better for the trial proposed in this project as an affordable field of trial.

Figure 3. Wizink Center in Madrid. (Source: Madrid Turismo).

2.2.3 Italian cluster

For the implementation of the eHealth use cases in Pisa site, an end-to-end (E2E) infrastructure composed of mobile radio access (including 5G indoor and outdoor coverages), transport, and cloud networks will be deployed to enable communications between two hospitals located in Pisa and Massa. In details, the use cases will be implemented at the Consiglio Nazionale delle Ricerche (CNR) campus area in Pisa and at “Ospedale del Cuore G. Pasquinucci” hospital of Fondazione Toscana “Gabiele Monasterio” (FTGM) in Massa (see Figure 4 and Figure 5).

Figure 4. The CNR campus area in Pisa.

Figure 5. The hospital “Ospedale del Cuore G. Pasquinucci” in Massa.

3 Use cases detailed description

This section describes the different use cases of WP4, defining the objectives, actors, and activities of each use case and related trial. The section also reports the benefits and expected results that the proposed solutions can offer to end users in each of the use cases.

3.1 UC6: Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area (Athens/Madrid)

The Mass Casualty Incident (MCI) provides strategies for the basic approach to MCI response procedures, regardless of the type of threat. Safety resources should be built to handle MCI scenarios. Local fire/Emergency Medical Services (EMS) and Law Enforcement (LE) must have common tactics, communication capabilities, and terminology to have seamless, effective operations. The UC6 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) 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. Triage is of utmost importance in disasters and MCI, as it refers to contingency planning, the actions to be taken and the guidelines to be followed for the effective management of emergencies.

3.1.1 Use case definition

The goal of this use case is to provide innovative solutions developed by the project for the most effective coordination operation of first responders (medical personnel, police, rescuers, etc.) in the context of i) triage and coordination of resources at the scene of MCI due to incidents such as earthquakes, fires, building collapses, and ii) emergency evacuation in a large, crowded venue, such as in the case of a sports event.

This use case aims to provide more efficient and digitally traceable triage procedures and pre-hospital treatment by first responders in case of MCI, as well as showcase the feasibility of a coordinated response in a densely crowded location during which the collected data will be utilized to derive insights on for emergency crews to provide an optimal evacuation plan. This plan will include, with priority, optimal routes to the intervention targets (victims of the disasters), considering any obstacles or inaccessible sections that have been previously identified. Through this use case, innovative (also 6G-enabled) technologies will be demonstrated in a large-scale field exercise for more efficient communication between first responders and faster and more effective triage and pre-hospital treatment, and they will be compared to the baseline approach using traditional approaches/procedures.

Initially various data from the field are acquired via available data sources (e.g., video streaming or image capturing from cameras on robots or drones). These data are analyzed to provide insights to first responders on the situation in the field (estimated number of victims, support for primary triaging, estimated location of victims, initial estimation on optimal evacuation routes). Information is displayed to first responders via an appropriate dashboard, while suitable XR applications will also be provided (especially for the evacuation case). For the MCI part, once responders have arrived in the field and have come in contact with victims, they can equip victims with wearable devices to collect vital signs. This information will be used, along with the assessment from the first responders, for the secondary triaging and the continuous monitoring of the health status of victims. Data from the scene and health data are transmitted and displayed continuously to remote first responders and medical experts via the dashboard (displaying the appropriate type of information to each user category). The dashboard is implemented as a Web-based User Interface (UI) and thus, is accessible through mobile devices as well as laptops, desktops, and tablets. In the event of observed abnormalities either in the environment of the incident or in the vital sign values collected, notifications are sent to first responders or medical experts accordingly (remote and in the field) and alarms are raised to trigger the necessary actions e.g., update the triaging assessment or update of the evacuation routes. Notifications/alarms are also raised in case something is not yet abnormal, but the data analysis of recorded values show a trend towards a potential problematic situation (e.g., increasing blood pressure which has not yet reached a certain threshold, but may still be worrying). For the MCI case, all data accompanies a victim from the field to the hospital, at which point the system can provide doctors with insights for the final triaging and on the best hospital treatment. In the evacuation scenario, an XR application will also be provided for evacuees. This application will provide support on optimal evacuation routes to be followed. Also, in the evacuation use case the aim is to enhance the traceability of all the actions taken (Figure 6).

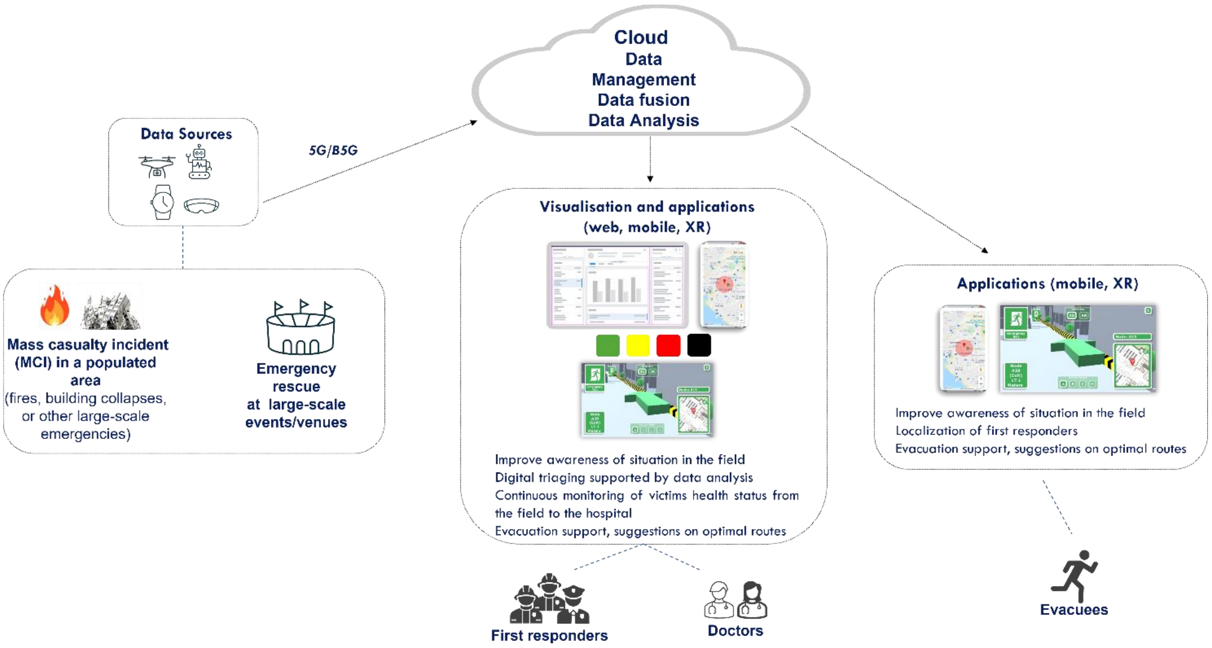

Figure 6. MCI and Emergency Rescue in populated area.

3.1.2 Implementation aspects

3.1.2.1 Application design

The proposed application design is based on the STARLIT++ platform (an enhancement of the STARLIT platform [7]) and involves the deployment of devices such as robots or drones with the appropriate equipment (thermal cameras, sensors, etc.) for real-time monitoring of a serious incident e.g., a fire, collapsed buildings which can cause injuries, or casualties during a cultural event/concert. 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, as already introduced, 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, etc.).

Figure 7. UC6 application design.

As shown in Figure 7, the STARLIT++ platform is designed for providing the users-responders with visualization and monitoring of the collected data, insights, notifications, and alerts. In the evacuation case, applications are also available for evacuees.

To implement the use case, the STARLIT++ multi-layered architecture will be utilised. This will consist of four main modules:

- **Data sources:** This module consists of various devices such as cameras, drones, and robots in order to collect the data for further analysis.
- **Data Collection and Analytics:** This module will be responsible for collecting data from the sources, (cameras, drones, and robots). The data will be processed and stored in a centralized database for analysis.
- **AI Analytics and Alerting Module:** This module will use AI techniques such as Neural Networks (NN) and Deep Learning (DL) to assess the state of the incident and the victims and produce alerts. The AI models will be trained with raw data and will also provide a real-time dashboard for monitoring the situation in order to first responder act quickly.
- **Dashboard and AR/VR Applications** for visualization.

The STARLIT++ platform is cloud-based and modular. So, in Madrid only the parts relevant to the evacuation scenario will need to be made available and configured accordingly to support evacuation at the Madrid venue/location.

3.1.2.2 Equipment and devices

The equipment, the technologies and the devices are required to develop and test the system for this use case is composed of the list of the devices reported in Table 1.

Table 1. Equipment and devices for UC6.

Equipment	Item	Description	Quantity
 	Tarot Quadcopter Custom Drone + PixHawk controller [9]	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.	1
	Thermal cameras [10]	Optical and thermal cameras can also be added to capture high altitude shots, detect heat signatures. Thermal cameras can detect heat signatures, which can be used to locate people who may be trapped or injured. Thermal imaging can also help identify hotspots that could potentially cause further damage or fires. The drone can transmit the data captured by its cameras and sensors to local MECs or cloud to be analysed by AI/ML algorithms that can help identify patterns and anomalies that could indicate the presence of people in the disaster area.	1

	Clearpath Robotics Jackal Unmanned Ground Vehicle [11]	This robot is a small, agile, and fast field robotics research platform that comes with an onboard computer, GPS, and Inertial Measurement Unit (IMU) fully integrated with ROS for out-of-the-box autonomous capability. The Jackal robot is plug-and-play compatible with a wide range of robot accessories, making it an excellent choice for expanding research and development quickly.	1
	Quectel RM500Q-AE[12]	For enabling wireless connectivity for robots, the Quectel RM500Q-AE will be used. This module is a 5G cellular module designed for high-speed data transmission in various industrial applications, enabling download speeds of up to 2.5 Gbps and upload speeds of up to 660 Mbps and supporting various cellular network standards, including 5G NR, LTE-A Pro, LTE-A, and WCDMA, allowing it to operate in different network environments. In addition, the module features built-in GNSS (Global Navigation Satellite System) support, including Global Positioning System (GPS), GLONASS, BeiDou, and Galileo. This enables the module to provide accurate positioning and timing information. The module is designed to withstand harsh environments, with a wide operating temperature range of -40°C to +85°C and high resistance to shock and vibration and suitable for remote healthcare, and video surveillance, among others. By streaming and sending high quality video and other information of the sensors the AI/ML algorithms and models can analyse the data captured and help identify patterns or even anomalies that could indicate the presence of people in the disaster areas, also sending information about their exact position and nearby obstacles that may be present.	1
	GPS device- Fixposition RTK2 [13]	GPS uses satellites to provide location information to the robot.	1
	Samsung Galaxy S10 5G [14]	This Smartphone will be used for the mobile applications, including the XR application that will be provided for the evacuation case.	at least 1

	Smart watch (A16) providing vital sign measurements Aitaer Technology Co., Ltd [15]	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.	at least 1

3.1.3 Infrastructure components and functionalities

This section describes the main infrastructure components and related functionalities that will be part of the use case implementation in Athens and Madrid sites.

3.1.3.1 STARLIT++

WINGS STARLIT++ is a cloud-based platform that interacts with different sensors and actuators as depicted in Figure 8. As already introduced, the services provided will be an extension of the functionalities of the existing STARLIT platform [7]. STARLIT++ will exploit devices such as cameras, drones and robots to develop an electronic triage monitoring application 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 described functionality will be available at the cloud infrastructure that WINGS will provide.

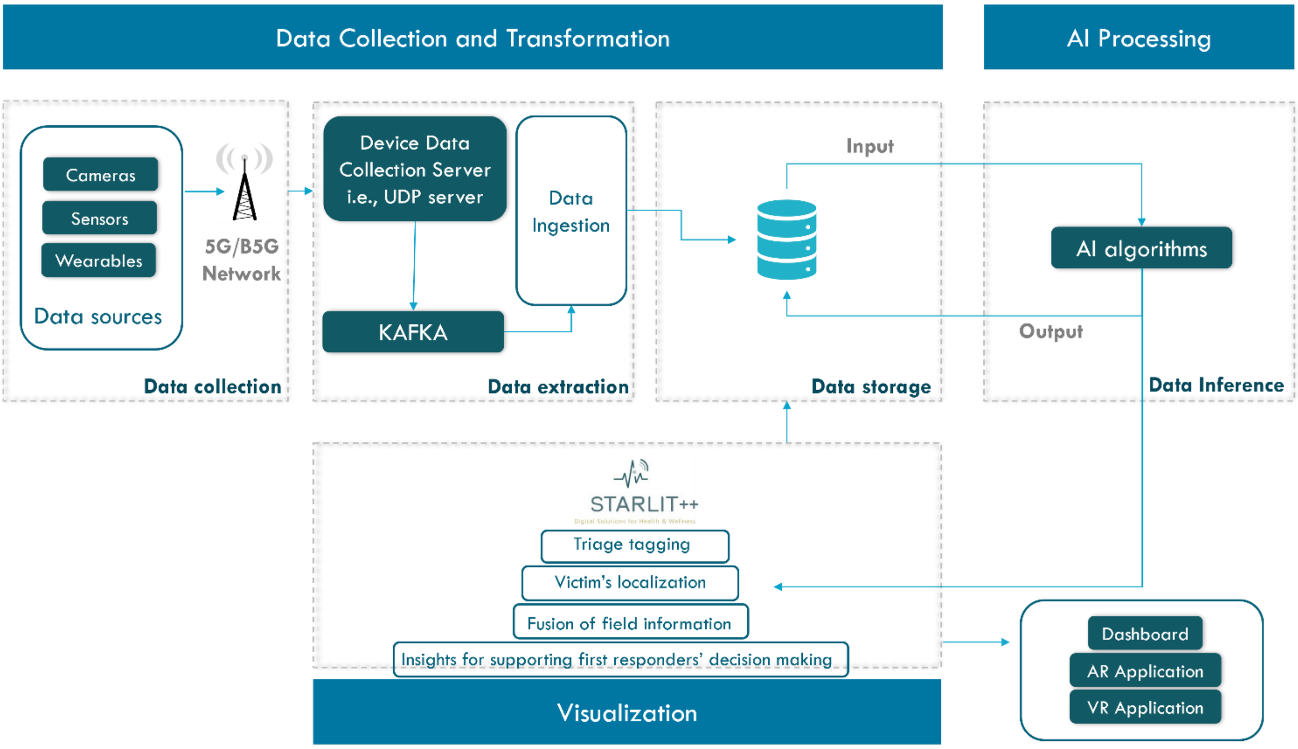

Figure 8. High level architecture diagram for UC6 (STARLIT++).

