5G-SHEAL

5G- enabled Surgery Planning with Holograms and Educational Streaming for NKUA Aretaieio Hospital

D2.1 Requirements Analysis & Use Case Definition

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Executive Summary

The document addresses the detailed description of the UC scenarios, driven by the Healthcare and Education (Medical Training) domains, which are considered of high added value SGIs by the consortium members. The requirements as perceived by the users are presented and the network KPI targets are also discussed and agreed. This document will serve as a reference for the upcoming network architecture, configuration, and testing activities as well as a starting point for the specific applications and services scenarios to be validated.

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List of Acronyms and Abbreviations

TERM	DESCRIPTION
2D/3D	Two dimensional/Three dimensional
5G	Fifth Generation
5G-PPP	5G Infrastructure Public Private Partnership
5G-SA	5G Stand Alone
6G	Sixth Generation
AI	Artificial Intelligence
AR/VR/XR	Augmented Reality/Virtual Reality/Extended Reality
CEF	Connecting Europe Facility
DICOM	Digital Imaging and Communications in Medicine
EC	European Commission
ECG	Electrocardiogram
EU	European Union
IEEE	Institute of Electrical and Electronics Engineers
KPI	Key Performance Indicator
MPN	Mobile Private Network
MR	Mixed Reality
MRI	Magnetic Resonance Imaging
PET-CT	Positron emission tomography–computed tomography
RAN	Radio Access Network
SGI	Services of General Interest
TMV WG	Test Measurement and Validation Working Group
UC	Use Case
WP	Work Package

1 Introduction

As outlined in the EC's CEF-DIG-2023-5GSMARTCOM-EDGE-WORKS call [1], in order for numerous Services of General Interest (SGIs) [2], [3], to flourish and contribute to economic progress and social cohesion, key enablers are identified, with 5G networks characterized as one of the most crucial ones. The proposed 5G infrastructures should be capable of delivering leading-edge connectivity with characteristics such as Gigabit performance, high-user-density, ubiquitous coverage, capacity to connect IoT devices, low latency, and high reliability.

For healthcare centres in particular according to the above call, "recent studies show that they need networks providing significant bandwidth to cover digital use cases integrating the use of electronic health records, real time medical imaging and patient health monitoring". In addition to that, in an environment such as a hospital, it is important to deploy and manage true low latency 5G infrastructure, through optimized 5G/ and standalone radio systems, and this can be achieved through a combination of physical proximity of control/computing resources and optimisation of the radio air interface.

Although, telemedicine has been widely applied under different circumstances and applications, it faced several difficulties stemming from the limited latency and speed, especially in telesurgery applications [4]. Greece has a complex geographical terrain with plenty of islands and high attitude mountains, making the delivery of medical services in rural areas more challenging. In addition to that, the surgical education for complex cases has almost never been established in rural low volume surgical departments. This makes the delivery of high-tech surgical technologies and exposure to complex surgical cases, to surgical residents limited or absent, that leads to discrimination in access to surgical education between rural and central areas. The latter leads to a plethora of surgical residents' applications to central hospitals that cannot sustain such demand. The net result is increased waiting times for the residents if the wish to apply at high volume surgical departments and limited surgical residency stuff in rural areas. Innovative virtual reality technologies can provide the ideal solution in such cases and enhance the surgical exposure in residents that serve in rural areas.

The strategic objective of the 5G-SHEAL project is to provide high-quality 5G connectivity to the doctors, students and patients of the Aretaieio University Hospital in Athens, Greece to enable efficient, state-of-the-art Healthcare and Education Services of General Interest (SGIs) and to support the deployment of 5G infrastructure as part of the European Gigabit Society EU strategy.

The project will thus facilitate the digital transformation of the Aretaieio University Hospital, improving surgical outcome through better surgical planning, supporting patients' treatment, and advancing medical students' education, and ultimately contribute to the overall advancement of medical services. The project will also contribute to 5G MPN relevant standardisation and regulatory activities.

This deliverable, D2.1, is the first technical deliverable published by the 5G-SHEAL consortium and presents the "Requirements Analysis & Use Case Definition" as defined during the first months of the project. The deliverable is produced as part of the Work Package 2 (WP2) "Requirements, Architecture & Scope of work" and Task 2.1 "Requirements/Security Analysis and Use Case/KPI definition" and marks the completion of the project's milestone MS2 "Use Case definition and target KPIs ready".

In the sections that follow the document presents the detailed requirements analysis of supporting the selected UCs and the expected network performance. The requirements, as determined also by external stakeholders (e.g. health professionals), are mapped to the UC scenarios and translated into technical requirements. This allows for the most appropriate network settings/configurations to be selected. Additionally, the relevant security requirements for the network and its communication with the end-users are identified which will drive the design of the protection and firewall systems to be included in the E2E architecture. Specific targeted KPIs are defined for the network performance. The outputs of this deliverable will be used to create the High- and Low-level Design of the network, and as such will act as input to Task T2.2 "5G End-2-End Architecture and Specifications" and Task T3.1 "Deployment prerequisites (procurement, licensing, etc.)".

The document is public and is addressed to a wide audience and specifically to the:

- project consortium itself, as a documented blueprint of the agreed technical scope and development plans and the means to validate that all objectives and proposed technological advancements have been analysed and, through the identified requirements, the next actions can be concretely derived.
- research community, other 5G projects and funding organisation, to summarise the scope, objectives and intended project innovations, describe the 5G-SHEAL UCs and performance targets together with the identified requirements that must be tackled to achieve the expected results to open the floor for fruitful exchange of opinions and collaboration.
- public, to obtain a better understanding of the framework and scope of the 5G-SHEAL project.

1.1 Structure of the document

The main topics addressed in this deliverable are presented through the following structure:

- Section 2 presents an overview of the project's scope of work, including the key objectives and core technical developments.
- Section 3 presents the demand analysis and requirements for the specifics of the Healthcare and Education SGIs, and correlates this regarding network and services platforms offerings to set the implementation targets. The 5G-SHEAL use cases that are integral to the 5G-SHEAL validation activities are elaborated.
- Section 4 provides concluding remarks and the next steps for facilitating the delivery of a fully operational and validated 5G-SHEAL network by the end of the project.

2 5G-SHEAL Scope of Work

5G-SHEAL project will deploy a 5G-SA Mobile Private Network (MPN) along with the required upgrades in the backhaul equipment, antennas and links to the rest of the network, supporting exclusively and only the needs of the Aretaieio Hospital operating rooms, Surgical Wards, Education centre and Other Departments, providing 5G coverage, high capacity, reduced latency, and high reliability mobile services. All the radio resources of this MPN will be accessible only by the users/devices (e.g. VR/XR glasses or smart wearable devices) equipped with designated SIM provisioned cards. Any other SIM card will be prohibited to access this MPN solution.

Besides the aforementioned works, key activities of the project comprise the specification and execution of use case scenarios for testing and validating the 5G infrastructure, particularly focusing on advanced functionalities such as natural rendering, remote mentoring (demonstrating high-quality real-time streaming capability), through applications related to Patient Monitoring, Surgical Planning, Oncology Imaging in Operating Rooms, Imaging related treatment, Surgical residency core training, Medical Students education and Patients education.

The identified indoor areas are not fully covered by 5G technology, so the investment will help in connecting these areas with cutting edge technologies and supporting demanding (high throughput, low latency) use cases.

