Expert Perspectives on Future 6G-Enabled Hospital Metaverse

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Abstract. This paper aims to understand the value-added services that the future 6G-enabled metaverse can and will bring to hospitals. This is important since most studies on 6G and the metaverse are heavily driven by technological solutions. Adopting a qualitative research approach, this paper collects experts' opinions on the usage scenarios of the 6G-enabled metaverse in hospitals. Six use cases within hospital contexts have been identified from open-ended interviews. The analysis of each case reveals that 6G, as a general-purpose technology, offers the necessary capabilities to support the development of the metaverse in hospitals. The metaverse-enabled services are expected to design future smart hospitals and improve work processes and resource allocation in hospitals, while also promoting preventive healthcare and training and enhancing the quality of care in emergency, treatment, and rehabilitation. Consequently, the development of both metaverse and 6G will progress in tandem, hand in hand, offering local services in hospitals. From a value perspective, this paper contributes to the development of the 6G and metaverse in the hospital vertical by understanding the needs, capabilities, and key values of the future 6G-enabled hospital metaverse.

Keywords: 6G · Metaverse · use cases · key values · hospital

1 Introduction

The hospital of future is digitally networked and closely connected to the digitalization of the health system [1]. The emergences of connected health, digital health, and mobile health result from the digital transformation of healthcare that reduces boundaries among health professionals, patients, devices, payers, upstream and downstream service providers, and other stakeholders [2]. In some scenarios, the focus is moving from clinical healthcare to home-based preventive healthcare or wellness covering a scale of daily well-being activities from mental, physical, and social aspects [3]. The preventive activities could be tailored to all age groups and levels of disabilities according to their health program.

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With the development of industrial 4.0 and the sixth generation of Mobile Networks (6G), the envisioned future for intelligent health relies on a wireless-based healthcare network that enables real-time patient intervention, monitoring, and transformation into data-centric, intelligent, and automated processes in a virtual environment [3, 4]. However, the needs and key values (KVs) for 6G and metaverse in hospitals remain unclear. Therefore, our paper focuses on 6G and metaverse technologies in hospitals, and the potential to improve patient outcomes and create new opportunities for technological advancements in healthcare [4].

The 6G technology will be a disruption of wireless mobile communications enabling the development of services not seen before. The services are evolved by gathering data from numerous sources, analyzing it with AI, and sharing the refined data through various platforms and applications in various use cases of businesses. The 6G technology makes possible several new functionalities like sensing, positioning, and imaging [5]. Subsequently, the 6G enables large-scale metaverse implementation, which integrates the virtual world (digital twins and information) and the real world (objects) by creating a digital realm where people can interact with computer-generated environments and other users in real-time. The application of the metaverse integrates the virtual world and the real world, addressing the challenges of remote healthcare services caused by the absence of healthcare professionals at the location [6].

Most technology-focused academic research drives the development of 6G and Metaverse and its application in healthcare by focusing on vision, technical solutions, scenarios, and use cases. However, from a value-creation perspective, making the Metaverse real in a hospital context requires sensing, data connection, and physical and virtual models to enable interaction and exchange of information between the real and virtual world [7], thus involving multiple stakeholders to address a variety of needs.

In this study, the metaverse is seen as a critical application for deployment of the 6G network, and the 6G is observed to be a particularly important enabler for the metaverse development in healthcare. Viewing hospitals as ecosystems, the metaverse introduces an innovative approach to interaction within hospital environments. However, the development of 6G-enabled metaverse services, including aspects such as usage, expected outcomes, capability, constraints, key values, and impact in hospitals, has not yet been clarified in parallel with the development of 6G and metaverse technologies. Therefore, this paper focuses on the demand side to understand the future of 6G-enabled metaverse in hospitals and proposes two research questions as follows:

- How could 6G-enabled metaverse create value for future hospitals?
- What needs and use cases could be identified for future 6G-enabled hospital metaverse?

This paper aims to address stakeholder needs, requirements, constraints, and expected outcomes from the demand side, and KVs along with 6G and metaverse technology development. This approach will guide new technology development direction, allocate resources reasonably for better acceptance and adoption by stakeholders, and deliver the value that stakeholders hoped for the 6G-enabled Metaverse services.

2 Relevant Literature

2.1 Digitalization in Healthcare

Digitalization in healthcare refers to the socio-technological process of integrating digital technologies to improve and transform healthcare processes, services, and outcomes. The establishment of a connected, intelligent medical services environment with integrated sensing and intelligence capabilities relies on technologies, such as the Internet of Things, mobile internet, cloud computing, big data, and artificial intelligence. The purpose of digitalization is to improve patient care, healthcare delivery efficiency, and satisfaction, and advance medical treatment and research.

Health-related technologies have reformed medical healthcare in the areas of electronic health records (EHRs) that enable a doctor to manage a patient's medical information without accessing diverse systems [8]. Telemedicine provides remote healthcare services using ICT solutions for consultation, rehabilitation, and monitoring. Web-based digital services known as eHealth have rapidly developed to provide services such as e-prescription, e-referrals, and e-discharges. As increased use of mobile devices, such as smartphones, tablets, software and sensors, a new set of mobile health (mHealth) solutions has been developed to enable access to authorized data regardless of geographical location without the need to change devices [9, 10].