3.1.3.2 5G Network Infrastructure (Athens)

To support the operation of smart service robots, a public 5G network, leveraging its high-speed connectivity, low latency, and wide coverage. Specifically, 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. Future versions of the public network will also be used. In addition, a WINGS owned, private network infrastructure will be utilized, in order to conduct testing activities, validation and demonstration, prior to the use case implementation on the field. Figure 9 depicts the architecture in a high-level manner.

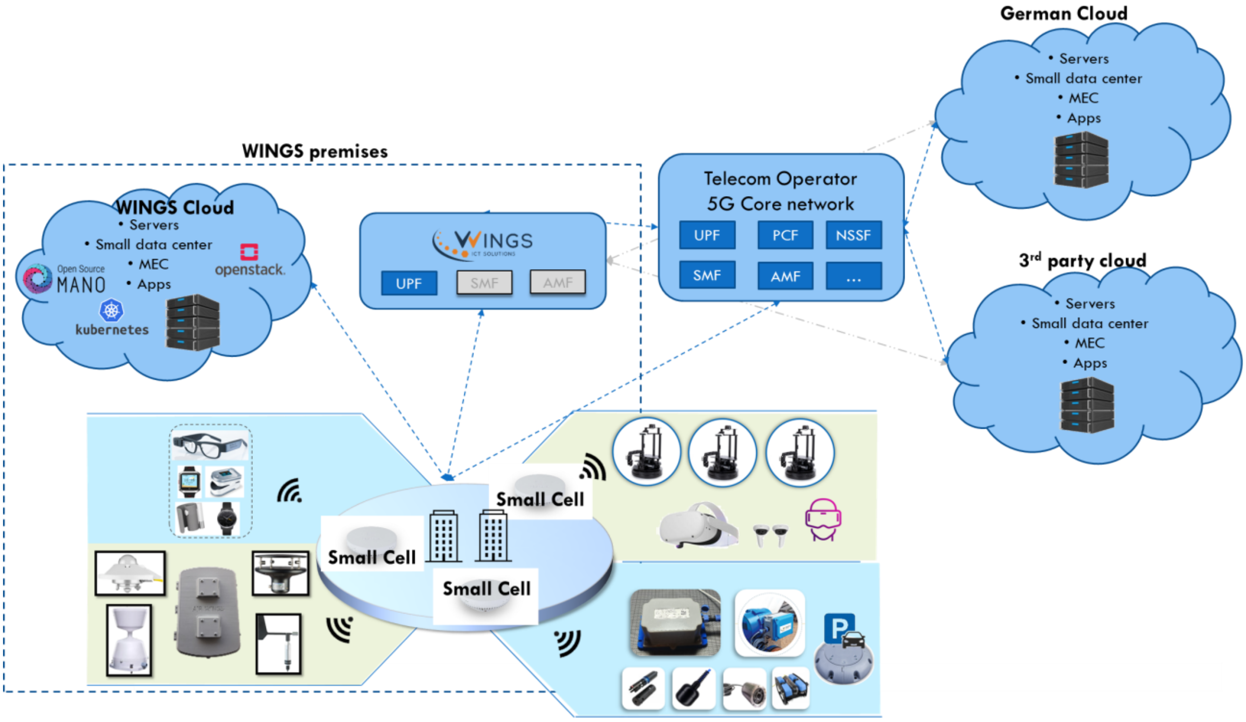

Figure 9. WINGS architecture for experiments.

The WINGS testbed provides end-to-end 5G/B5G functionality, along with extensive cloud and edge computing capabilities, leveraging the 3GPP (Release 16 and beyond) PNI-NPN (Public Network Integrated Non-Public Network) with shared Control Plane (CP), in a first phase, and isolated, SNPN (Stand-alone Non-Public Network), with all network functions (UP - User Plane - 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 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 use cases. WINGS testbed serves as a testing ground for services, equipment, and new features before they are commercially released. Detailed description of the testbed will be provided in D2.1.

3.1.3.3 5G Network Infrastructure (Madrid)

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). All the experimental devices that will be used for the use case implementation in the venue will connect only to such NPN, while the commercial devices will use the public network. A diagram of the infrastructure is depicted in Figure 10.

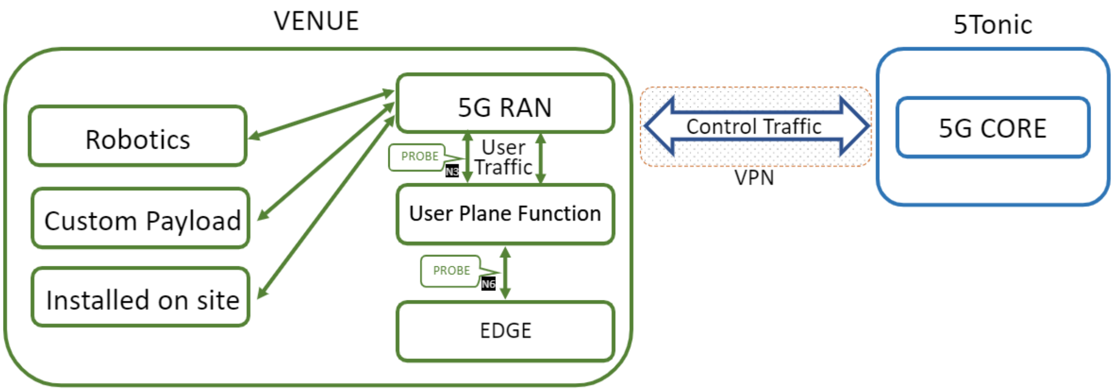

Figure 10. UC6 NPN infrastructure.

The Ericsson 5G NPN infrastructure is a distributed 5G Stand-Alone architecture (SA) network. The 5G SA architecture adopts the new concept of Service-Based interfaces. This means that the Network Functions (NFs) that include logic and functionality for processing signaling flows are not interconnected via point-to-point interfaces but instead exposing and making available services to the rest of NFs. Thus, there is a separation that broadens the range of possible locations in which the network elements can be located. The Radio Access Network (RAN) and the User Plane Function (UPF) are installed at venue premises, while the rest of components of the 5G Core (5GC), the control plane components, are running on the 5Tonic infrastructure (Leganés, Madrid) [8]. This model is interesting because verticals do not need to have their own full 5G deployed, making the service a lot more cost-efficient for them. With this solution, the 5G RAN equipment splits the user plane traffic and the control traffic. The use case traffic is directed via the UPF towards the vertical applications. This way, the user plane traffic remains geographically close to the end user devices, keeping a very low latency. Complementarily, the control and management planes of the 5G equipment are done from a remote location in 5Tonic via VPN, as control traffic does not require as low latency and high-speed levels as the local user plane traffic.

On-site, 5G connectivity to the network will be provided through proper 5G Customer Premise Equipment (CPE) that will be installed depending on the required technology (mid-band or mmWave). To collect network metrics there are two software probes on N3 and N6 interfaces to obtain the network measurements. The N3 interface is responsible for providing connectivity between the 5G RAN and the 5G Core and N6 is the Interface between UPF and the Edge computing. For the application modules, some servers dedicated to this application will be needed to implement the use case as described above. They can be hosted in the venue or, depending on the network capabilities, in the Edge. Detailed description of the 5G infrastructure that will be used for the Spanish cluster will be provided in D2.1

3.1.4 Trial description

The aim of the trial is to showcase how 5G/B5G technologies can contribute to improving the efficiency of operations in Mass Casualty Incidents and Emergency evacuation in a large, populated area or venue, in case of man-made security threats, fires, natural disasters, etc. The trial aims to showcase on one side how relevant operations could be improved and on the other side how major KPIs necessary for this use case are addressed by the 5G/B5G technologies. In Athens both the Mass Casualty Incidents and Emergency evacuation cases will be tested while in Madrid the focus will be on the Emergency evacuation.

Scenario 1: Earthquakes and building collapses/with fires - Pre-hospital treatment

During a cultural event/concert a serious incident e.g., a fire, a building collapse takes place in which many victims are reported. The sequence of actions will be as follows:

- Drones/robots equipped with cameras collect data on the condition of the area, the buildings and on the status of potential victims or injured people.
- To have a clearer picture of how the land may have moved in case of earthquake and to assess further risk of landslides, drones are provided also to collect data to develop maps. The latter will be exploited by first responders for risk assessment and decision making on rescuing process.
- The collected data is transmitted and analyzed by AI and DL algorithms to detect any potential hazards, victims, or injured people and in general to provide information to first responders on the situation in the field (estimated number of victims, support for primary triaging, estimated location of victims).
- Information is displayed to first responders (including designated members of appropriate city authorities) via a dashboard, which also displays alerts and notifications based on the data analysis. Recommendations will be displayed on actions that need to be taken to ensure the safety or the pre-hospital treatment of victims by the first responders who will have arrived in the specific area.
- Wearable devices are connected to the patient and send main vital sign information.
- Remote experts monitor the emergency services and an ambulance can be consigned. A remote Medical Specialist at the hospital can support and advise the ambulance staff until the patient's stability is achieved.
- Then the patient is taken to the hospital, where the medical staff and devices are prepared for his/her arrival.

Scenario 2: Evacuation in the context of a large-scale event in a sports venue

- For the evacuation in the context of a large-scale event in a sports venue first responders will be equipped with smart systems and services in order to control and act in real time for these incidents.
- The floor plan area to create its digital twin in the mobile application is required for the indoor scenario (buildings) along with the initial designated evacuation routes as prescribed by the law, while aerial maps (e.g. top views) accompanied with the respective distance metrics will be used for outdoor incidents (fires, floods, etc.).
- Camera images or video from drones or robots will be used to derive insights on the status in the field.
- All available information will be used for the calculation of optimal routes that rescuers and evacuees need to follow so that a) there is a quick intervention in the shortest possible time, b) they will avoid obstacles or dangerous sections for which they may not be aware of and c) will not to be trapped in a dead-end route which may compromise their safe evacuation from the scene.
- The proposed evacuation system will comprise an XR-mobile application for easy-to-perceive guidance.
- The optimal evacuation routes will provide personalized guidance based on proximity to the exit, updated data for the even distribution between the available exits and avoidance of obstacles that may trap evacuees in dangerous dead ends.

Table 2 and Table 3 below respectively provide a detailed description of the trials related to the two scenarios described above.

Table 2. UC6 trial description for Mass Casualty Incident scenario.

<table>
<tr><th>Trial ID / Name</th><th colspan="2">Trial 6.1 / Mass Casualty Incident (MCI) in Populated Area</th></tr>
<tr><th>Infrastructure / Venue</th><th colspan="2">Public 5G network / Technopolis Athens</th></tr>
<tr><td>Description</td><td colspan="2">This test case focuses on the efficient handling of an MCI. It utilizes robots, drones, wearable devices, AI including image processing, and the power of 5G/B5G communications to improve situational awareness, support triaging, provide digital traceability and overall help first responders in efficiently handling MCIs.</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>• Robots
• Robotic Software
• Robotic Applications
• Cameras
• Thermal cameras
• Sensors
• Mobile devices (Tablets, Smartphones)
• XR-Mobile Application
• AI software (analysis)
• Cloud-based storage for collected data and analysis
• Virtual Reality (VR) headsets
• Augmented Reality (AR) devices
• 5G internet connection to enable real-time data sharing and communication</td></tr>
<tr><td>Configuration</td><td>• The robot, thermal cameras, sensors should be connected to the 5G network to enable real-time data collection and analysis.
• The mobile devices should be configured to access info and receive live events and alerts over the network.</td></tr>
</table>

		• Monitoring tools should be installed, to measure latency and throughput.
Trial procedure	Pre-conditions	• The devices should be fully charged and properly configured to connect to the network. • Before executing the trial, the robot or drone should be deployed to collect data. • The test signals from the cameras and sensors should be sent to STARLIT++ to verify connectivity and ensure proper data collection and analysis. • Communication between the robots or drones and STARLIT ++ should be verified.
	Trial steps	• The robots are deployed to monitor and do crowd analysis. • The robots and drones use their sensors to monitor any incident and provide insights on estimated number, location and status of victims, the situation in the field (e.g. fires, collapsed buildings, gases, etc.) . • The robot will combine mobility capabilities, sensors, and thermal cameras for tasks such as showing the crowded area and the situation in real time. • Object detection by optimal evacuation routes analysis is used to identify any difficulty for the injured people. • STARLIT++ analyses the collected data using diverse AI techniques such as NNs and DL. • Based on the assessment, STARLIT ++ platform displays alerts, notification and potential actions as well as vital signs and triaging and health assessment of victims. • First responders can access all information through also through mobile devices to view and check any issues that require attention and face the situation on time.
Measurements	Methodology	KPIs such as latency, service reliability, service availability, throughput, etc, will be monitored and compared against the target values (see Table 11 in section 4.1). Staff from the involved partners will act as first responders or patients equipped with the appropriate devices. Users will be provided with questionnaires to provide input on KVIs (see Table 13 in section 4.1). Demonstrations to relevant stakeholders will be made to obtain further feedback.
	Complementary measurements	Accuracy, specificity, and precision of AI mechanisms.
	Calculation process	Repeated tests will be performed to collect a large sample of KPI values and measurements. Different methods will be used (see also section 4.1). The average value will be compared to the target value set. The overall functionality of the system will be assessed to ensure that the system "behaves" as it should. Usability will be measured via questionnaires.

Expected Result	• Automated estimation of number and location of victims’ • Insights for supporting first responders' decision making in triaging process • Improved triaging process • Improved efficiency of operations

Table 3. UC6 trial description for Emergency evacuation scenario.