5G-SHEAL will also bring benefits to the broader healthcare ecosystem supporting a more rapid cloud-based sharing of large datasets, as in the case of medical imaging, enhancing collaboration and boosting. With 5G the use of innovative user interfaces in augmented and virtual reality environments for clinical and educational purposes can be supported effectively.

Figure 1: 5G-SHEAL – Aretaieio Hospital

Specifically, 5G-SHEAL is set to implement the following objectives:

O1. Deploy a 5G-SA Mobile Private Network (MPN) to support exclusively and only the needs of the 5G-SHEAL for NKUA Aretaieio, providing 5G coverage, high capacity, reduced latency, and high reliability mobile services. All the radio resources of this MPN will be accessible only by the users/devices (eg HoloLens glasses) equipped with designated SIM provisioned cards. Any other SIM card will be prohibited to access this MPN solution. Emergency communication at the hospital (Patient Health Monitoring) will be granted to medical personnel through the 5G MPN and thus guaranteed coverage, connectivity and capacity will be provided in case of an emergency.

O2. Enable and demonstrate advanced Healthcare and Education domain SGIs, such as patients' diagnostic applications and Medical Students and Patients education applications, leveraging the new 5G RAN infrastructure that will be implemented. Training programme will also be provided to the medical professionals to ensure effective utilization of the technology in enhancing healthcare delivery and education.

O3. Support 5G best practices beacons in different sectors that can serve as templates for possible replication with other resources, national or EU Recovery and Resilience Facility (RRF)._Recommendations will be produced towards the realisation of challenging applications in hospitals, focusing primarily on Digital Health and Medical Education services.

O4. Outreach to public audience, key stakeholders, dissemination, standardisation and further exploitation of the project's main achievements with Special focus to the benefits in the Healthcare and Education domains, provision of an end-to-end, 5G-based Healthcare and Medical Education service solution for further commercial exploitation beyond the project completion by project partners and contribution to 5G MPN relevant standardisation and regulatory activities.

High-quality 5G-SA (3.5 GHz) indoor network connectivity will provide coverage in the selected areas The novel 5G RAN base stations will be connected to OTE local MPN transport and 5G-SA Private Core Network (Stand Alone). Cloud and edge computing resources will be provided by WINGS and ApoQlar to support the envisaged services. The network management framework of OTE will provide performance monitoring, proactive/reactive fault management and anomaly detection functionalities of the MPN. The 5G-SHEAL network will be validated through extended amount of measurement data (both on physical/lower layer as well as service-level) to provide statistical confidence and heterogeneity. Furthermore, a detailed analysis of the performance of the 5G deployed infrastructure for various realistic network load conditions and use cases will be performed.

3 5G-SHEAL Use Cases and Requirements

Section 3 sets the strategy to implement the 5G-SHEAL mission to provide 5G network deployments suitable for Healthcare and Education UCs. We will present what are the requirements for each of the services of interest in terms of 5G potential to digitally transform end user services and analyse 5G-SHEAL scenarios for demonstrating these.

The process of identifying the appropriate requirements has included the identification of the key stakeholders that are affected by the requirements considered. These include the end-users, the OTE engineering teams (such as planners, designers, operation teams) as well as the technology solutions providers (WINGS, ApoQlar). The requirements gathered are organised as Technical and User Requirements. Furthermore, the process followed has addressed the full life cycle, design-deploy-operate, towards the appropriate 5G-SHEAL UCs realisation.

The Use Cases described in the next sections reflect the capabilities of the 5G-SHEAL network and applications to serve the needs of the Hospital. The actual implementations on site will be determined during the implementation phases, based on the specific requirements per case and selected out of the scenarios elaborated in the document.

The 5G-PPP TMV WG White Paper “5G PPP Trials Results 2022 - Key Performance Indicators measured in advanced 5G Trial Sites” [5], is used throughout the document as a benchmark with regards to state-of-the-art 5G network capabilities. In [5], not only are 5G KPIs defined and described but also results in terms of performance and validation requirements are summarized and compared for various applications and user communities (e.g. Health, Logistics, PPDR, Smart Cities, etc), covering Europe-wide trials of 5G-based networks.

3.1 Healthcare

5G is selected for its capability to support real time services, high data rates and mass number connected sensors. The sheer capacity of 5G combined with AI, and the capability to transfer and analyse data (near) real-time, can be valuable in understanding the development of disease progression and improving forecasting capabilities. According to a recent study by PwC [6], as use of 5G in healthcare increases, with its applications boosted by advances in robotics, IoT and AI, a new connected healthcare ecosystem will take shape. This ecosystem will align with a relatively recent idea known as 4P medicine—that is, it will be predictive, preventative, personalised and participatory. For even more challenging cases robotic assisted surgery is the next asset in the surgical communities.

Healthcare and life sciences organizations have long invested in individual technologies to advance care and discovery. While targeted solutions continue to provide great value, they are often disconnected from each other, resulting in data silos, disjointed patient experiences, and operational inefficiencies. Digital health represents the convergence between technology and care and is transforming how healthcare is delivered by incorporating technological innovations directly into patient treatment plans. Systems like telemedicine platforms, mobile health applications and cloud-based diagnostic tools connect patients with providers while enabling real-time health monitoring. Furthermore, wearable health trackers and remote monitoring systems also transmit real-time data to healthcare providers, thereby enabling more proactive responses.

Artificial intelligence is reshaping diagnostics, treatment strategies and hospital operations. Machine learning algorithms analyse vast amounts of medical data to provide quicker and more accurate diagnoses. In addition, predictive models use this information to help create tailored treatment plans and improve the quality of care. AI-powered tools can also be used to manage routine tasks such as scheduling or monitoring, allowing healthcare professionals to prioritise critical responsibilities.

All of these advancements reduce administrative workloads, streamline processes and improve clinical outcomes, making AI an essential resource for healthcare organisations facing modern medical challenges.

A key baseline for the project is the work of "Global5G.org for Health", [7] which in association with 5G-PPP, promotes 5G Health use cases, navigates relevant standardisation efforts and timelines, and supports the new e-Health business landscaping. The advent of 5G seamless connectivity with guaranteed levels of performance including low latency, high throughput and reliability, smartphones and mobile apps, cloud services and smart connected devices, can enable distributed, patient-centred delivery at multiple points of care, individualised health information and the ability to track patient health metrics powered by big data analytics.

3.1.1 Use Case H1: Patient health monitoring & emergency situation notification

This use case demonstrates the 5G-SHEAL network capabilities to support the "connected patient", through smart wearable with real time biometric data, HR, SPO2, temp, Blood pressure and GPS position for patients via real-time voice/video communication and 24hrs monitoring center. This case will be validated in the patients wards in the main hospital building, based on WINGS digital health platform **wi.CARE+**[1] (WINGS machine learning for health improvement), (Figure 3).

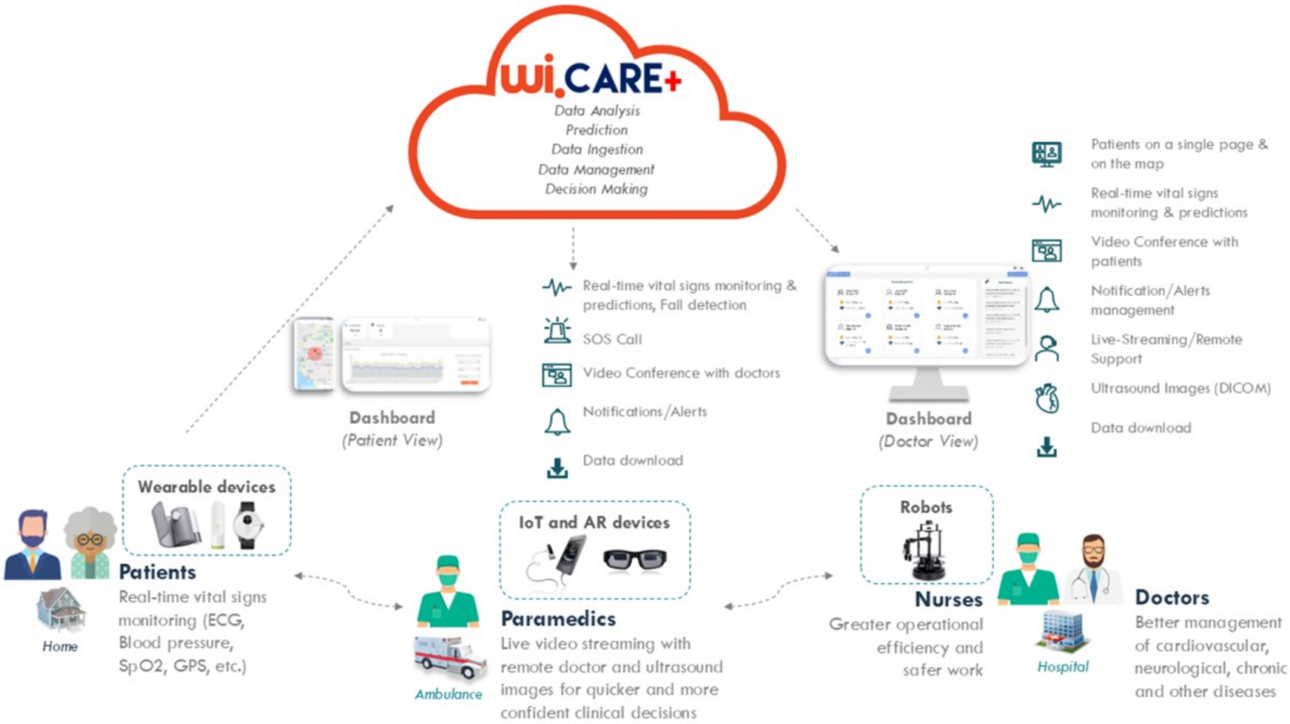


Figure 2 wi.CARE+ platform.

[1] https://www.wings-ict-solutions.eu/wi-careplus/

wi.CARE + supports the simultaneous connection of high-tech and precision devices to monitor vital signs of patients within the hospital by performing tests **(smart watch, cardiograph/digital blood pressure monitor, spirometer, portable thermometer)** in real time. It offers **instant warning for values that deviate from normal – expected and at the same time helps to prevent or detect** emergencies. The platform includes also Location Tracking & Fall Detection, for **emergencies within the hospital** and also **supports the use of a simple and easy-to-use panic button.** All data is synchronized in the Cloud, which can be accessed by Health Professionals (such as General Practitioner, Nurse, Hospital Executives). The monitoring of measurements can be carried out from any desktop, laptop, ipad and any distance as long as the user is authorized by offering classified access. wi. CARE+ is already used in private clinics and hospitals (IASO Thessaly and Evangelistria Clinic in Athens).

wi.CARE+ incorporates accredited and certified smart devices (Figure 3) which cover a diverse range of needs in terms of capabilities / cost / application, for accomplishing its role. A selection that is relevant to this use case is:

- **Wearable devices** which collect vital signs: Heart Rate, Cardiac Rhythm, arterial blood pressure, (Electrocardiogram/ECG), Oxygen Saturation (SpO2), Body Temperature
- **Smart Medical Devices** (spirometer, oximeter, blood glucose meter, Electrocardiogram/ECG 24/7 etc)
- **Specialized Devices** that provide other measurements and features e.g. GPS (geofencing), SOS buttons (emergency calls), Altitude, Acceleration, Activity, etc.

Figure 3 wi.CARE+ devices.

wi.CARE+ comprises a suite of **AI and predictive analytics** algorithms (Figure 4) for:

- Analysis of ECG signals to derive useful information for the detection of cardiovascular diseases such as arrhythmia and myocardial infraction.
- Low blood pressure (hypotension) forecasting via personalized prediction models, which can be an emerging situation for post operative patients
- Analysis of oxygen saturation signal to derive insights for the detection of adverse respiratory events.

- Analysis of blood glucose levels and prediction of future values, for the early detection of hypoglycemia, especially in diabetic patients that are fasting due to surgery or patients with total pancreatectomy.