Trial ID / Name	**Trial 6.2 / Emergency evacuation in Populated Area**	
Infrastructure / Venue	**Public 5G network / Technopolis Athens, 5Tonic / Sports venue Madrid**	
Description	This test case focuses on the efficient handling of an Emergency evacuation. It utilizes AI, XR application and the power of 5G/B5G communications to improve situational awareness, provide digital traceability and overall support more efficient evacuation in emergency situations.	
Components and Configuration	Components	• Robots • Robotic Software • Robotic Applications • Cameras • Thermal cameras • Sensors • Mobile devices (Tablets, Smartphones) • XR-Mobile Application • AI software (analysis) • Cloud-based storage for collected data and analysis • VR headsets • Augmented Reality (AR) devices • 5G internet connection to enable real-time data sharing and communication • Mobile devices (Tablets, Smartphones) • XR-Mobile Application • AI software (analysis) • Cloud-based storage for collected data and analysis • VR headsets • 5G internet connection to enable real-time data sharing and communication
	Configuration	• The robot, thermal cameras, sensors should be connected to the 5G network to enable real-time data collection and analysis. • The mobile devices should be connected to the 5G network and be configured to access info and receive live events and alerts over the network. • Monitoring tool should be installed on the devices, to measure latency and throughput.
Trial procedure	Pre-conditions	• The devices should be fully charged and properly configured to connect to the network. • Before executing the trial, the robot or drone should be deployed to collect data.

		• The test signals from cameras and sensors should be sent to STARLIT++ to verify connectivity and ensure proper data collection and analysis. • Communication between the robots or drones and STARLIT ++ should be verified.
	Trial steps	• The robots are deployed to monitor and do crowd analysis. • The robots and drones use their sensors to monitor any incident and detect any anomalies or issues (e.g., fire incident). • The robot will combine mobility capabilities, sensors, and thermal cameras for tasks such as showing the crowded area and the situation on real time. • Object detection by optimal evacuation routes analysis is used to identify any issues. • All available information will be used for the calculation of optimal routes that rescuers and evacuees need to follow so that a) there is a quick intervention in the shortest possible time, b) they will avoid obstacles or dangerous sections for which they may not be aware of and c) will not to be trapped in a dead-end route which may compromise their safe evacuation from the scene. • First responders can view information on XR applications on mobile phones and smart glasses. Evacuees can follow personalized evacuation guidance on an XR mobile application.
Measurements	Methodology	The performance of the AI mechanisms will be tested. The overall functionality of the system for the use case will be tested. KPIs such as latency, service reliability, service availability, throughput, etc, will be monitored and compared against the target values (see Table 12 in section 4.1). Staff from the involved partners will act as first responders or patients equipped with the appropriate devices. Users will be provided with questionnaires to provide input on KVIs (see Table 13 in section 4.1). Demonstrations to relevant stakeholders will be made to obtain further feedback.
	Complementary measurements	• Accuracy, specificity, and precision of AI mechanisms • Performance of evacuation routing algorithms
	Calculation process	Repeated tests will be performed to collect a large sample of KPI values and measurements. Different methods will be used (see also section 4.1). The average value will be compared to the target value set. The overall functionality of the system will be assessed to ensure that the system "behaves" as it should. Usability will be measured via questionnaires.

Expected Result	• Automated estimation of number and location of people to be evacuated. • Insights for supporting first responders' decision making in evacuation process. • Improved efficiency of evacuation operations.

The trial descriptions reported in Table 2 and Table 3 are intended to be complemented with the specific KPIs and KVIs definition and measurements reported in section 4.1.2.

3.2 UC7: Remote Proctoring

The newly trained surgeons for interventional cardiology must undergo training in hospitals with demonstrated experience in the field. Usually, the newly trained interventionalists require the physical presence of an experienced proctor to safely observe the activity and ultimately act if any sort of complications occur when it comes time to perform the very first cases.

The time duration of surgical proctorship is highly variable, greatly depending on the complexity of the procedure, the operators' skill level, and their level of confidence. Even though the close supervision of a skilled surgeon appears to be required to ensure adequate patient safety, this stage of the learning process can significantly slow down the diffusion of novel interventional techniques due to the costs and logistical challenges associated with the proctor's physical presence. The traditional in-person coaching strategy will naturally evolve into remote proctoring support. This cutting-edge proctoring method facilitates a quicker learning process by minimizing the organizational work required for each in-person training session, minimizing travel time for expert proctors, increasing the number of monitored procedures for each proctor, and minimizing costs for the National healthcare system.

3.2.1 Use case definition

Today, new cutting-edge technologies for telepresence can make remote proctorship just as effective as conventional proctor support to safely direct the surgery. With these tools, the remote proctor should theoretically have the same field of view as the operators to completely understand what is happening. Furthermore, multiple virtual participants can join the same proctored session. However, these technologies require smooth connectivity with high stability and efficiency, therefore today these activities are mainly based on wired connection. To enable new functionalities and ensure efficiency in remote proctoring activities in the field of interventional cardiology, this use case offers new solutions based on enhanced telepresence, thanks to the implementation of 5G-radio connectivity. The final aim of this use case will be to demonstrate the possibility of ensuring a telepresence support in surgical field based on 5G wireless network and not by fully wired connection as currently done.

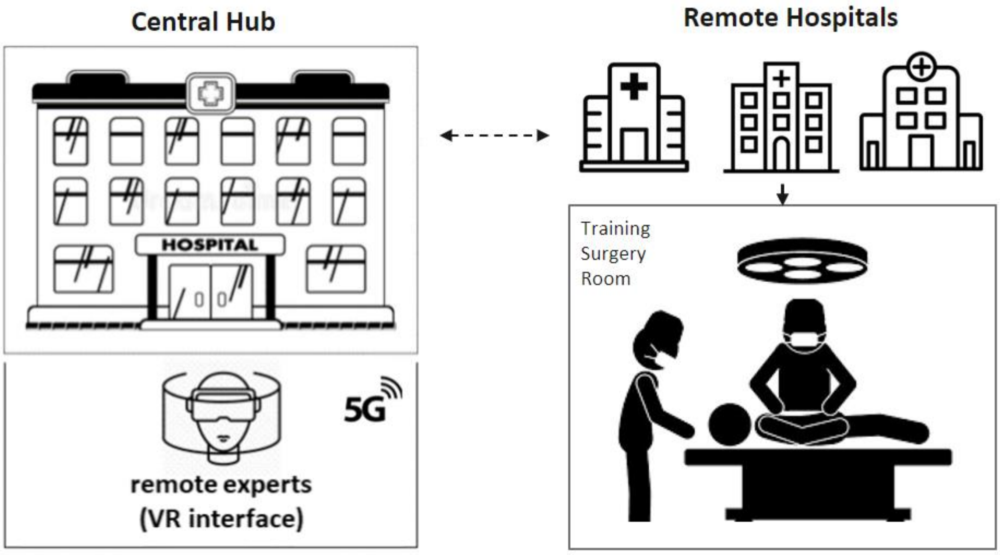

Figure 11. Remote proctoring use case concept.

This use case will implement the remote proctoring activities in the field of interventional cardiology that will take place in two Italian hospitals located in Pisa and Massa respectively. This use case will develop an E2E solution based on a telepresence platform that will enable a remote expert cardiologist in Pisa to efficiently join a proctored surgery session in Massa. A dedicated 5G indoor coverage will support the connectivity in the Pisa hospital while a VPN link will be setup to provide a secure and stable connection between the two hospitals.

In the trial of UC7, the expert proctor will be located at a central hospital hub site in CNR campus in Pisa. The remote hospital site in Massa will host the surgical training room where new trained interventionalists will perform under the remote observation of the expert proctor. As illustrated in Figure 11, this use case aims to specifically deploy an indoor in-field cellular coverage network, based on a dedicated 5G network, for real-time remote proctoring applications to offer the best quality of connectivity. The remote proctor in central hospital hub will be equipped with a telepresence station to monitor and support the surgeons in surgery training room in the remote hospital via the telepresence system. This will enable the experienced proctors to supervise many surgical operations and, by means of wireless connectivity instead of cable one, has the advantage of being location-independent and, in a more general application, enables it to be a truly portable tool that expert proctors can use even outside of a specific hospital.

3.2.2 Implementation aspects

3.2.2.1 Application design

In the UC7, two operational macro-modules will be implemented, one operating in a remote hospital and the second one in the central hospital (see Figure 11 and Figure 13).

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. All the acquisition tools will be wirelessly connected to the connection hub, which will be wired-connected to the hospital network. The connection hub will be equipped with specific software (commercial software of telepresence system) to securely broadcast multiple live videos from the acquisition tools in operating room to the remote expert.

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. The workstation of telepresence platform will be equipped with the software of telepresence system with a dashboard that will give the remote expert the surgeon's view of the operational room, the complete view of entire operating room, and the view of clinical monitors. The software will also permit the remote expert to communicate directly through audio and chat with the surgeon. In the trial, the possibility of using as interface of remote expert a VR headset will be explored and tested. In this case, the VR headset will be connected to the workstation, and it will be used to give to the expert an immersive surgeon's view. Currently, different commercial telepresence solutions (e.g. Rods&Cones system, Figure 12) are being tested to find the optimal platform for the UC7 trial.

Figure 12. Testing of Rods&Cones telepresence system for surgery.

3.2.2.2 Equipment and devices

The equipment and devices that will be needed to perform the trial of UC7 are reported in Table 4 .

Table 4. Equipment and devices for UC7.

Equipment	Item	Description	Quantity
	To be defined	Clinical-certified real-time Telepresence System for training surgical room composed by: • smart glasses for surgeon • room camera • hub for clinical information video streaming	1
	To be defined	Clinical-certified real-time Telepresence System for remote proctor running on a workstation.	1
	To be defined	VR headset for remote expert	1

3.2.3 Infrastructure components and functionalities

In the UC7 trial, an expert proctor (i.e., an expert cardiologist) of the unit of “Diagnostic and Interventional Cardiology” of FTGM will operate in the FTGM central hospital hub site located in the CNR Campus in Pisa. The newly trained interventionalists will operate in a dedicated training surgical room in the FTGM hospital site in Massa, under the remote supervision of the proctor.

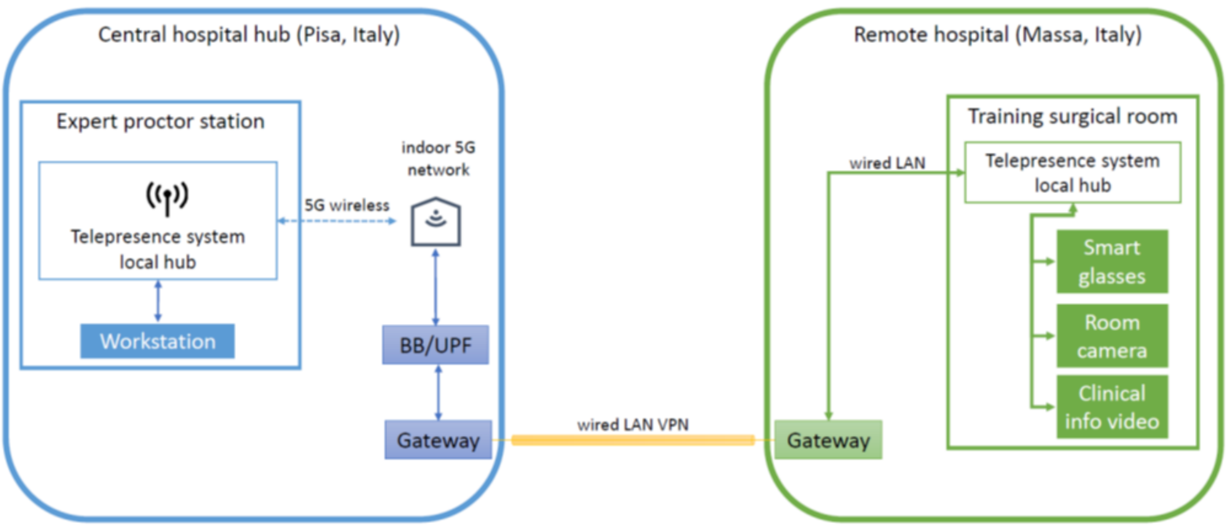

Figure 13. Remote proctoring connection flow.

Both the central hospital hub in Pisa (left side of Figure 13) and the training surgical room in Massa (right side of Figure 13) will be equipped with a commercial and clinical-certified telepresence system. The telepresence system in Pisa will benefit from an indoor 5G connectivity able to provide the required performances to enforce the UC with the expected QoE. Pisa and Massa, on a geographical distance, will be connected through a dedicated VPN tunnel at 10 Gbps subtended between two gateways (packet switches).

3.2.3.1 5G network infrastructure

The mentioned 5G infrastructure is composed by a portable system (i.e., "Telepresence system local hub" in Figure 13) connected via a CPE to the RAN, and a Core Network (CN).

The Telepresence System's local hub and the related workstation are both located in "Central Hospital Hub". This system is connected to the 5G network via a CPE, which uses a SIM card provided by TIM to ensure access to the network. The CPE can be directly connected to the Telepresence System or can act as a dedicated Wi-Fi hotspot, where the Telepresence System can be connected using the best available Wi-Fi technology.

The RAN, which is based on Ericsson systems, consists of two main components. The first component is the baseband unit, which is responsible for processing baseband signals (that have not yet been modulated to the radio frequency (RF) domain). 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:** this module is hosted in the TIM Innovation site located in Turin and it is responsible for managing the user data and profile information that is needed for authentication, authorization, and accounting purposes.
- **UPF module:** this module is hosted in Pisa and it is responsible for handling the user data (user plane traffic) that flows between the 5G network ensuring that it is delivered efficiently and reliably.

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 [16], located at TIM's premises in Turin. Additionally, a second orchestration module, specifically designed to manage vertical use cases that require more challenging handling of end-to-end QoS with optimal usage of the underlying infrastructure resources, has been deployed by Ericsson Research in Pisa within 5Growth project [17]. This provides further support for the overall 5G infrastructure. More details on this part will be provided in the deliverable D2.1 of WP2.

3.2.4 Trial description

The trial of UC7 will aim to demonstrate the possibility of ensuring efficient and stable real-time bi-directional communication between a remote proctor and surgical training room at a geographical distance, via a dedicated VPN and by equipping the central hospital hub where the remote proctor is located with 5G-radio connectivity. The UC success will demonstrate the possibility to use, not only high speed wired LAN, but also dedicated 5G wireless based network for proctoring and supporting in surgical field. The trial will compare the performance and quality of the 5G wireless network connection, and the subjective telepresence experience compared to the standard wired connection (high speed wired LAN).

In the UC7 trial, two different sessions of remote training operations will be performed: i) a Control Session (CS) in which the remote proctoring will be conducted by using the current wired connection between the proctor and the distant surgical training room, ii) an Experimental Session (ES), in which the remote proctoring will be conducted by using the new 5G-based connection between the proctor and the distant surgical training room.