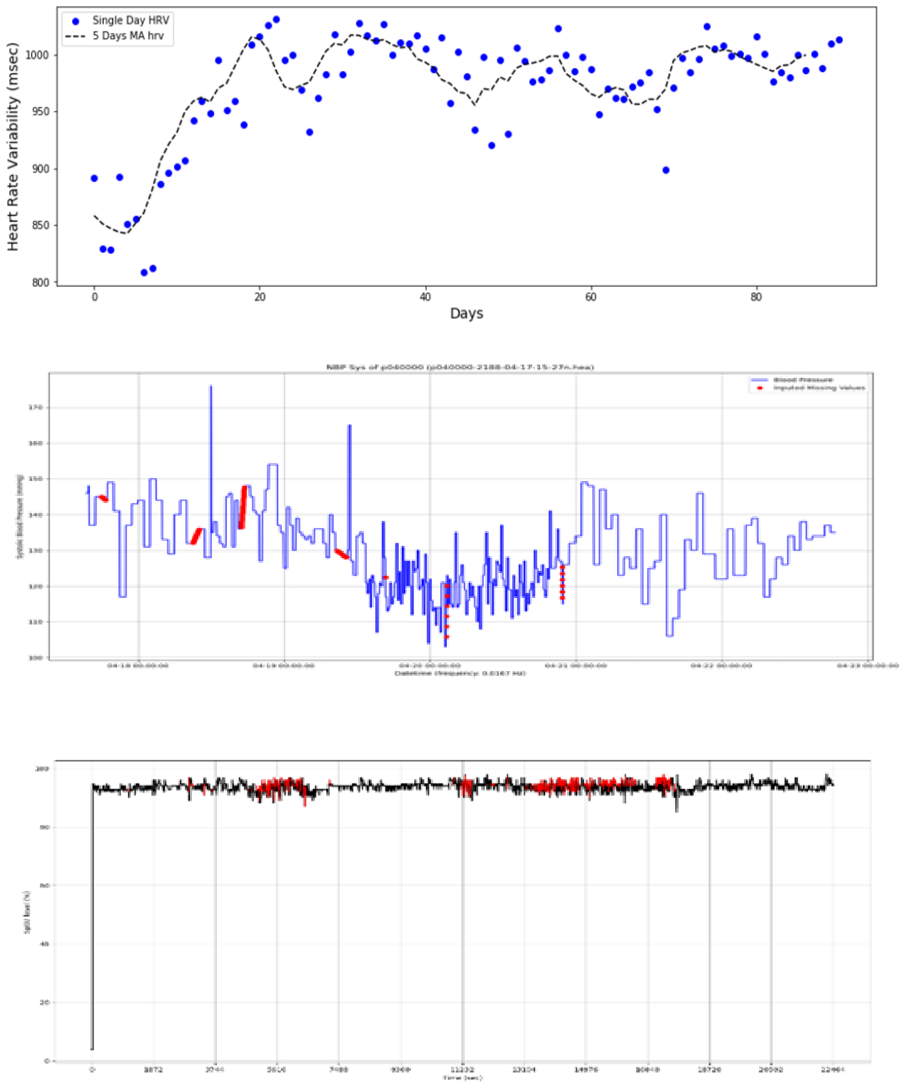
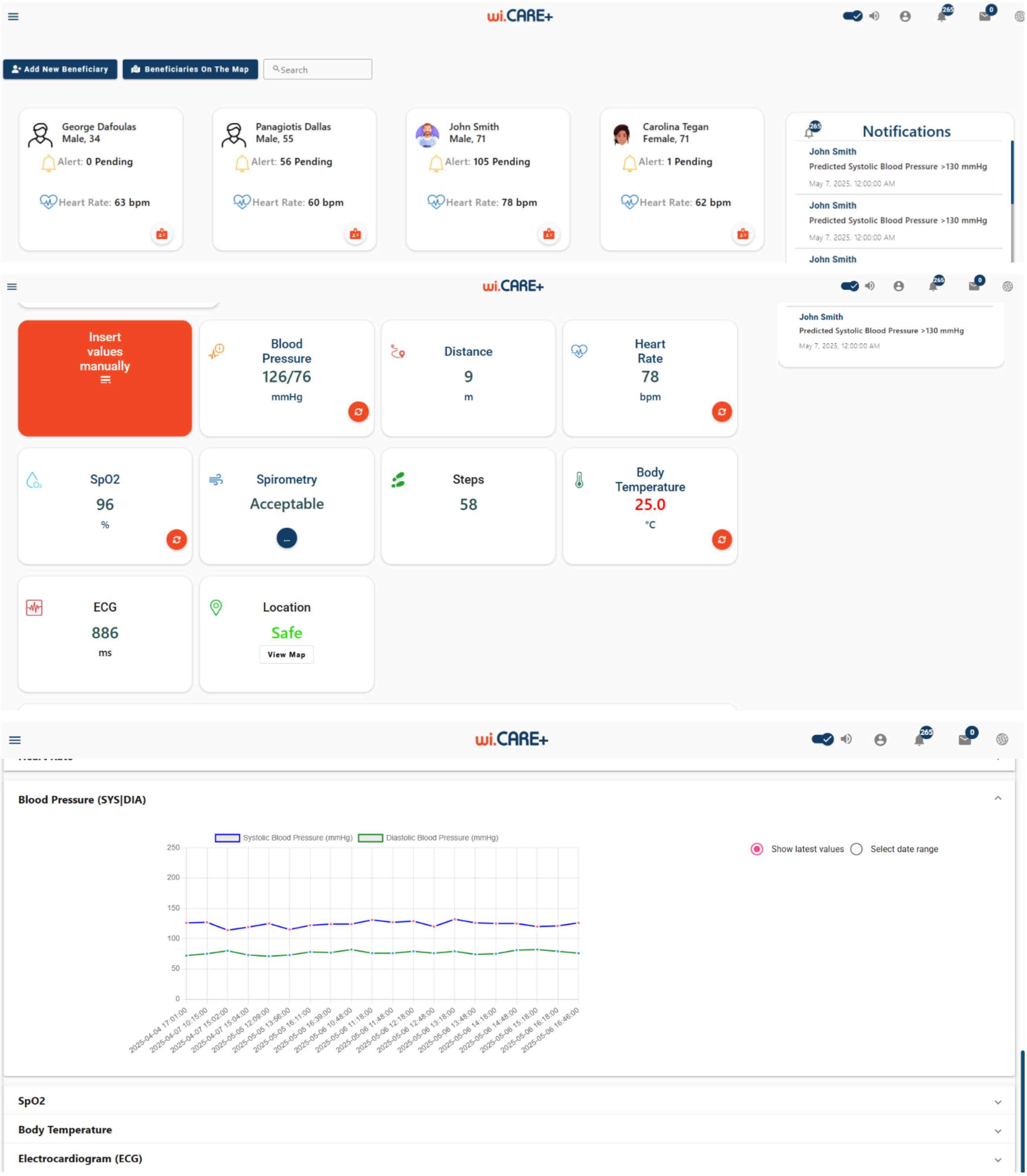


Figure 4 wi.CARE+ Intelligence and Data Analysis

The wi.CARE+ visualization dashboard (Figure 5) provides an intuitive, user-friendly interface for tracking patients' health metrics in real-time. Key features include:

1. Dynamic Visualizations: Interactive charts and graphs display vital signs like heart rate, blood pressure, oxygen saturation, and temperature trends.
2. Patient Overview: A centralized panel summarizes individual or grouped patient data.
3. Alerts and Notifications: Real-time alerts flag abnormal readings, fall detections, etc. enabling timely interventions.
4. Health Insights: Visualisation of predictive analytics highlight potential health risks, supported by AI-driven recommendations.
5. Secure Access: Data is protected with encryption and user-based access controls to ensure privacy compliance.

The dashboard empowers healthcare professionals with actionable insights, promoting proactive and efficient remote care. Furthermore, mobile applications for both healthcare professionals and patients/beneficiaries have been implemented for iOS and Android. The mobile applications offer the same functions and capabilities as the wi.CARE+ web dashboard.



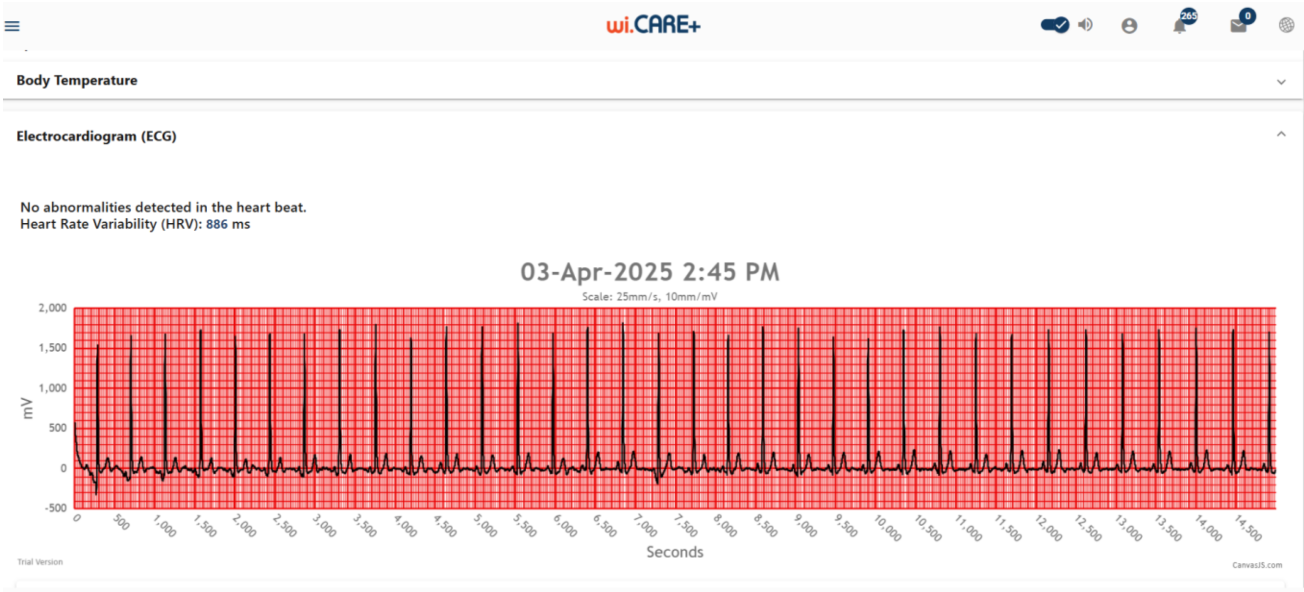


Figure 5 wi.CARE+ dashboard

The benefits for the hospital through the utilization of the proposed solutions in 5G-SHEAL, can be identified as:

- Concentration of measurements and services in the patient's digital file for easy and direct access by hospital staff, eliminating the risk of the human factor – error.
- Using modern IoT and AI tools to predict out-of-normal values in the coming hours and days
- Increase the scope and quality of social welfare services.
- Upgrading the quality provision of nursing care to patients through the time that staff can use more efficiently, since they will no longer be burdened with the same number of face-to-face measurements as in the past.
- Provision of statistical reports on efficiency and management of alerts, through response times / response times of system alerts will promote the level of information regarding the situation of the citizen.
- Unpleasant emergencies can either be prevented or dealt with more quickly (increased sense of security for the citizen).
- Implementation of technologies that reduce the patient's length of stay (LOS) and optimize patient flow management. Reducing the variable costs associated with unnecessary prolonged hospitalization would improve operational margins and more efficient use of hospital beds.
- Enhancing the safety of hospitalized patients since prolonged hospital stays increases the risk of nosocomial infections and severe psychological complications.

In the following Table 1, the targeted scenarios and individual elements of the offered system are analyzed.

Table 1: UC H1 Scenarios

Use Case Name	H1: Patient monitoring & emergency situation notification	
Scenarios	Description	Actors
Vital signs monitoring and predictive analysis (Blood	Blood pressure and/or Glucose levels are monitored by the health professional, while the patient is hospitalized in a clinic. The system analyses the data	Patients/medical personnel/

Use Case Name	H1: Patient monitoring & emergency situation notification	
Scenarios	**Description**	**Actors**
Pressure, Glucose, ECG, etc)	in order to detect and/or predict anomalies through AI.	Devices/Wearable patches/smart watch/application server
Alerting/Emergency Handling	If predefined limits are reached, there is an alerting functionality so that first aid responders can be directed to the patient.	
Data download	The patient's medical file can be accessed along with his current vital signs' status, so that the health professional can assess the patients' condition more effectively.	Application server

3.1.2 Use Case H2: Pre-Surgical Planning

Before surgery the planning will be discussed with the members of the surgical team to build up the strategic plan and outline the most critical steps during the procedure. This UC leverages VSI HoloMedicine®[2], an advanced mixed reality (MR) platform developed by apoQlar, which transforms traditional medical imaging into immersive, interactive experiences to enhance surgical preparedness.[3]

Using VSI HoloMedicine®, surgeons can convert conventional 2D DICOM files—such as CT or MRI scans—into highly detailed 3D holographic representations of patient anatomy. These 3D models can be accessed and manipulated in a shared or individual MR environment, allowing users to interact with the visualized data in real space using mixed reality headsets such as the Microsoft HoloLens. The platform facilitates:

- Step 1: Web-based portal for Upload – The radiological scans (e.g., CT, MRI) are securely uploaded to the VSI Manager (a web-based portal with data anonymization and GDPR compliant).

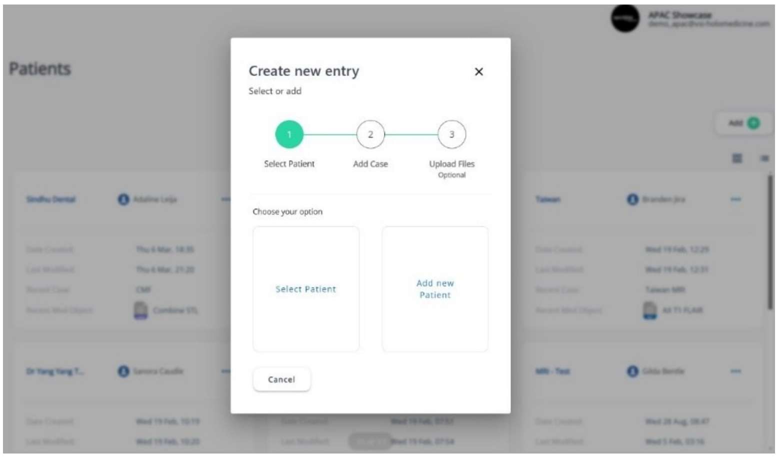


Figure 6 Snapshot of VSI Manager (A web-based portal) for Uploading of DICOMs

[2] https://apoqlar.com/mixed-reality-for-surgical-planning/

[3] *VSI HoloMedicine® is a certified Class I medical device under the European Medical Device Regulation (EU MDR 2017/745), intended for visualization and surgical planning, and not for diagnostic or therapeutic decision-making.*

- Step 2: Conversion – The scans are rendered into 3D holograms and prepared for the MR device. (with few clicks)
- Step 3: Visualization using Microsoft HoloLens 2 – Users can explore the holograms using intuitive hand gestures, zooming, rotating, or dissecting views for better insight.

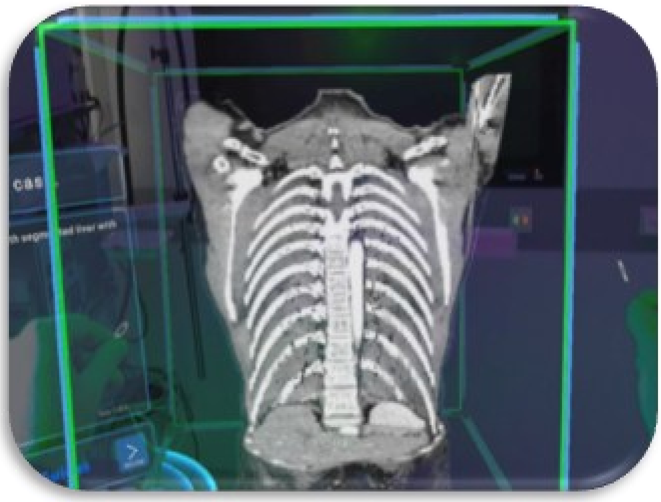


Figure 7 3D Holographic imaging as seen through VSI HoloMedicine®

- Step 4: Collaboration – Surgeons, radiologists, and clinical teams can join a shared MR session to discuss the case in real-time, regardless of their location.
- Step 5: Planning – Detailed surgical strategies can be outlined, anatomical risks assessed, and operative steps rehearsed virtually to optimize patient outcomes.

By enabling precise 3D visualization, improving the understanding of complex anatomical interrelations, and supporting pre-operative simulation, VSI HoloMedicine® empowers surgical teams to reduce uncertainty, enhance procedural precision, and improve communication. This technology is particularly valuable for high-risk or anatomically challenging surgeries performed at Aretaieio University Hospital, where conventional 2D imaging may limit depth perception and spatial context.

In the following Table 2, an overview of the offered system functionalities is provided.