During both CS and ES, the network performance indicators (see Section 4.2.2) will be collected to evaluate the efficiency and stability of the new indoor 5G-based network connection. In addition, the subject evaluation of the remote proctor about the telepresence experience will be collected by a tailored structured questionnaire ("Subjective network quality assessment questionnaire", see Table 15) after each session (both for CS and ES). In total, at least 10 CS and 10 ES will be performed. The results of both network performance indices and subjective telepresence experience will be compared to evaluate the efficiency of the ES with respect to the CS.

The following Table 5 reports the trial description.

Table 5. UC7 trial description.

Trial ID / Name	Trial 7.1 / Remote Proctoring	
Infrastructure / Venue	**Ad-hoc 5G indoor coverage / Central hospital hub in Pisa**	
Description	A network was deployed, including an indoor dedicated 5G coverage, for real-time bi-directional communication between a remote proctor and surgical training room at a geographical distance.	
Components and Configuration	Components	• Telepresence system for surgical room. • Telepresence system for remote proctor. • Cellular wireless and wired network resources.
	Configuration	The 5G infrastructure is composed of a RAN, a CN, and a portable telepresence System local hub connected via a CPE, which uses a SIM card to ensure network access. The RAN consists of a baseband unit and an indoor radio antenna. The CN is composed of the UDM module and the UPF module.
Trial procedure	Pre-conditions	• Test for telepresence system with standard connection (no indoor 5G network). • Test of usability for newly trained surgeons. • Test of usability for remote proctor.
	Trial steps	• Telepresence system in surgical room connected to network. • Remote proctor station connected to network by a) wired standard connection (control sessions) or b) indoor 5G-based connection (experimental sessions). • Connection between telepresence system and remote proctor station. • Surgical training session and collection of performance indices of network connection. • Subjective network quality assessment questionnaire administration.
Measurements	Methodology	The monitoring time is a function of time duration of the surgical training session. The monitoring tool presents the two assessment domains: a network domain (performance indices) and a subjective network quality domain ("Subjective network quality assessment questionnaire").
	Complementary measurements	As part of network performance assessment, the following E2E parameters can be measured: minimum (guaranteed) and average data rate, roundtrip latency, jitter, and packet loss. Additionally, network availability can be estimated, and radio signal quality can be evaluated during coverage map planning.
	Calculation process	The difference between control and experimental sessions for performance indices of the network connection will be evaluated by using the Wilcoxon signed-rank tests. The "Subjective network quality assessment questionnaire" has different measures with ordinal scales and dichotomous measures. The

		difference between control and experimental sessions will be evaluated by using the Chi-Square tests for dichotomous measures and by using the Wilcoxon signed-rank tests for ordinal measures.
Expected Result	• Higher values of network domain measures for experimental sessions with respect to control sessions. • Higher values of subjective network quality domain measures for experimental sessions with respect to control sessions.	

The trial description reported in Table 5 is intended to be complemented with the specific KPIs and KVIs definition and measurements reported in section 4.2.2.

3.3 UC8: Smart Ambulance

The prognosis of acute coronary syndromes (ACS) and, in particular, the ST-segment elevation myocardial infarction (STEMI), is strongly depending on the time between the onset of the symptoms and the reperfusion of the coronary artery responsible for the ischemic event. The protocol for STEMI care involves primary percutaneous coronary intervention (PCI), or pharmacological reperfusion with thrombolysis. Any delay in therapeutical actions increases the patient's mortality or loss of myocardial muscle with consequent cardiac dysfunction. The first hour from symptoms onset is called the “golden hour” because this time is burdened by high mortality. In this scenario, ambulances are not only a mere tool for quick transportation of a patient’s living area to a hospital equipped with Cath lab[1] facilities for coronary intervention, but they also offer early pre-hospital evaluation for a precise diagnosis and preliminary therapeutic support.

A better disease outcome may result in pre-hospital diagnosis and appropriate care of the condition in individuals with chest discomfort. Although usually there isn't a cardiologist on the ambulance, the hospital staff already receives patient data from the ambulance such as blood pressure, oxygen saturation, and electrocardiogram.

3.3.1 Use case definition

Currently, ambulances are not equipped with instruments that allow HD real-time patient vision and echocardiographic video to allow an efficient real-time visualization of patient heath information for the remote expert in the hospitals. In some cases, specialists in hospitals can be called to remotely assist the emergency operator onboard (usually paramedics) with specific treatments or diagnostic tests while the ambulance is getting to the hospital, improving the efficiency of the emergency service. In addition, the specialists in the hospital can better manage and treat the emergency patients if they are a detailed patient heath view before her/his arrival in hospital. Therefore, it is crucial to have an effective and active remote audio/video communication channel between hospitals and emergency ambulances for the STEMI treatment and, in general, for any health emergency in real-world environment.

This use case will propose a 5G-connected smart ambulance operating outdoor in the hospitals area in Pisa and connected to the hospital in Massa. The use case will develop an infrastructure that will enable ambulances (or small Emergency centres) to share diagnostic information with the main centre, adopting a “hub and spoke” strategy. The proposed infrastructure will be designed and implemented to equip the ambulance with diagnostic tools for cardiological pathology and smart devices to guarantee an efficient and fast 5G connection in remote locations and mobility conditions. In particular, see Figure 14, the ambulance will be equipped with modern STEMI diagnostic tool (echocardiography) and a 5G hub to ensure a reliable connection in all conditions,

[1] Cath lab stands for catheterization laboratory, that is an examination room in a hospital or clinic with diagnostic imaging equipment used to visualize the arteries of the heart and the chambers of the heart and treat any stenosis or abnormality found.

including emergency high-speed transport through congested urban areas. Synergies with UC7 will be carried out for what concerns E2E slices orchestration.

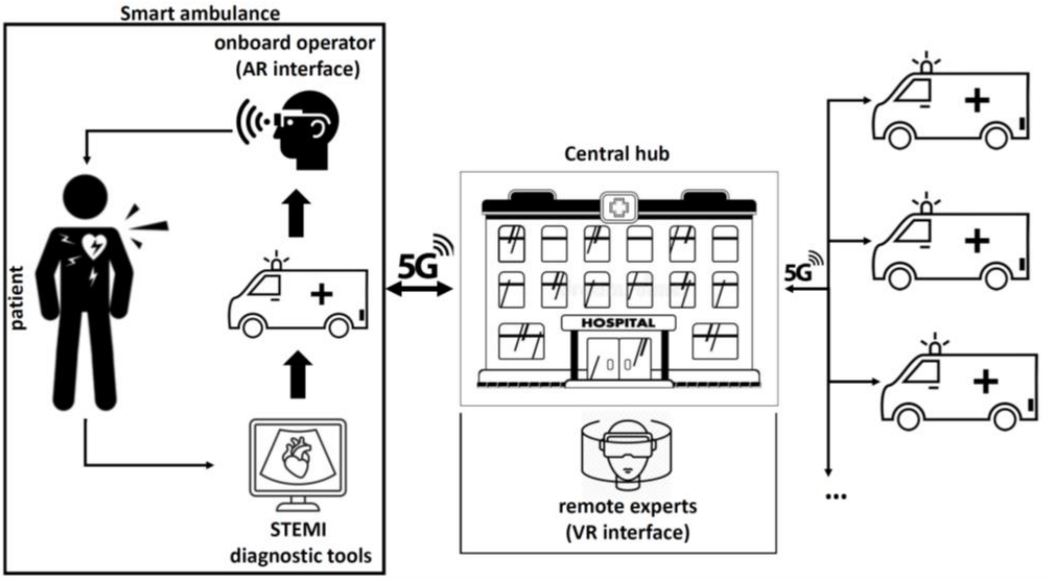

Figure 14. Smart ambulance use case concept.

From the implementation point of view, a bi-directional audio/video communication network from and to the central hub (hospital for primary PCI) will be deployed. In this way, the onboard emergency operator can send information and big data batches (such real-time video and 3D imaging, like in echocardiography) to a central hub with low latency and the central hub will provide real-time information to local operators to maximize early intervention. To have more specific information about the clinical status of the patient and the emergency setting, the remote experts in the central hub will get information from ambulances and onboard operators via VR headsets. The emergency operator onboard the ambulance will be equipped with an AR headset with cameras to receive information from the central hub and to send the video of emergency setting to the central hub.

To send data and a HD video in real-time between the ambulance in mobility and the hospital hub, low latency 5G is essential. In addition, video from onboard emergency operator cameras can be transmitted live via the very high throughput provided by 5G without any quality loss or buffering.

3.3.2 Implementation aspects

3.3.2.1 Application design

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 (see Figure 14 and Figure 16).

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 ambulance will operate within the CNR campus area in Pisa in an internal vehicular area (see Figure 15) to simulate emergency operations in mobility. The ambulance will be equipped with the 5G modem and echocardiography with real-time stream video functionality and Wi-Fi connectivity. The echocardiography will be wirelessly connected to the 5G modem in the ambulance. The onboard emergency operator will be equipped with the AR headset on the ambulance, also the AR headset will be connected to a 5G modem on the ambulance. The AR headset will be selected to ensure HD video streaming and audio communication. The connection of the 5G modem in the CNR area will be obtained thanks to the 5G-based outdoor network infrastructure that will be implemented in the area during the project.

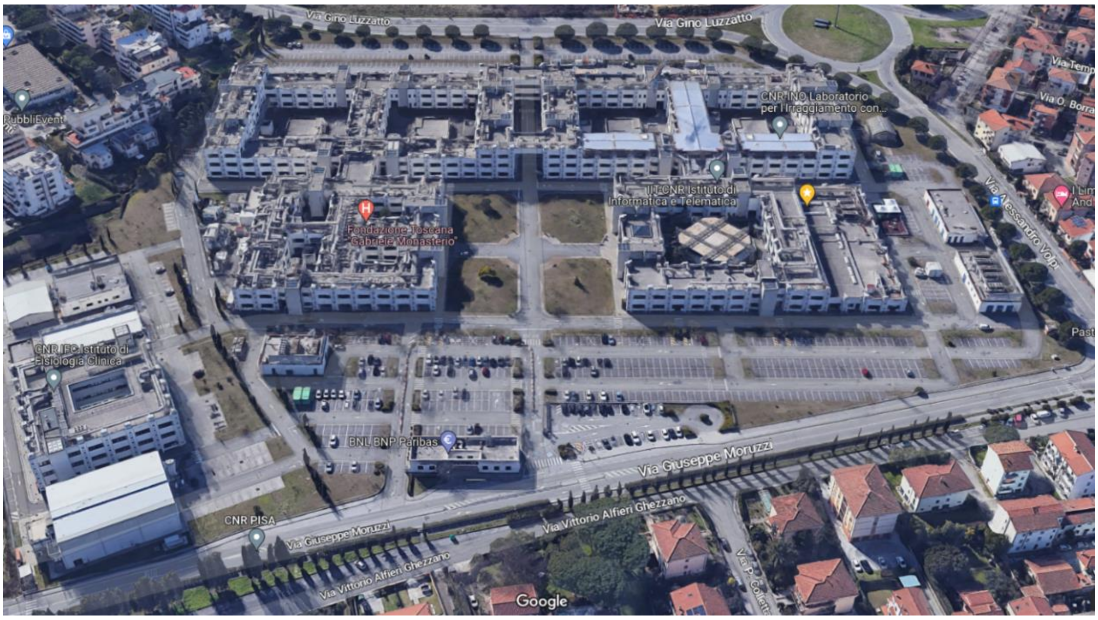

Figure 15. Map of CNR campus area in Pisa.

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. The VR headset will be connected to the local wired LAN of the hospital through the workstation. The workstation will be equipped with software to enable the connection with remote echocardiography on the smart ambulance and with the AR headset worn by the onboard emergency operator. The software will have a dashboard to manage the different video streams and enable bidirectional audio communication between the remote expert and the local operator.

3.3.2.2 Equipment and devices

The equipment and devices that will be needed to perform the trial of UC8 are reported in Table 6.

Table 6. Equipment and devices for UC8.

Equipment	Item	Description	Quantity
	To be defined	VR headset for remote expert cardiologist of emergency control unit	1
	To be defined	AR headset for the onboard emergency operator on smart ambulance	1
	To be defined	Clinical-certified echocardiograph with real-time stream video functionality on smart ambulance	1

	To be defined	Workstation connected with VR headset	1
	To be defined	5G modem for the smart ambulance	1

3.3.3 Infrastructure components and functionalities

The smart ambulance (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, both the indoor and the outdoor antennas shares the same baseband system.

In the UC8 trial (see Figure 14 and Figure 16) the ambulance with onboard emergency operators and simulated patients will be in the CNR Area in Pisa. The area of CNR contains vehicular areas and internal roads that allows to simulate the emergency condition of the ambulance in mobility in a secure and controlled environment. The distant expert cardiologist of the emergency unit, for supporting the onboard emergency operators, will be in the hospital site of FTGM in Massa and will be equipped with a VR headset. The CNR area of Pisa and the hospital site of FTGM in Massa are currently connected by a wired 10 Gigabit LAN VPN as already reported in UC7.

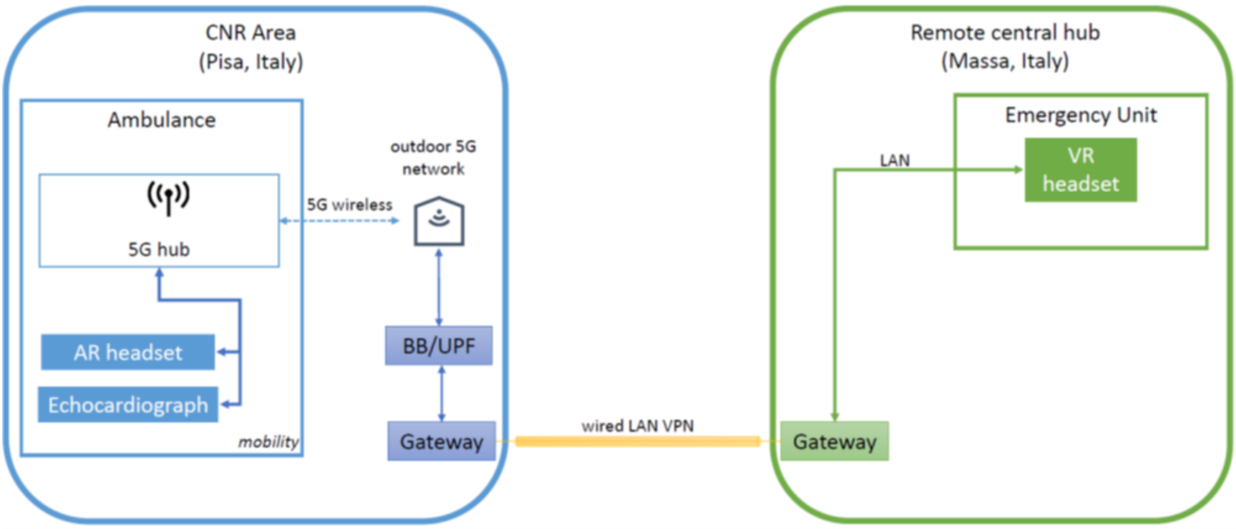

Figure 16. Smart Ambulance connection flow.