Table 2: UC H2 Scenarios

Use Case Name	H2: Surgical Planning	
Scenarios	Description	Actors
Pre-surgical imaging visualization	Diagnostic imaging results (e.g., CT, MRI) are converted into 3D DICOM holograms for detailed visualization of anatomical structures and pathology.	Surgeons, Radiologists, VSI platform
Interactive multi-user session	Multi-disciplinary teams engage in real-time, interactive planning using VSI HoloMedicine® across departments or locations.	
Anatomical Segmentation	Segmentation tools enable selective visualization of bones and vessels allowing the surgical team to focus on specific regions of interest and pathology with anatomical accuracy.	Surgeons, VSI platform

3.1.3 Use Case H3: Oncology Imaging

In complex oncological surgeries—such as those involving the liver, pancreas, biliary tract, and sarcomas—precise visualization of the tumor and its proximity to critical anatomical structures is vital for surgical success and patient safety[4].

All procedures involving the use of patient imaging data for holographic visualization are conducted in accordance with institutional policies and approved by the Ethics Committee of Aretaieio University Hospital in Athens. Patient data is pseudonymized, and informed consent is obtained prior to any clinical use of mixed reality technologies, in compliance with applicable regulatory and data protection standards.

The UC leverages ApoQlar's VSI HoloMedicine® platform, which allows for advanced surgical training by overlaying segmented 3D models (derived from CT, MRI, or PET-CT scans) directly onto a cadaver or phantom through mixed reality (MR) devices. These overlays include detailed renderings of organs, tumors, vascular pathways, and nerves.

In the following Table 3, the targeted scenarios and individual elements of the offered system are extensively analyzed.

Table 3: UC H3 Scenarios

Use Case Name	H3: Oncology Imaging in Operating Rooms	
Scenarios	Description	Actors
Collaborative visualization and review	Multi-user sessions enable real-time consultation with remote oncology experts, providing input into surgical decisions during the operation.	Surgeons, Remote Specialists, Tumor Boards, VSI platform
Surgical Planning 3D imaging	High-resolution CT/MRI/PET-CT images are uploaded and converted into segmented 3D holograms showing tumor location in relation to vasculature, organs, and other vital structures, enabling detailed preoperative assessment.	
Tumor and anatomical segmentation	Oncological structures such as tumors and surrounding critical anatomy (e.g., vessels, bile ducts) are segmented and color-coded for enhanced clarity and planning accuracy.	Surgeons, VSI platform
Mixed reality overlays	Segmented 3D holograms are overlaid onto the cadaver or phantom using MR headsets (e.g., HoloLens), providing visual alignment of tumor location with the actual surgical site. This will be extremely helpful, especially for minimally invasive surgery and the trocar placement or robot arm docking.	Surgeons, Trainee, VSI platform

[4] *Disclaimer: A healthcare professional must always rely on his or her own professional clinical judgment when deciding whether to use a particular product when treating a particular patient. VSI HoloMedicine® does not dispense medical advice and recommends that healthcare professionals be trained in the use of any product before using it in a procedure or surgery. A healthcare professional must always refer to the package insert, product label and/or instructions for use before using any product.*

Use Case Name	H3: Oncology Imaging in Operating Rooms	
Scenarios	Description	Actors
Dynamic surgical plan adjustments	The holographic interface allows the surgeon to manipulate, zoom, or rotate 3D models hands-free, facilitating real-time revisions to the surgical approach.	Surgeons, VSI platform

3.1.4 Use Case H4: Robotic Surgical Proctoring & Residency Core Training

Robotic-assisted surgeries offer a new frontier for surgical education. This UC leverages HoloMedicine® Robotics to bridge the gap between surgical training and real-time operating environments. Through 3D stereoscopic visualization, surgical trainees gain deeper insight into surgical skills. Additionally, remote trainees can virtually "scrub in" to the procedure using ***Vision Pro***, observing the surgeon's view and learning.

This setup creates a scalable, immersive training environment that supports both onsite and remote surgical education, advancing the development of residency programs and proctoring systems in minimally invasive robotic surgery.

Figure 8 Immersive Surgical Skills Education in Robotic Surgery

Figure 9 HoloStreamer® which is to be connected to Robotics devices

In the following Table 4, an overview of the offered system functionalities is provided.

Table 4: UC H4 Scenarios

Use Case Name	H4: Robotic Surgical Proctoring & Residency Core Training	
Scenarios	Description	Actors
3D Stereoscopic Observation	Trainee remotely observes the surgery via stereoscopic 3D visualization through Vision Pro.	Surgeons, Residents, VSI platform
Real-time Proctoring	Mentor provides real-time feedback and proctoring to a remote trainee during surgery.	
Global Surgical Education	Live-streamed surgeries and interactive training for a global audience of surgical trainees.	Surgical Trainees, Surgeons, VSI platform

3.1.5 Technical and User Requirements for Healthcare Use Cases

Based on [5] and in particular also three recent Horizon projects relevant to 5G for healthcare, 5G-VINNI [8], 5G-TOURS [9] and 5G-HEART [10], the network and user requirements and results stemming out of these projects are used as reference in the 5G-SHEAL Healthcare Use Case. While varying in range depending on the actual scenario to be implemented, the network requirements identified in Table 5**Error! Reference source not found.** are targeted.

Table 5: KPIs with target values for Healthcare UCs

Use Cases	KPI	Target value
H1: Patients health monitoring & emergency situation notification	Downlink throughput per device	50 – 200 Mbps
	Uplink throughput per device	10 - 50 Mbps
	Latency - round trip	<50 ms
	Latency - RAN	<15 ms
	Application round-trip latency	<150 ms
	Network Availability	99,99%
	Network Reliability	99,999%
	Device Density	10 dev/km^2
	Location Accuracy	<5m
H2: Pre-Surgical Planning	Downlink throughput per device	100 – 200 Mbps
	Uplink throughput per device	20 – 50 Mbps

Use Cases	KPI	Target value
	Latency – round trip	<20ms
	Latency - RAN	<10ms
	Application round-trip latency	<60ms
	Real-time Interaction Latency	<40ms
	Network Availability	99.999%
	Device Density	5 dev/ km^2
	Quality of Service (QoS)	Guaranteed bandwidth with low jitter
H3: Oncology Planning	Downlink throughput per device	150 – 200 Mbps
	Uplink throughput per device	50 – 100 Mbps
	Latency – round trip	<15ms
	Latency - RAN	<5ms
	Application round-trip latency	<50ms
	Real-time Interaction Latency	<30ms
	Network Availability	99.999%
	Device Density	5 dev/ km^2
	Quality of Service (QoS)	Guaranteed bandwidth with low jitter
H4: Robotic Surgical Proctoring & Residency Core Training	Downlink throughput per device	150 – 200 Mbps
	Uplink throughput per device	50 – 100 Mbps
	Latency – round trip	<15ms
	Latency - RAN	<5ms
	Application round-trip latency	<50ms
	Real-time Interaction Latency	<30ms
	Network Availability	99.999%

Use Cases	KPI	Target value
	Device Density	5 dev/ km^2
	Quality of Service (QoS)	Guaranteed bandwidth with low jitter

The network requirements are to be verified as part of the evaluation of the performance of the UCs. For the implementation of this UC the following requirements from the user perspective are identified (Table 6).

Table 6: User requirements for Healthcare UCs

Use Cases	Requirement	Description
H1: Patients health monitoring & emergency situation notification	Video Reception/ Transmission	The medical specialist requests a video connection via the WINGS wi.CARE+ platform if patient status demands video communication.
	Data Reception/ Transmission	1. The wearable devices used for the monitoring of vital signs are connected and start sending real-time data to the wi.CARE+ platform. The data is shared via suitable mobile apps and/or dashboards with family members and authorized medical specialists. 2. In case an emergency is identified by the wi.CARE+ platform (e.g. due to one or more of the monitored vital signs or parameters exceeding a predefined threshold or indicating a problem), the WINGS wi.CARE+ platform issues an emergency notification to the medical specialist
	Voice communication	The patient can have a voice call in parallel to/or alongside any type of video communication.
	Location information	The determination of the location is important for fast and efficient response, but not as critical as in next UC.
	Fast response	It is important to minimise video stuttering and frame-loss.
	Reliability/Availability/Users' Acceptance Survey	The network should provide uninterrupted connectivity, due to the sensitivity of the situation involving potentially critical conditions. In addition, a user's acceptance scale will be used for the respective evaluation.
	Battery life	Wearable and UE devices should provide reasonable autonomy, while maintaining essential connectivity.

Use Cases	Requirement	Description
	Security/Privacy	A patient registers to the Remote Health Monitoring service of the WINGS wi.CARE+ platform. This way data privacy is ensured.
H2: Pre-Surgical Planning	Video Reception/ Transmission	1. The surgical team requests a video connection to discuss pre-surgical plans using the VSI HoloMedicine® platform. 2. 5G-SHEAL infrastructure ensures smooth streaming of 3D holographic models and CT/MRI scans to support decision-making for surgery planning.
	Data Reception/ Transmission	1. Diagnostic imaging data (CT, MRI) is securely uploaded to the VSI Manager for processing. 2. Once processed, the 3D models are transmitted to HoloLens 2 or other MR devices for visualization.
	Voice Communication	Surgeons and radiologists can maintain voice communication during the planning process, especially in multi-user environments. This ensures collaborative decision-making while interacting with 3D models in real-time.
	Advanced Holographic Manipulation	Surgeons interact with detailed 3D holograms of patient anatomy, enabling advanced actions such as zooming into complex structures and simulating surgical steps.
	Fast Response	Minimal latency in the transmission of 3D models and images is essential. Fast response ensures that surgeons can manipulate and interact with 3D holograms without delays, making planning more effective.
	Reliability/Availability/Users' Acceptance Survey	Network connectivity must be reliable and continuously available to support uninterrupted pre-surgical planning. Additionally, a user acceptance survey will measure the effectiveness of the platform and the overall experience for the surgeons and medical teams.
H3: Oncology Planning	Video Reception/ Transmission	1. Surgeons and trainees engage in live video sessions, where robotic surgery is streamed to remote trainees. 2. The 5G-SHEAL infrastructure provides high-quality video feeds, ensuring minimal latency for seamless interaction during surgeries.
	Data Reception/	1. Mentors and proctors provide live feedback to remote trainees during surgery, guiding them through critical

Use Cases	Requirement	Description
	Transmission	steps. 2. Feedback can include real-time voice communication.
	Voice Communication	Surgeons, mentors, and trainees can all interact within the same virtual environment using HoloMedicine® to enhance collaborative learning. Remote trainees can “scrub in” and participate in the procedure through the MR platform.
	Advanced Holographic Manipulation	Ensure that the video and data streams are delivered with low latency to maintain synchronization between the remote trainees and the ongoing surgery. Minimize stuttering, lag, or delay to prevent disruption in training.
	Fast Response	The system must provide uninterrupted connectivity to ensure that all parties involved (mentor, trainee, surgeon) can engage in real-time feedback and collaboration. Post-session user surveys assess user satisfaction and effectiveness of the platform in the training process.
	Reliability/Availability/Users' Acceptance Survey	Patient data and training data must be secure and anonymized. Only authorized individuals should have access to live video streams and surgical data to ensure privacy compliance.
H4: Robotic Surgical Proctoring & Residency Core Training	Immersive Interface & Video Streaming	High-definition 3D stereoscopic video of robotic surgery is streamed in real time to remote proctors and residents via HoloStreamer®, supported by 5G-SHEAL network for low-latency, synchronized delivery.
	Device Integration	Supports multiple video feeds (3D/2D) enabling immersive and holistic surgical training.
	Remote Proctoring & Scalability	Enables global participation with real-time interaction and spatial audio, removing geographic barriers and promoting equitable access to expert mentorship.
	Reliability & Usability Evaluation	Continuous, resilient connectivity is required for uninterrupted sessions. Post-training surveys assess clarity, usability, and learning outcomes.
	Privacy & Security	All data access is restricted to authorized users, fully compliant with GDPR and clinical ethics requirements.

3.2 Education

The advances in medical imaging technology, coupled with enhanced connectivity through 5G, have transformed surgical education from traditional hands-on training in the operating room to hybrid simulation practices. These practices, supported by enhanced reality tools, offer exceptional preparation for surgical skills, helping bridge the gap before performing in real-life operating conditions. Recent advances have also been leveraged in fields like radiation oncology and minimally invasive techniques, including stereotactic invasive and non-invasive methods, delivering precision that was previously unimaginable in oncology care.

Furthermore, the evolving landscape of healthcare services underscores the importance of embracing innovative solutions, such as mixed reality (MR) applications. The incorporation of extended reality (XR) has the potential to revolutionize medical training, enhance surgical procedures, and foster remote collaboration among healthcare professionals. By improving connectivity, XR enables real-time sharing of data, surgical feeds, and 3D models, creating new opportunities for learning, communication, and collaboration. This transformation ultimately leads to more effective patient care and improved overall healthcare outcomes.

The use of XR in medical education also offers unparalleled opportunities for interactive learning. By immersing students and healthcare professionals in virtual environments, XR technology allows them to practice and refine their skills in a safe, controlled space, free from the risks associated with traditional hands-on training. With access to lifelike simulations and real-time feedback, trainees can experiment with different techniques, diagnose conditions, and practice complex procedures before ever stepping into a real operating room. This hands-on virtual practice enhances learning retention, boosts confidence, and ensures that professionals are better prepared to handle high-pressure scenarios when they encounter them in clinical practice.

3.2.1 Use Case E1: Medical Students Education

Transform medical education with a comprehensive suite of tools that integrate various forms of content into a single, cohesive learning environment. Explore 3D anatomical models, 3D and 2D DICOMs, and 360-degree immersive videos to connect theoretical concepts with real patient data. Solo, peer-to-peer, and class learning are all possible with virtual learning tools such as presentations and annotations. By applying the principles of experiential learning, medical students can engage in hands-on practice and reflective observation, using quizzes and annotation tools to enhance collaboration and understanding. This interactive and immersive learning approach helps students gain a deeper understanding of complex medical concepts and their application in clinical settings.

Figure 10 Medical students' education room

In the following Table 7, an overview of the offered system functionalities is provided.

Table 7: UC E1 Scenarios

Use Case Name	E1: Medical Students Education	
Scenarios	Description	Actors
3D Anatomical Models and DICOM Exploration	Medical students interact with 3D anatomical models and both 3D/2D DICOM images to understand anatomical structures and pathologies. This immersive, hands-on exploration improves spatial awareness and clinical reasoning.	Students/surgeons/VSI platform
Virtual Learning and Collaboration	Students engage in virtual classes using interactive presentations, annotations, and quizzes. Peer-to-peer and instructor-led discussions enhance collaborative learning and group analysis.	
Interactive 360-Degree Immersive Videos	Students experience immersive 360° videos of real clinical scenarios, surgeries, and ward activities. This allows reflective observation and exposure to diverse cases, even remotely.	
Remote Surgical Training	Students remotely observe live surgeries with surgeons during procedures. Enhances access to rare or complex surgical cases.	