3.3.3.1 5G network infrastructure

The 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.

A second difference is related to the CPE that will be used in the ambulance. It is expected that the best option is to cover the interior of the ambulance with a Wi-Fi network originated from a 5G modem. Two installation options will be considered:

- **Option 1:** Installing a specific 5G modem and router inside the ambulance and connecting them to an external antenna through an Ethernet cable. The antenna is shaped like a "hockey puck" and magnetically anchored to the top roof of the ambulance. This solution has the advantage that the Wi-Fi hotspot is completely indoors, and the 5GHz bandwidth can be used for better wireless network performance.
- **Option 2:** Mounting the 5G modem, antennas, and router on the exterior of the ambulance in a single, aerodynamic, and ruggedized "shark fin" casing. This simplified form factor reduces installation complexity and cost, but the Wi-Fi hotspot is outside the ambulance, and the 5GHz bandwidth cannot be used.

Both options allow for the possibility of connecting medical equipment using conventional 2.5 GbE RJ45 cables as an alternative to Wi-Fi. If multiple devices need to be connected, an Ethernet hub can be used to increase the number of access points. A Wi-Fi connection provide by the 5G modem, would also allow commercially available AR headsets and portable echocardiographs to be connected. In the future, such devices could be directly equipped with embedded cellular modems for direct access to 5G and its evolutions.

The high throughput and low latency required by UC8 will be achieved through 5G network slicing, for which a dedicated slice of the network resources that is optimized for real-time communication and emergency services can be assigned to the ambulance. This slice allocation will provide high throughput connectivity and low latency communication, allowing medical personnel to remotely diagnose and treat patients in real-time, even while the ambulance is in motion. To achieve this, an Orchestrator (see also UC7 related section) will configure the slice with strict QoS requirements, which would ensure that the ambulance's connection to the hospital is prioritized over other network traffic. This would help preventing delays or interruptions in the ambulance's communication with the hospital, even if the network is congested. More details on this part will be provided in the deliverable D2.1 of WP2.

3.3.4 Trial description

The trial of UC8 will aim to define and demonstrate, in a controlled environment, reliable and stable real-time bi-directional communication between an emergency ambulance in mobility and an emergency unit in a central hospital.

The trial will test the smart ambulance functionality in a demonstration without acute myocardial infarction (AMI) patients but with healthy subjects (“simulated patients”) to reach the aims of the trial without any risk to patients in a real application. Simulated patients will be people who will be trained to portray patients with STEMI in a realistic way.

The trial will consist of the following phases:

- The simulated patient simulates a STEMI in an open area of CNR campus area in Pisa.
- The smart ambulance reaches the simulated patient and the onboard emergency operator equipped with the connected AR headset gets out of the ambulance and gives first aid to the patient. The remote expert in Massa receives the video stream from the AR headset of the emergency operator.
- The remote expert provides support and guidance on first aid to the emergency operator.
- The simulated patient and emergency operator get in the smart ambulance, and the ambulance leaves.
- During the ambulance ride inside the CNR campus area, the emergency operator performs echocardiography on the simulated patient inside the ambulance. The remote expert follows the echocardiography through real-time video streaming.
- During the ambulance ride, the remote expert provides support and guidance on the echocardiography to the emergency operator.

During the trial, the network performance indices (see Table 19) will be collected to evaluate the efficiency and stability of the outdoor 5G-based network connection.

The trial will be filmed to demonstrate the functionality of the smart ambulance with the 5G network infrastructure and related orchestration functionalities. Table 7 reports the trial description.

Table 7. UC8 trial description.

Trial ID / Name	**Trial 8.1 / Smart Ambulance**	
Infrastructure / Venue	**Ad-hoc 5G outdoor coverage / Central hospital hub in Pisa**	
Description	The trial will develop and test a reliable and stable real-time audio/video bi-directional communication between an emergency ambulance in mobility and an emergency control unit in a central hospital.	
Components and Configuration	Components	• AR headset for the onboard emergency operator • VR headset for the remote expert of control unit • Clinical-certified echocardiograph • Cellular wireless and wired Network resources • Workstation
	Configuration	The 5G infrastructure is composed of a RAN, a CN, 5G modem that includes a specific SIM card to ensure network access. The RAN consists of a baseband unit and an outdoor radio antenna. The CN is composed of the UDM module and the UPF module.
Trial procedure	Pre-conditions	• Test for functionality of AR headset • Test for functionality of VR headset • Test for functionality of echocardiograph
	Trial steps	• The simulated patient simulates an AMI. • The smart ambulance reaches the simulated patient, and the onboard emergency operator gives first aid to the patient. The remote expert receives the video stream from emergency operator. • The remote expert provides support for the emergency operator. • The simulated patient and emergency operator get in the smart ambulance. • During the ambulance ride, the emergency operator performs echocardiography on the simulated patient. The remote expert follows the echocardiography through real-time video streaming. • During the ambulance ride, the remote expert provides support to the emergency operator.
Measurements	Methodology	The monitoring time is a function of time duration of the demo. The network performance indices will be collected to evaluate the efficiency and stability of the outdoor 5G-based network connection.
	Complementary measurements	As part of network performance assessment, the following E2E parameters can be measured: minimum (guaranteed) and average data rate, roundtrip latency, jitter, and packet loss. Additionally, network availability can be estimated. For network performance evaluation, the ambulance can be first considered

		stationary and then moved at a realistic speed for an actual emergency situation.
	Calculation process	The mean, minimum and maximum values of network performance indices will be extracted.
Expected Result	Each single value of network performance indices will be within the limit ranges in the KPI table.	

The trial description reported in Table 7 is intended to be complemented with the specific KPIs and KVIs definition and measurements reported in section 4.3.2.

3.4 UC9: Adaptive Control of Hannes Prosthetic Device

Upper limb prosthetic systems have the potential of being life changing devices for amputees. However, an excessive cognitive load requested to the user for driving them might be a possible reason for rejection. In recent shared autonomy frameworks this is mitigated since a semi-autonomous control system reduces explicit user inputs, by using sensory information (e.g., color images, electromyography, etc.). However, processing and extracting meaningful data from this kind of information requires the employment of AI methods, mainly based on Deep Neural Networks, which run on specialized HW that might be hardly embedded in a wearable device. This use case involves the design of advanced control capabilities for prosthetic devices using AI techniques and their deployment on the Hannes arm. The aim is to improve the user experience using the prosthesis, leveraging on radio connectivity to provide sufficient computing power to the prosthesis to deploy recent AI methods with high reliability and minimal latency.

3.4.1 Use case definition

In this use case, the Hannes prosthesis will be used and will be equipped with sensors providing images of the environment (i.e., the object to be grasped) and Electromyography (EMG) signals measuring the muscle activation of the user. The aim is to introduce sensor-driven autonomous behavior to reduce the need of explicit control by the user during a prosthetic object grasping. Therefore, in the target efficient shared autonomy control system, AI methods are used to control arm's joints using the sensory information from the prosthesis (EMG as well as images from an embedded camera). Thus, the task is to interpret the user's grasp intention exploiting sensory information and control some of the available joints accordingly, such as the wrist and the thumb. Information from other types of sensors, such as IMU and EMG signals mounted on the prosthesis, can be considered, in addition to images, for this purpose. All these sensors stream information at high frame rates and convey useful information for the on-line prosthesis control. For this reason, high and stable data rates are required. More details about this are given in the next paragraphs.

The AI methods that will be employed are based on Deep Neural Networks and require powerful and specialized HW for both training and deployment. At the same time the control system is requested to be reactive to user's intention changes and modifications of the surrounding environment. For this reason, the required computation will be de-localized at the edge of the Network and an ultra-reliable low latency connection will allow the continuous interaction between the sensors, the device and the AI machine that will be located outside the prosthesis.

The system will control a part of the Degrees of Freedom (DoF) of the prosthesis while the user is driving it and controls the remaining ones. Therefore, the system needs to be accurate, reactive and highly reliable. However, being embedded in a wearable device, it presents specific constraints in terms of efficiency as well, motivating the adoption of devices that have small footprints in terms of power consumption, space and weight.

3.4.2 Implementation aspects

3.4.2.1 Application design

The application developed in this use case re-configures some of the DoF of the Hannes prosthetic hand during a grasping movement. The aim is to automatically adapt (*pre-shape*) the hand to the intended grasp movement by the human, which can be inferred by the type of object to grab and the approach direction to it. The application will follow the framework of the *shared autonomy* splitting the control between the human and the AI based system.

The different elements that will compose this application's architecture are reported in Figure 17. The Hannes prosthetic arm will be equipped with different sensors, such as EMG, IMU and a video camera. Specifically, this latter will be mounted either on the wrist or on the palm of the prosthesis and it will be wired connected to an embedded electronic board (e.g., through Universal Serial Bus – USB – connection). This latter will be equipped with 5G network devices that will allow to stream the data via radio from the sensors to a server (the "*AI Machine*" in Figure 17) where the AI method, based on Deep Neural Networks, is running. The data from the sensors mounted on the prosthesis are used by the AI method to gather information about the surrounding environment (like, e.g., the object to grasp and the direction of approach) and predict the correct configuration of the prosthetic arm joints that would allow to perfectly grab the object while adapting to the user's movements.

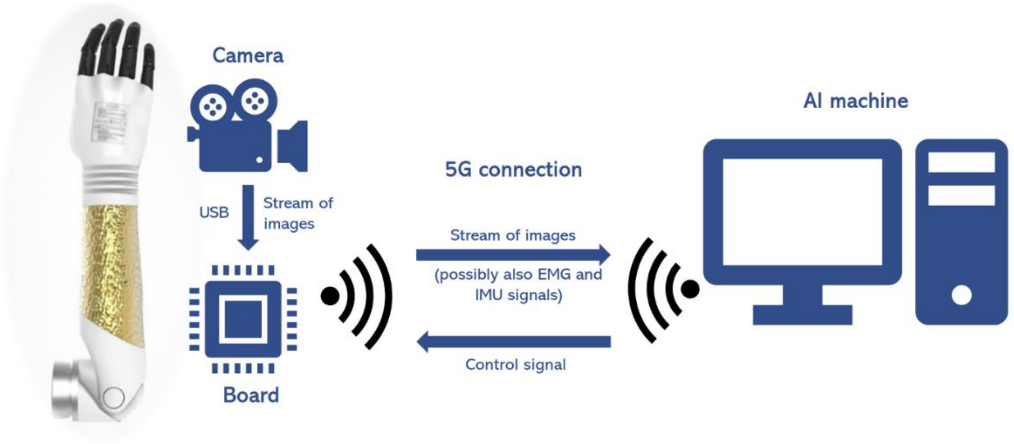

Figure 17. Architecture of the application for the Use Case 9.

The developed AI method will be based on previous work [18]. Specifically, it will be used an eye-in-hand learning-based approach for hand pre-shape classification from RGB sequences. The system is designed to support the possibility to grasp each object part with a different grasp type. The learning architecture relies on a well-established model with the following architecture: (i) Convolutional Neural Network (CNN) based feature extraction (CNN backbone), followed by (ii) a pre-shape classifier. The first block encodes each image into a convolutional feature vector which is then taken as input by the classifier to predict a pre-shape for each image. The Mobilnet V2 [19] is used as CNN backbone for its efficiency at inference time, using pre-trained weights on the ImageNet dataset [20]. Instead, two stacked fully connected layers are adopted for the hand pre-shape classification.

Ideally, the cooperation between the control system and the human should be transparent to the user to allow a natural prosthesis utilization with the lightest cognitive load possible. At the same time, the user should feel to be in full control of the prosthesis and not vice-versa. To this aim, the start of a grasp movement, the timing for the fingers closure around the object and the force to apply could be left to the user (e.g., by means of muscle activation read through EMG sensors). On the contrary, the movement of the wrist and the selection of the hand pre-shape can be delegated to the developed AI-based control system.

For the considered application, a grasp movement of 3 seconds will be considered (see Figure 18). After the start, the approach lasts ~2 seconds and the system collects RGB frames from the mounted camera. For the hand pre-shape classification (see upper diagram in Figure 18), these frames are sent from the board embedded into the prosthesis to the AI machine, through 5G network connectivity. These frames are then fed to the AI-based model and a pre-shape class is predicted. This is converted into the corresponding thumb configuration which is sent to the on-board control electronics that finally translates it into control signals for the joints. Next, these signals need to be sent from the AI machine to the board embedded into the prosthesis such that the pre-shape can be executed and then the fingers close around the object. Possibly, the control of the wrist could be implemented as well. In this case, the joints of the wrist need to be re-configured at each frame during the approach such that the palm of the hand is directed to the object to grasp as depicted in Figure 18.

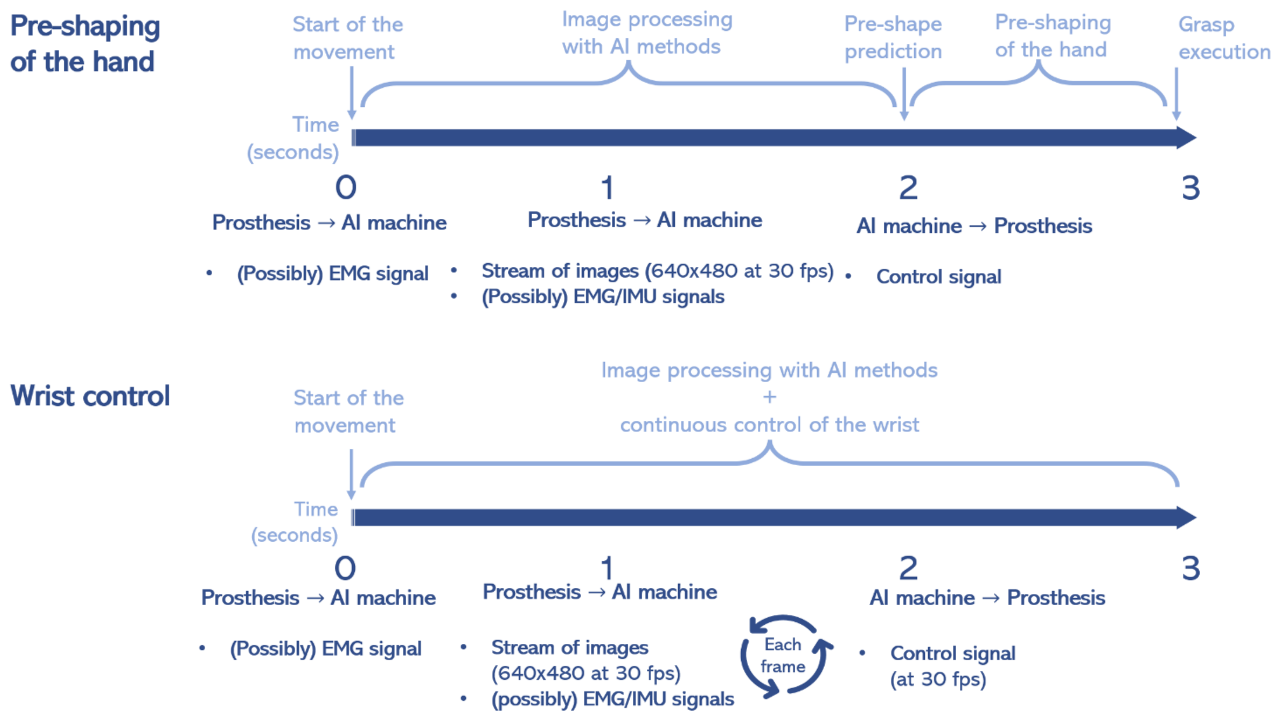

Figure 18. Functioning of the control pipelines for pre-shaping of the hand and for the wrist orientation.

3.4.2.2 Equipment and devices

The equipment required to develop and test the system for this use case is composed of the list of the devices reported in the following Table.

Table 8. Equipment and devices for UC9.

Equipment	Item	Description	Quantity
 **Prosthetic arm**	Hannes[21]	Hannes consists of three main components: a myoelectric poly-articulated prosthetic hand that exploits a differential underactuated mechanism; a passive flexion-extension (F/E) wrist module; and a myoelectric interface/controller that includes two surface EMG sensors, battery pack, and control electronics.	1
Embedded USB video camera	To be defined	This camera needs to be embedded either into the palm or into the wrist of Hannes. Therefore, it needs to be as compact as possible. Moreover, since it will be connected to the embedded electronic board, it needs to have a USB connection. Finally, this Use case requires a camera with a	At least 1

		resolution in pixels equal to or greater than 640x480 and with frame rate equal to or greater than 30 frames per second.	
Embedded electronic board	To be defined	This electronic board is embedded into the prosthesis. It receives the signal from all the sensors, including the video camera and can perform common computation, allowing for instance the pre-processing of the various signals from the sensors before sending them to the AI machine. It does not support the deployment of Deep Neural Networks.	At least 1
External able-bodied adapter	To be defined	An adapter will be used to allow a healthy user to safely and smoothly drive the Hannes prosthesis, in order to enable the testing of the developed system.	1
AI Machine	To be defined	For the deployment of the AI methods used to control the prosthesis, specialized H is required. Specifically, the Deep Neural Networks based approaches need to run on a server equipped with a recent and powerful graphical card (GPU) and a recent multicore CPU with sufficient amount of RAM.	At least 1
Dongle 5G	To be defined	High speed device able to support 2,5 Gbps NSA, during the first phase of integration activity, and 2,7 Gbps for SA used in the second phase of the laboratory integration and in field trial. The dongle can be connected to the electronic board of the Hannes prosthesis through a USB 3.1 Type-C connector.	At least 1

3.4.3 Infrastructure components and functionalities

3.4.3.1 5G network infrastructure

The use case will be first implemented and tested in the Ericsson R&D laboratory in Genoa, where a 5G network infrastructure based on 3GPP Rel-15.0 5G NSA is provided. The NSA provides connectivity for combined LTE and NR systems where LTE provides the control plane function while LTE and NR are used for the user plane. The 5G Ericsson deployment is supported by the Ericsson Radio System and Evolved Packet Core (EPC) solutions. The main components of the laboratory 5G network solution are summarized below:

- **RAN:** Radio Access Network composed of LTE and NR radios and basebands (Digital Unit) connected to the transport layer.
- **Transport network:** routers to implement fronthaul and backhaul to implement optimized baseband/radio interconnection.
- **Core solution:** the main components are the Home Subscriber Server (HSS), the MME, the Evolved Packet Gateway (EPG)

This architecture will allow to get a baseline set of information during the first characterization phase. Afterward, it will migrate to a SA Core architecture enlarging the set of functionalities on Network side.

In the second phase in Pisa, 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. The 5G infrastructure is composed by a RAN and a CN. The RAN, which is based on Ericsson systems, consists of two main components: the first component is the baseband unit, which is responsible for processing baseband signals that have not yet been modulated to the radio frequency (RF) domain; the second component is an indoor radio antenna that covers the experimental area. Regarding the CN, part will be hosted in Pisa and part in Turin as already described for UC7.

For both 5G network infrastructures that will be used for the implementation of this use case, details will be provided in the deliverable D2.1 of WP2.

3.4.3.2 Hannes arm components

From the application point of view, this Use case will rely on infrastructure and functionalities solutions from both groups Rehab Technology (Rehab) laboratory [22] and Humanoid Sensing and Perception (HSP) [23]. The application will require both HW and software components. Specifically, from the HW point of view the main components are:

- **A Hannes arm (Rehab group):** It comprises of a movable wrist and thumb joints, equipped with EMG and IMU sensors.
- **An electronic board:** Mounted on Hannes, it receives sensors signals, including the video camera, and performs basic computation, like the pre-processing of the images before sending them to the AI machine.
- **A video camera:** To collect images during the user movement, to predict the correct grasp. The camera needs to be embedded either into the palm or into the wrist of Hannes. This integration is realized by the HSP and Rehab in collaboration.
- **GPU-enabled server:** For the deployment of the DL based methods, a specialized server with recent multicore CPU and enough RAM and a powerful GPU is required. In preliminary phases of the project, powerful local laptops or workstations will be used to simulate it.

Regarding instead the software part, the main components are:

- **Signal pre-processing modules:** The signals coming from the different sensors, including the video camera, embedded into the prosthesis, will be pre-processed and prepared before being sent via radio to the GPU-enabled server. This will run on the electronic board mounted on Hannes.
- **A DL based control system** from the HSP group: This component is a software module which relies on a DL earning based trained models to process the images coming from the camera on the palm of the hand and predict the necessary adjustments to the Hannes' joints in order to complete the grasp. The different submodules of this component will run on the GPU-enabled server and will use the Yarp middleware for communications between them.
- **Direct control system for Hannes joints:** This module directly controls the movements of the different joints of the prosthesis according to the predictions of the DL based control system. This will run on the electronic board mounted on Hannes.

3.4.4 Trial description

The aim of UC9 is to demonstrate that it is possible to improve the user experience using a prosthetic arm, leveraging on radio connectivity to provide sufficient computing power to deploy recent AI methods on the prosthesis with high reliability and minimal latency. The system will be validated with experiments on the field with the Hannes prosthetic arm. The system performance will be verified in both laboratory and field tests, in terms of accuracy, reliability and efficiency.

The demonstration will consist of different ESs, where users grasp different objects, placed on a table, with different approaching directions. Each grasping trial will be structured as follows:

- A user, handling the prosthesis (by means of the external able-bodied adapter), stands in front of the object to grasp, placed on a table (see Figure 19).

- After a starting trigger (for this analysis, a keyboard signal or an EMG signal from the user will be considered), the user approaches the object, moving the prosthesis towards it as to grasp it. The approach lasts ~2 seconds and the system collects RGB frames from the camera mounted on the prosthesis.
- These frames are firstly sent from the video camera to the embedded electronic board (through USB connection) and then from the board to the DNN-based methods in the AI machine through 5G connectivity.
- DNN-based method processes the received signal and the pre-shape is predicted after ~2 seconds.
- The pre-shape class is converted into the corresponding thumb configuration.
- The thumb configuration is sent by means of 5G connectivity to the embedded electronic board which translates it into control signals for the joints.
- Next, the pre-shape is executed and then the fingers close around the object

Figure 19. Trial setup for the execution of a prosthetic object grasping.

The application developed for this use case will be tested at two different levels:

- **Application level:** The grasping success rate can be measured to evaluate the effectiveness of the developed system to help users in grasping objects with the prosthesis.
- **User level:** The experience of the users can be taken into consideration to evaluate how the network connection impacts on the execution of the different movements and on the reactiveness of the prosthesis. This can be measured through a questionnaire.

As described in the previous section, the use case will be first implemented and tested in a laboratory context, while the final trial phase will take place in Pisa. Two experimental trial sites will be considered for this Use Case. The first site will be in the Ericsson R&D laboratories in Genoa. This site will be used for the first phase of the use case implementation to test the developed prototypes and their integration until an advanced level of readiness of the system. The trials will follow the steps described above and will be used to refine the design of the architecture and of the required 5G network infrastructure as well as to tune all the different components. The trials will be done in two different time span with the following objectives:

- In the first months, the aim is to try the different components together with a preliminary mock-up, simulating the components that are still not available and setup baselines that will be used at later stages of the project.
- At a later stage, these trials will be used to test the developed prototypes and their integration until an advanced level of readiness of the system.

The second site will be the CNR premises in Pisa. This site will be used for the final trial of the use case to test the integrated system. The trial will be executed following the steps as reported in the previous sections and will be used to evaluate the performance of the system using the described metrics. More details about the trails setup and UC9 trial can be found in Table 9.

Table 9. UC9 trial description.

<table>
<tr><th>Trial ID / Name</th><th colspan="2">Trial 9.1 / Adaptive Control of Hannes Prosthetic Device</th></tr>
<tr><th>Infrastructure / Venue</th><th colspan="2">Ad-hoc 5G indoor coverage / Central hospital hub in Pisa</th></tr>
<tr><td>Description</td><td colspan="2">This use case involves the design of advanced control capabilities for the Hannes prosthesis based on AI techniques. The aim is to improve the user experience using the prosthesis, leveraging on 5G connectivity to provide sufficient computing power to deploy recent AI methods with high reliability and minimal latency on the prosthesis.</td></tr>
<tr><td rowspan="2">Components and Configuration</td><td>Components</td><td>The main HW components for the application will be: (i) the Hannes prosthesis, (ii) an embedded USB camera, (iii) an embedded electronic board and (iv) a GPU-enabled machine to run the DL based application.

The main software components for the application will be: (i) Signal pre-processing modules, (ii) a DL based control system and (iii) a Direct control system for Hannes joints.</td></tr>
<tr><td>Configuration</td><td>The main components of the network will be: (i) a RAN composed of NR radios and basebands (Digital Unit) connected to the transport layer, (ii) Routers to implement backhaul and fronthaul and optimized baseband/radio interconnection and (iii) the core components (e.g., the SMF, the PCF, the NEF, etc).</td></tr>
<tr><td rowspan="2">Trial procedure</td><td>Pre-conditions</td><td>• 5G Network up and running.
• User Equipment (e.g., 5G Dongle) with dedicated sim to attach to the 5G Network.
• Server to run Fondazione Istituto Italiano Di Tecnologia’s (IIT) AI-based control algorithms (e.g., on Virtual Machine).
• Hannes prosthesis with embedded camera and electronic board, connected to the UE via USB.</td></tr>
<tr><td>Trial steps</td><td>• A user, handling the prosthesis stands in front of the object to grasp, placed on a table.
• Check that all components are correctly connected.
• After a starting trigger, the user approaches the object, moving the prosthesis towards it as to grasp it. The system collects RGB frames from the embedded camera.
• These frames are firstly sent from the video camera to the embedded electronic board and then from the board to the AI machine through 5G connectivity.
• DNN-based method processes the received signals from the prosthesis and the pre-shape is predicted after ~2 seconds. This is converted into the corresponding thumb configuration which is sent by means of 5G connectivity to the embedded electronic board which translates it into control signals for the prosthesis joints.</td></tr>
</table>

		• The pre-shape is executed and the fingers close around the object.
Measurements	Methodology	The test should be repeated from 2 to 5 times for each different grasp type for each object considered in the experimentation. The system performance will be measured during the execution of the grasp sequences. Finally, the user will be asked, e.g., through a questionnaire, feedback on the user experience of the system.
	Complementary measurements	Not defined
	Calculation process	The *grasping success rate* can be considered as a measure to evaluate the system usability. This is the measure of the number of successful grasps executed on the total number of attempts. The user experience will be measured by considering the user's answers from the given questionnaire.
Expected Result	The 5G connectivity is expected to be exploited to help the user perform smooth grasping movements with limited latency, resulting in a high success rate and good feedback on the user experience.	

The trial description reported in Table 9 is intended to be complemented with the specific KPIs and KVIs definition and measurements reported in section 4.4.2.

4 Technical requirements and evaluation methodology

This section provides the technical requirements and the evaluation methodologies that will be addressed by each use case of WP4.

4.1 UC6: Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area (Athens/Madrid)

4.1.1 Preliminary technical requirements

The preliminary technical requirements of UC6 are reported in Table 10.

Table 10. Preliminary technical requirements for UC6.

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

4.1.2 KPIs/KVIs definition and measurement

The relevant KPIs for Scenario 1 and 2 and KVIs of UC6 are described in Table 11, Table 12 and Table 13, respectively. The KPIs and KVIs are evaluated based on activities described in the trial description section of UC6. The KPIs and KVIs for this use case are aimed at achieving optimal performance with the current technology available. In cases where the technology is currently not affordable, the aim is to set a benchmark for future network evolution. As for KPIs, throughput measurements will be collected via probes, iPerf [24] and Ookla [25]. Latency measurements will be collected at the application layer by adding timestamps to requests between functional entities/service components of the overall application. Then the difference in time will be calculated between the request from one entity (e.g., client) and the response from the other entity (e.g., server). Additional measurements will also be collected e.g., with the use of iPerf. Location accuracy will be measured as the difference between the position to which a device (e.g., robot) is directed and the actual position where it ends up and the difference between the position of a device estimated by the overall system and the actual position. Service availability will be measured by measuring the packet loss rate at the application layer (packets that arrive delayed or erroneous are considered as lost packets). Service reliability will be calculated based on packet loss and round-trip time (RTT) latency measurements.