3.2.2 Use Case E2: Patients Education

This UC aims at facilitating patient understanding of medical conditions and treatment options through 3D holographic images, providing an interactive and visually enhanced approach to conveying complex medical information.

Using HoloMedicine® and mixed reality technologies, clinicians can now project 3D models of anatomy, pathologies, and upcoming surgical procedures directly in front of patients. This allows patients to view and interact with visualizations of their own medical imaging data—such as CT or MRI scans—rendered in three dimensions. Rather than relying on static 2D images or complex jargon, clinicians can guide patients through their diagnosis and treatment plan with intuitive and immersive visuals.

This approach empowers patients to become active participants in their care journey. By improving comprehension and reducing anxiety, holographic patient education fosters shared decision-making and enhances the trust between doctors and patients. It is particularly beneficial in surgical planning discussions, oncology treatment roadmaps, and chronic condition management, where patients need to grasp the sequence and impact of medical interventions reflected in the informed consent signing.

Such interactive education not only improves patient satisfaction and adherence to treatment but also reduces the time clinicians spend explaining complex conditions repeatedly, enabling more efficient consultations and better outcomes.

Figure 11 Patients Education

In the following Table 8, an overview of the offered system functionalities is provided.

Table 8: UC E2 Scenarios

Use Case Name	E2: Patients Education	
Scenarios	Description	Actors
Surgical Procedure Explanation	Surgeons use 3D holograms to walk patients through a shared session on the planned surgical approach, including anatomical landmarks, surgical access points, and expected outcomes.	Doctors and Patients, VSI platform
Diagnosis Visualization	Patients view holographic representations of their own anatomy or pathology (e.g., tumors, fractures) derived from CT/MRI scans. This enhances understanding of their condition, the rationale for the intervention and supports shared decision-making.	
Remote Education and Follow-up via MS Teams.	Patients in rural or remote areas engage in 3D virtual consultations and education sessions using holographic streaming, reducing the need for physical hospital visits via MS Teams.	Surgeons and Remote surgeon/patients, VSI platform
Family & Caregiver Involvement (Multi-User Environment)	Multi-user Holographic sessions are used to educate family members or caregivers about the patient's condition, home care protocols, and support strategies—especially valuable for geriatric and post-operative care. This fosters a collaborative care environment and enhances treatment adherence.	Surgeons, Patients, Nurses, Caregivers, Family Members, VSI platform

3.2.3 Technical and User Requirements for Education Use Cases

Based on [5] and drawing insights from three key Horizon projects—5G-VINNI [8], 5G-TOURS [9], and 5G-HEART [10] —the 5G-SHEAL platform incorporates network and user requirements that support extended reality (XR)-enabled medical education. These prior initiatives demonstrated the importance of low-latency, high-bandwidth, and reliable connectivity for delivering immersive training content such as 3D anatomical models, live-streamed surgeries, and interactive simulations. Accordingly, the network requirements summarized in Table 9 have been tailored to meet the specific needs of education use cases, such as patient education and collaborative medical learning environments.

Table 9: KPIs with target values for Education UCs

Use Cases	KPI	Target value
E1 – Medical Students Education	End-to-end latency	≤ 30 ms (for smooth XR interactivity)
	Uplink throughput	≥ 40 Mbps (for real-time 3D video/data)
	Downlink throughput	≥ 80 Mbps (for holographic streaming)
	Availability	≥ 99.999% (for uninterrupted training)
	User concurrency	≥ 10 concurrent users per session
	Frame rate (XR content)	≥ 60 FPS (for visual clarity & realism)
	Localization accuracy	≤ 1 meter (for AR overlays in educational space)
	Security and privacy compliance	100% compliance (GDPR/HIPAA-aligned)
E2 – Patient Education	End-to-end latency	≤ 40 ms (interactive 3D visualization)
	Downlink throughput	≥ 40 Mbps (for smooth hologram rendering)
	Availability	≥ 99.99% (reliable access for patients)
	Security and privacy compliance	100% compliance (GDPR/HIPAA-aligned)

The network requirements are to be verified as part of the evaluation of the performance of the UCs. For the implementation of this UC the following requirements from the user perspective are identified (Table 10).

Table 10: User requirements for Education UCs

Use Cases	Requirement	Description
E1 – Medical Student Education	High-Resolution 360 Video Streaming	Enables clear visualization of surgical procedures, anatomical models, and real-time ward interactions without frame drops or latency.
	Device Accessibility	Students should be able to access the XR learning environment via Meta through HoloMedicine® Spaces and HoloLens for VSI HoloMedicine®
	Immersive 3D Visualization	Supports manipulation of 3D anatomical structures, DICOMs, and holographic patient models to foster spatial understanding and interactive learning.
	Collaborative Learning Tools	Enables group annotations, quizzes, and peer interaction for synchronous or asynchronous collaborative education sessions.
	User satisfaction (survey-based)	≥ 90% positive feedback
	Security and Privacy Compliance	All educational sessions must comply with GDPR and institutional ethics guidelines, especially when patient data is used.
E2 – Patient Education	3D Holographic Visualization	Conditions and treatments are presented in interactive 3D models to enhance patient understanding.
	Clinician-Guided Interactions	Healthcare providers guide patients through XR experiences to use HoloLens, answering questions and pointing out key details in real-time using shared experience.
	Ease of use (usability score)	≥ 85/100 (System Usability Scale)
	Patient comprehension (post-visit quiz)	≥ 80% average score
	Session duration	≤ 15 minutes (for optimal engagement)
	User satisfaction (patient surveys)	≥ 90% positive feedback
	Data Protection and Consent	Patients provide informed consent to use, and their data is secured and anonymized according to healthcare data regulations.

4 Conclusions

This document provides the UC scenarios and associated network and platforms characteristics to articulate the functional and performance requirements of the 5G-SHEAL SGIs, Healthcare and Education. These requirements will be considered by architecture, system design and implementation experts in WP2, 3 and 4, to select for each site location the most relevant scenario and parameters to validate 5G-SHEAL. These UC requirements will be taken forward in WP5 to determine the most appropriate way to measure performance against the required KPIs and develop verification and validation implementations.

Requirements management in 5G-SHEAL has not finished for WP2. It is not a one-way or waterfall process, but rather a concurrent or iterative development process. UC analysts have identified a need for validation of requirements, and particularly the User requirements. User expectations of 5G capabilities based on their desires may in some cases exceed expected standard 5G deployments, and in some instances even though 5G can meet the requirements, requirements are potentially over specified. Thus, WP2 has identified a need to, and shall, maintain user requirement dialogues through to project completion.

The phased delivery of the sites and services will result in a continual evolution of deployed and available capabilities at each of the UC trial sites. This presents challenges for WP3, WP4 and WP5. UC and platform verification and validation relies on correlating technical performance measurements from the systems along with data gathered from users based on their Quality of Experience and willingness to pay responses.

The final version of the technical requirements of the UCs and deployment implications will be included in the last deliverable of WP5, D5.3, to be delivered at the end of the project.

5 References

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