Table 11. KPIs of UC6 for the MCI.

KPI name	Description/KPI definition	KPI target
Downlink throughput per device	The amount of data that can be transmitted over the network in a certain amount of time	50Mbps (min), 150Mbps
Uplink throughput per device	The amount of data that can be transmitted over the network in a certain amount of time	10Mbps (min), 30 (recommended)
App latency (glass to glass)	Delay between the image captured by the camera and it showed in the screen of the user device	800 msec
Location accuracy	Accuracy in the positioning of the device	5 meters
Latency	Round-trip time for successful delivery of a packet from transmitter (e.g., device) to receiver (e.g. dashboard) plus the time it takes to send the response back.	10-100 msec
Service availability	Capability of transmitting a given amount of traffic within a predetermined time duration with high success probability (calculated based on packet loss)	99.999%
Service reliability	Success probability of transmitting a layer 2/3 packet within a maximum latency required by the targeted service (ITU-R M.2410)	99.999%

Table 12. KPIs of UC6 for the Evacuation.

KPI name	Description/KPI definition	KPI target
RTT latency	Delay between the image captured by the camera and it showed in the screen of the user device	15 msec
Downlink Throughput	The amount of data that can be transmitted over the network in a certain amount of time	500 Mbps
Uplink Throughput	The amount of data that can be transmitted over the network in a certain amount of time	250 Mbps
Service availability	Capability of transmitting a given amount of traffic within a predetermined time duration with high success probability (calculated based on packet loss)	99.999%
Service Reliability	Success probability of transmitting a layer 2/3 packet within a maximum latency required by the targeted service (ITU-R M.2410)	99.999%
Location Accuracy	Accuracy in the positioning of the device	5 m

Table 13. KVIs of UC6 (for both MCI and Evacuation).

KVI name	Description/KVI definition	Value
User experience	Perceived easiness of the experience	The users evaluating the system in test session and expressing positive evaluation
Trustworthiness	The extent to which a system is reliable, secure and safe, and inspires confidence in its users.	The users evaluating the system in test

		session and expressing positive evaluation
Resilience	Reported confidence in the reliability of the devices, network and over-the-top developed services and applications	The users evaluating the system in test session and expressing positive evaluation regarding the reliability of the devices, network, developed applications and services

4.2 UC7: Remote Proctoring

4.2.1 Preliminary technical requirements

The preliminary technical requirements of UC7 are reported in Table 14. Refer to Figure 11 to identify the devices in the UC7 scenario.

Table 14. Preliminary technical requirements for UC7.

Device Type	Requirements	Target
Expert Proctor Workstation	Downlink rate from remote camera on smart glasses of trainee	5 Mbps for 1080p streaming With packet loss < 1%
Expert Proctor Workstation	Downlink network latency from smart glasses of trainee	This latency will be evaluated during preliminary lab tests
Expert Proctor Workstation	Downlink rate of remote room camera video	5 Mbps for 1080p streaming 10 Mbps for 4K streaming With packet loss < 1%
Expert Proctor Workstation	Downlink network latency from remote room camera	This latency will be evaluated during preliminary lab tests
Expert Proctor Workstation	Downlink rate of remote clinical info video	5 Mbps for 1080p streaming 10 Mbps for 4K streaming With packet loss < 1%
Expert Proctor Workstation	Downlink network latency from clinical info video	This latency will be evaluated during preliminary lab tests
Smart Glasses	Uplink latency from expert proctor workstation to trainee smart glasses	50 ms (maximum)

4.2.2 KPIs/KVIs definition and measurement

The relevant KPIs and KVIs, related to network domain of UC7, are described in Table 16 and Table 17, respectively. The KPIs and KVIs are evaluated based on activities described in the trial description section of UC7. The KPIs and KVIs for this use case are aimed at achieving optimal performance with the current technology available. In cases where the technology is currently not affordable, the aim is to set a benchmark for future network advancements.

As for KPIs, Table 14 provides rough estimates on the target performance needed to roll out the experimentation: it is worth mentioning that the numbers could be subjected to revision and refinement. The throughput can be evaluated using iPerf tool.

To measure latency, lab tools will be used to measure the transmission delay using a RTT (round-trip time) loop with packets labelled with timestamps. Note that the specific open-source software tool TC – NETEM [26] has been already deployed to introduce latency in the transmission link and to determine the maximum tolerated latency for the specific application of UC7.

The availability parameter refers to the percentage of time during which the radio network ensures the support of the services with the expected QoS. It is the ratio between the up time of the radio link over the total time of the radio link is planned to operate. As the expected availability is in the order of "five-nines", an in-field measurement would require at least one year of continuous test to intercept an "out of order" time with a statistical meaning. In addition, the radio system in the pilot is not a 1+1 (full redundancy) for cost reasons while, typically, a real deployment would have a full 1+1 redundancy. The measurements in the pilot area would bring to availability values poorer than more realistic commercial deployments.

Concerning the KVIs, the subject evaluation of the user about the telepresence experience will be collected by a tailored structured questionnaire ("Subjective network quality assessment questionnaire", see Table 15) after each ES.

Table 15. Subjective network quality assessment questionnaire.

Have you noticed a lag or breakdown in connection during telepresence connection for surgery?	Y/N
Did network disconnections occur during telepresence connection for surgery?	Y/N
Have you noticed connection slowdowns during telepresence connection for surgery?	Y/N
Have you experienced symptoms of motion sickness, such as vomiting, nausea, dizziness, etc.?	Y/N
Do you usually suffer from it?	Y/N
How would you rate the fluidity of the images broadcast during the telepresence connection for surgery?	1-10
How do you rate your level of immersion (i.e., the perception of being physically present) during the telepresence connection for surgery?	1-10
How do you rate the quality of telepresence connection for surgery overall?	1-10
How do you rate the experience of using telepresence connection for surgery as a whole?	1-10

Table 16. KPIs of UC7.

KPI name	Description/KPI definition	KPI target
Downlink throughput	Downlink cumulative throughput from glasses/cameras located in the remote hospital to the expert proctor workstation located in the hub hospital considering that the video flows specified in Table 14	25 Mbps
Downlink latency	The transmission delay from the video sources at the remote hospital to the expert proctor workstation at the hub hospital.	This latency will be evaluated during preliminary lab tests. During test sessions, specific software tools will be used to introduce additional delay up to the maximum tolerable amount, to determine the highest acceptable delay that

		will be used as a threshold value for this target.
Uplink latency	Uplink latency from expert proctor workstation to trainee smart glasses	50 ms
Availability	The unavailability time must be as low as possible (approximately 0). The system availability includes the availability of all the important elements such as the medical instruments and the connectivity infrastructure. "Five nines" availability is especially important for healthcare applications and emergency services, where even a short period of downtime can have serious consequences.	The service should be available for use 99.999% of the time (i.e. "five-nines"), which equates to a downtime of five minutes and 15 seconds per year.

Table 17. KVIs of UC7.

KVI name	Description/KVI definition	KVI target
Improved user experience	The ability of the remote proctoring system, if combined with a 5G network, to improve the experience of the remote proctor to instruct remote trainees from a central hub hospital to at least one remote hospital and of the trainees to receive and apply instructions and guidance from the proctor.	Doctors and trainees of the partner's hospitals evaluating the system in practical test sessions and expressing positive evaluation.
Realistic telepresence	The ability of the 5G connectivity to enhance the perceived realism and effectiveness of remote proctoring systems by ensuring that every person involved in the training session has a clear and direct understanding of the proctor's instructions and feedbacks, as if the proctor were on-site.	Doctors and trainees of the partner's hospitals evaluating the system in practical test sessions and expressing positive evaluation.

4.3 UC8: Smart Ambulance

4.3.1 Preliminary technical requirements

The preliminary technical requirements of UC8 are reported in Table 18. Refer to Figure 14 to identify the devices in the UC8 scenario.

Table 18. Preliminary technical requirements for UC8.

Device Type	Requirements	Target
Camera	Uplink data rate from ambulance camera to emergency unit room	5 Mbps for 1080p streaming 10 Mbps for 4K streaming With packet loss < 1%
Echocardiograph	Uplink data rate from echocardiograph in ambulance to emergency unit room	5 Mbps for 1080p streaming With packet loss < 1%

Smart Glasses	Downlink data rate from emergency unit room to the AR glasses in ambulance	5 Mbps for 1080p streaming With packet loss < 1%
Smart Glasses	Downlink latency from emergency unit room to the AR glasses in ambulance	This latency will be evaluated during preliminary lab tests During test sessions, specific software tools will be used to introduce additional delay up to the maximum tolerable amount, to determine the highest acceptable delay that will be used as a target for this target.

4.3.2 KPIs/KVIs definition and measurement

The relevant KPIs and KVIs related to network domain of UC8 are described in Table 19 and Table 20, respectively. The KPIs and KVIs are evaluated based on activities described in Trial description section of UC8. The KPIs and KVIs for this use case are aimed at achieving optimal performance with the current technology available. In cases where the technology is currently not affordable, the aim is to set a benchmark for future network advancements.

As for KPIs, Table 19 provides rough estimates on the target performance needed to roll out the experimentation: as in UC7, it is worth mentioning that the numbers could be subjected to revision and refinement. The throughput can be evaluated using iPerf tool. To measure latency, lab tools can be used to measure the transmission delay using a RTT (round-trip) loop with packets labelled with timestamps.

As for availability, the same considerations expressed for UC8 are also valid for UC9.

Table 19. KPIs of UC8.

KPI name	Description/KPI definition	KPI target
Uplink throughput	Uplink cumulative throughput from camera, echocardiograph and smart glasses located inside the ambulance to the emergency unit located in the hospital considering that the video and data flows specified in Table 18.	25 Mbps
Downlink latency	The transmission delay from the video sources at the remote hospital to the expert proctor workstation at the hub hospital.	This latency will be evaluated during preliminary lab tests. During test sessions, specific software tools will be used to introduce additional delay up to the maximum tolerable amount, to determine the highest acceptable delay that will be used as a threshold value for this target.
Uplink latency	Uplink latency from expert proctor workstation to trainee smart glasses	50 ms
Availability	The unavailability time must be as low as possible (ideally 0). The system availability includes the availability of all the important elements such as the medical instruments and the connectivity infrastructure. “Five nines” availability is especially	The service should be available for use 99.999% of the time, which equates to a downtime of five minutes and 15 seconds per year.

	important for healthcare applications and emergency services, where even a short period of downtime can have serious consequences.	

Table 20. KVIs of UC8.

KVI name	Description/KVI definition	KVI target
Affordable and stable communication up to high vehicle speeds	Thanks to the 5G connectivity, the system should be capable of streaming video from a camera inside the ambulance towards the hospital without any interruptions or degradation in quality, even while the ambulance is in motion at a high vehicle speed through an urban or rural scenario. It should also be able to transmit large amounts of data quickly, such as echocardiography data.	Operators on ambulance and remote experts evaluating the system in demo session and expressing positive evaluation
Improved augmented reality experience for remote guidance	By leveraging on a low latency affordable communication, the augmented reality experience in the ambulance should be seamless, allowing emergency staff to perform advanced procedures guided by instructions from the hospital (for example in using the echocardiograph). This is in response to the video streaming and diagnostic data previously transmitted from the ambulance to the emergency unit.	Operators on ambulance and remote experts evaluating the system in demo session and expressing positive evaluation

4.4 UC9: Adaptive Control of Hannes Prosthetic device

4.4.1 Preliminary technical requirements

The preliminary technical requirements for UC9 are mainly related to:

- **Latency.** This parameter is important for UC9 since a high latency would affect the prosthesis control reactiveness and smoothness and consequently the execution of the different movements that should rapidly adapt to user intents variations.
- **Uplink Throughput.** This parameter is important for UC9 since images need to be sent at high frame rates from the electronic board embedded into the prosthesis to the AI machine. This will be better characterized in the first months of the project during the lab trials. Specifically, different compression levels will be experimented to verify the impact on the overall E2E process.

Specifically, the main preliminary technical requirements are reported in Table 21.

Table 21. Preliminary technical requirements for UC9.

Device Type	Requirements	Target
Prosthesis	Maximum latency	90 ms (might be updated during lab trials)
Prosthesis	Maximum number of packets lost:	Will be defined during lab trials

Prosthesis	Throughput min (up and down):	60 Mbps (might be updated during lab trials)
Prosthesis	Throughput recommended	90 Mbps (might be updated during lab trials)
Prosthesis	Number of users connected to the prosthesis	Max. 2 users. 1 supervisor operator, 1 User of the prosthesis
Prosthesis	Cybersecurity	VPN tunnel is required (ideal VPN IPSec) (to be confirmed)
Prosthesis	Recommended latency	10 ms (might be updated during lab trials)
Embedded camera	Throughput min	Min 40 Mbps (might be updated during lab trials)

4.4.2 KPIs/KVIs definition and measurement

This UC foresees the use of upper limb prostheses that is equipped with sensors providing images of the environment and EMG measuring the muscle activation of the user. This information is sent to a server where AI methods are used to control the prosthesis device to interpret the user's grasp intention and control the wrist and thumb accordingly. All these sensors stream information at high frame rates and convey useful information for the online prosthesis control; for this reason, high and stable data rates are required. At the same time, the control system is requested to be reactive to the user's intention changes and modifications of the surrounding environment. The required computation is going to be de-localized at the edge of the Network and for this purpose an ultra-reliable low latency connection is required.

The most relevant KPIs for UC9 are:

- **Latency:** it will be measured using ping between the probes A and B positioned as reported Figure 20
- **Uplink throughput**: it will be measured using the tool iPerf between the probes A and B positioned as reported Figure 20

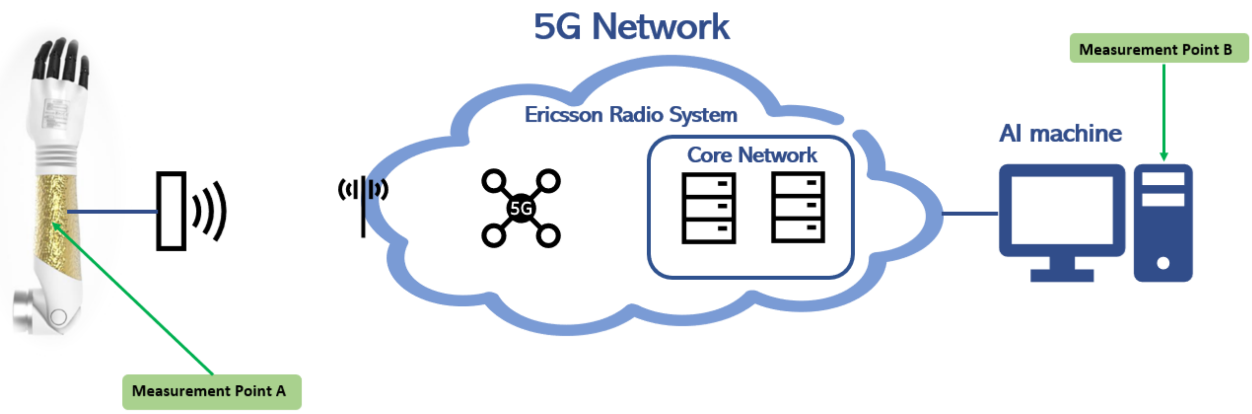

Figure 20. UC9 Adaptive Control of Hannes Prosthetic Device architecture and probes positioning.

The KPIs and KVIs for this use case are aimed at achieving optimal performance with the current technology available. In cases where the technology is currently not affordable, the aim is to set a benchmark for future network evolution.

The most relevant KPIs and KVIs for UC9 are reported in Table 22 and Table 23, respectively. The KPIs and KVIs are evaluated based on activities described in Trial description section of UC9.

Table 22. KPIs of UC9.

KPI name	Description/KPI definition	KPI target
Uplink throughput	Uplink cumulative throughput from the prosthesis located in the remote hospital to the AI machine.	90 Mbps (might be updated during lab trials)
Roundtrip latency	The transmission delay from the prosthesis to the AI machine.	10 ms
Availability	The unavailability time must be as low as possible (approximately 0). The system availability includes the availability of all the important elements such as the components and the connectivity infrastructure. “Five nines" availability is especially important for healthcare applications and emergency services, where even a short period of downtime can have serious consequences.	The service should be available for use 99.999% of the time, that equates to a downtime of 5 minutes and 15 seconds per year.
Reliability	Reliability accounts for the percentage of packets properly received within the given maximum E2E latency (One way Time Trip (OTT) or RTT depending on the service.	99%

Table 23. KVIs of UC9.

KVI name	Description/KVI definition	KVI target
System success rate	This family of KVI is related to the effectiveness of the developed system to help users in grasping objects with the prosthesis. This can be measured firstly using the *grasping success rate* of users grasping objects. It is the measure of the number of successful grasps executed on the total number of attempts. Another metric to evaluate the effectiveness of the proposed approach is the *accuracy* of the DL based system used in the considered experimental settings (the lab site and the Pisa site).	Prosthesis users evaluating the system in practical test sessions and expressing positive evaluation.
Experience of the users	Another important measure is the experience of the prosthesis users. This evaluates how the network connection impacts on the execution of the different movements and on the reactiveness of the prosthesis. This can be measured through questionnaires.	Prosthesis users evaluating the system in practical test sessions and expressing positive evaluation.

5 Implementation time plan

This section defines the time plan related to the implementation of the use cases. The Table 24 summarizes the overall WP4 time plan in terms of the milestones that are defined for each use case in the following sub-sections.

Table 24. Overall WP4 time plan for use cases implementation.

	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
UC6		MS1		MS2				MS3			MS4	
UC7		MS1		MS2				MS3			MS4	
UC8		MS1				MS2		MS3		MS4		
UC9				MS1			MS2			MS3		

5.1 UC6: Mass Casualty Incident (MCI) and Emergency Rescue in Populated Area (Athens/Madrid)

The time plan of UC6 in Athens site is reported in Table 25. For what concern the UC6 in Madrid there is no a specific time plan since the same application developed for Athens will be used in conjunction with the trial activities and related time plans of UC1 [5] and UC10 [6].

Table 25. Time plan for UC6.

	Activities	Description	Use Case Milestone	Time plan
1	**UC definition**	A pre-trial phase to lay the foundations of the activities and the definition of UC	MS1	Q2 2023
2	**Devices**	HW acquisition of end devices (headset, telepresence system)	MS2	Q4 2023
3	**Infrastructure design**	Design infrastructure for Athens site		
4	**Device lab testing**	Set-up and lab testing of HW and end devices		
5	**Infrastructure deployment**	Deployment and set-up of network infrastructure for Athens site	MS3	Q3 2024
6	**Devices integration**	Integration of HW and end devices into network infrastructure		
7	**Initial demonstration**	Initial UCs demonstrations		Q4 2024
8	**Trials execution**	Uses case trials scenario deployment	MS4	Q3 2025
9	**KPI and KVI collection**	KPI and KVI collection		

The milestones of UC6 are:

- **MS1** (Q2 2023): This milestone involves the definition of the trial, user needs and technical needs. The aim is to obtain a specific description of all the activities/tasks of UC6.

- **MS2** (Q4 2023): This milestone involves the design of technical tools needed to UC6. The main aim is the design of the network infrastructure. The HW and technical tools of telepresence system will be acquired, set-up and tested.
- **MS3** (Q4 2024): This milestone involves the development, set-up and integration of network infrastructure and devices.
- **MS4** (Q3 2025): This milestone involves the execution of control and ESs of the trial.

5.2 UC7: Remote Proctoring

The time plan of UC7 is reported in Table 26.

Table 26. Time plan for UC7.

	Activities	Description	Use Case Milestone	Time plan
1	**UC definition**	A pre-trial phase to lay the foundations of the activities and the definition of UC	MS1	Q2 2023
2	**Devices**	HW acquisition of end devices (headset, telepresence system…)	MS2	Q4 2023
3	**Infrastructure design**	Design infrastructure for Pisa and Massa site		
4	**Device lab testing**	Set-up and lab testing of HW and end devices		
5	**Infrastructure deployment**	Deployment and set-up of network infrastructure for Pisa and Massa site	MS3	Q3 2024
6	**Devices integration**	Integration of HW and end devices into network infrastructure		
7	**Initial demonstration**	Initial UCs demonstrations		Q4 2024
8	**Trials execution**	Uses case trials scenario deployment	MS4	Q3 2025
9	**KPI and KVI collection**	KPI and KVI collection		

The milestones of UC7 are:

- **MS1** (Q2 2023): This milestone involves the definition of the trial, user needs and technical needs. The aim is to obtain a specific description of all the activities/tasks of UC7.
- **MS2** (Q4 2023): This milestone involves the design of technical tools needed to UC7. The main aim is the design of the network infrastructure. The HW and technical tools of telepresence system will be acquired, set-up and tested.
- **MS3** (Q4 2024): This milestone involves the development, set-up and integration of network infrastructure and devices.
- **MS4** (Q3 2025): This milestone involves the execution of control and ESs of the trial.

5.3 UC8: Smart Ambulance

The time plan of UC8 is reported in Table 27.

Table 27. Time plan for UC8.

	Activities	Description	Use Case Milestone	Time plan
1	**UC definition**	A pre-trial phase to lay the foundations of the activities and the definition of UC	MS1	Q2 2023
2	**Devices**	HW acquisition of end devices (headset, echo-cardiograph,…)	MS2	Q4 2023
3	**Infrastructure design**	Design infrastructure for Pisa and Massa site		
4	**Device lab testing**	Set-up and lab testing of HW and end devices		Q2 2024
5	**Infrastructure deployment**	Deployment and set-up of network infrastructure for Pisa and Massa site	MS3	Q4 2024
6	**Devices integration**	Integration of HW and end devices into network infrastructure		Q1 2025
7	**Trials execution**	Uses case trials scenario deployment	MS4	Q2 2025
8	**KPI and KVI collection**	KPI and KVI collection		Q2 2025

The milestones of UC8 are:

- **MS1** (Q2 2023): This milestone involves the definition of the trial, user needs and technical needs. The aim is to obtain a specific description of all the activities/tasks of UC8.
- **MS2** (Q4 2023): This milestone involves the design of technical tools needed to UC8. The main aim is the design of the network infrastructure. The HW and technical tools of telepresence system will be acquired, set-up and tested.
- **MS3** (Q1 2025): This milestone involves the development, set-up and integration of network infrastructure and devices.
- **MS4** (Q2 2025): This milestone involves the execution of the demo of the trial.

5.4 UC9: Adaptive Control of Hannes Prosthetic device

The time plan of UC9 is reported in Table 28.

Table 28. Time plan for UC9.

	Activities	Description	Use Case Milestone	Time plan
1	**Single components**	Development and refinement of single HW and SW modules/components	MS1	End Q2 2023
2	**First integration**	Preliminary integration at Ericsson		End Q3 2023
3	**Baselines definition**	Second step of integration and tests at Ericsson and baselines definition.		End Q4 2023
4	**Components refinement**	Refinement according to tests results	MS2	Mid Q3 2024

5	**Advanced integration**	Advanced integration and tests at Ericsson		End Q3 2024
6	**Network performance**	Network advanced test at Ericsson and performance record (including KPI collection)	MS3	Mid Q2 2025
7	**Trials in Pisa**	Trials execution at the Pisa Site (including KPI and KVI collection)		End Q2 2025

The milestones of UC9 are:

- **MS1** (Q4 2023): This milestone involves the accomplishment of the first three activities described in the Time plan. The main aim is to develop a first version of the required components and define the baselines of the system.
- **MS2** (Q3 2024): This milestone involves the accomplishment of the fourth and fifth activities described in the Time plan. The main aim is to refine the developed components according to the first results and perform integration tests.
- **MS3** (Q2 2025): This milestone involves the accomplishment of the last two activities described in the Time plan. The main aim is to record the performance of the system in the two trials sites considered for this UC (i.e., Ericsson laboratories in Genoa and the Pisa site).

6 Conclusions

This deliverable defined the use case that will be implemented by TrialsNet in the eHE domain in thecontext of the Greek, Spanish and Italian clusters. For each use case, the document provides the related specific requirements, as they are defined by the relevant verticals in collaboration with the application developers. This document builds on those requirements and the initial architecture blueprint for each of the trial sites, providing a high-level overview of the trials to be conducted in Madrid, Athens, and Pisa.

Furthermore, the document provides an overview of the application design, infrastructure components and functionalities, preliminary technical requirements, and evaluation methodology (in terms of KPIs/KVIs definition and measurement), planning and experimentation procedures for each use case. The technical requirements that have been defined for each use case, will be an input to the platform and network solutions to be designed and deployed in WP2. In addition, the document also reports use cases' implementation and testing procedures, to be used as input towards WP6 together with the measurements that will be performed during the trial phase. It aims to provide insights into the network needs for supporting the planned services and evaluating user satisfaction. Although the four WP4 use cases only provide a focused view of the potential innovations that could be brought about by B5G/6G technologies in the eHE domain, they provide comprehensive analyses addressing feasibility and main benefits of the four use cases, which could gain other applications as well.

This deliverable is the first step towards the implementation of the use case which preliminary results will be captured in the second deliverable D4.2 "First results of Use cases implementation for eHE domain". An initial time plan and main milestones per use case towards the completion of the trials planning has been defined, pointing out the various activities to be carried out for each UC progress and the associated tests of the B5G/6G technologies. One of the main expected results of the trials activities, will be to understand which are the limitations of the current network solutions and related technologies, and from there derive new requirements towards the next generation mobile networks.

Acknowledgment

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

References

[1] https://trialsnet.eu
[2] TrialsNet Deliverable D1.1, "Project Management Handbook", 31 March 2023
[3] TrialsNet Deliverable D8.1, "H - Requirement No.1", 31 March 2023
[4] TrialsNet Deliverable D1.2, "Ethics Assessment Plan", 31 March 2023
[5] TrialsNet Deliverable D3.1, "Use Cases definition for Infrastructure, Transportation and Safety & Security (ITSS) domain", 30 April 2023
[6] TrialsNet Deliverable D5.1, "Use Cases definition for Culture, Tourism and Entertainment (CTE) domain", 30 April 2023
[7] https://www.wings-ict-solutions.eu/startlit/
[8] http://www.5tonic.org/
[9] https://ardupilot.org/copter/docs/common-pixhawk-overview.html
[10] https://www.flir.eu/products/a35/
[11] https://clearpathrobotics.com/jackal-small-unmanned-ground-vehicle/#
[12] https://hardware.iot.telekom.com/document/4441/Quectel_RM500Q-AE_5G_Specification_V1.2
[13] https://www.fixposition.com/news/frankfurt-fixposition-vision-rtk2-outperforms-rtk-gnss-only-solution
[14] https://www.samsung.com/s10/
[15] https://www.linkedin.com/company/aitaer-technology-co-ltd/
[16] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/end-to-end-network-slicing-orchestration
[17] 5GROWTH D3.6: "Execution report of in-house use cases for Pilots".
[18] Vasile, F., Maiettini, E., Pasquale, G., Florio, A., Boccardo, N., & Natale, L. (2022, October). Grasp Pre-shape Selection by Synthetic Training: Eye-in-hand Shared Control on the Hannes Prosthesis. In 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 13112-13119). IEEE.
[19] Sandler, M., Howard, A., Zhu, M., Zhmoginov, A., & Chen, L. C. (2018). Mobilenetv2: Inverted residuals and linear bottlenecks. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 4510-4520).
[20] Russakovsky, O., Deng, J., Su, H., Krause, J., Satheesh, S., Ma, S., ... & Fei-Fei, L. (2015). Imagenet large scale visual recognition challenge. International journal of computer vision, 115, 211-252.
[21] Laffranchi, M., Boccardo, N., Traverso, S., Lombardi, L., Canepa, M., Lince, A., ... & De Michieli, L. (2020). The Hannes hand prosthesis replicates the key biological properties of the human hand. Science robotics, 5(46), eabb0467.
[22] https://rehab.iit.it/
[23] https://www.iit.it/it/web/humanoid-sensing-and-perception/home
[24] https://iperf.fr/
[25] https://www.ookla.com/
[26] https://www.linux.org/docs/man8/tc-netem.html