Digitalization improves the patient service process through digital platforms and self-services, such as online booking, self-symptom check, online chat, medical data access, and online prescription renewal. Digital tools have facilitated communication between patients and health professionals which saves cost and time. Digitalization has also empowered patients by granting access and management of their health and well-being through medical data access, digital care pathways, and commercially available apps that focus on health, diet, and exercise [11].

The outcomes of digitalization in healthcare are to integrate medical resources, optimize medical service processes, improve diagnostic and treatment efficiency, assist in clinical and hospital management decision-making, and achieve convenience in patient medical care, intelligent medical services, and refined hospital management. Facilitating by new technology, innovations, a connected infrastructure of medical devices, software applications, and health systems makes it possible for health professionals to care for patients anywhere, at any time, while empowering patients to take an active role in self-care and achieve preventive, predictive, personalized and participatory medicine [12, 13].

2.2 Wireless in Healthcare

The envisioned future 6G network is an integrated space-aerial-terrestrial network, encompassing interactions from device to terrestrial and satellite communications and driving the development of holographic-type communications, ubiquitous intelligence, tactile internet, multi-sense experience, and digital twin [18]. The goal of the future 6G network is to build a hyperconnected society where everyone and everything is connected [14]. The 6G goes beyond the 5G network in supporting tailored service provisioning, dynamic data exchange, and collaboration among objects, processes, people, and machines. The 6G will fulfill the requirements of diverse, dynamic, and locally tailored vertical applications that 5G cannot achieve due to stringent resource constraints [14].

The health industry has been identified as one of the vertical industries that can benefit from the 6G network [15]. The areas that can be supported by the 6G network include new local private networks, seamless robotic-assisted surgeries, telemedicine, emergency services, and the integration of interconnected devices for deep-body implants. The independent and uncoordinated subnetworks in hospitals require high reliability, determinism, and semi-autonomy in hospital contexts, e.g., to control robot arms and critical on-body devices [16], and local and indoor solutions. Therefore, medical wireless devices, machines, and sensors will require the 6G network for seamless connection, transmission, and processing of real-time health data [17, 18] in a secure and safe way of data exchange [19].

2.3 Metaverse in Healthcare

Metaverse has been defined by "*as a technology-mediated network of scalable and potentially interoperable extended reality environments merging the physical and virtual realities to provide experiences characterized by their level of immersiveness, environmental fidelity, and sociability*" [20]. The 3D-modelled virtual worlds and avatars connect the real world and users through augmented reality (AR), virtual reality (VR), and digital twins [21]. AR and VR offer improved 3D visualization and can be utilized repeatedly. This makes them ideal for various preoperative applications, such as training for young doctors and medical students [22], preoperative surgery planning, and remote monitoring. The combination of VR and AR allows geographically remote surgeons to guide surgeries by overlaying suggestions on their view through an AR system. Additionally, they enhance patient education through improved visualization [23]. AR/VR devices can also provide personalized therapeutic treatment and may apply to post-traumatic stress disorder (PTSD), anxiety and fear-related disorder (A&F), diseases of the nervous system (DNS), and pain management [24].

A digital twin makes a virtual replica of an object or system and receives updated data from the physical entity via real-time connection and may drive the healthcare revolution [25]. The concept of digital twins aims to simulate, diagnose, and predict outcomes using a digital replica, enabling the making of suitable decisions based on the results from the replica, which are then applied to the physical entity [26]. Digital twins are found to be useful for managing personal health by synchronizing data from various sensors and health registries in a timely manner [27, 28], and pre-surgery planning, and optimization of hospital facilities and inventory. Besides virtual replicas of objects and systems, the digital twin can be created from humans, which brings totally new aspects to the visioning of future healthcare [29].

2.4 Stakeholders and Key Values

Stakeholders play a crucial role in representing diverse demands and needs from both human and machine users specific to private and public organizations in the vertical healthcare industry. Meanwhile, different stakeholders will supply the resources and assets required to address a variety of needs, the provision of physical infrastructure (such as facilities and sites), equipment (including devices and networks), and data (content and context), all within the regulatory framework established by policymakers [30].

In the health service ecosystem, the five major groups of stakeholders have been classified as (1) Regulators who set regulatory guidelines; (2) Service providers are health professionals who provide services in hospitals, nursing homes, and extended homes. (3) Payers, statutory health insurance, private health insurance, and government agencies (4) Suppliers are the research organizations and technological companies that develop new products and services for treatments, and (5) Patients are the beneficiaries of the care [31]. The multiple stakeholders involved in a 6G ecosystem in the health industry include e.g. healthcare service providers, financial sources, telecommunication operators, mobile device providers, medical device providers, and users [32].

The goal of the future 6G network is to fulfill stakeholders' needs and requirements for creating value for individuals, organizations, businesses, and society through spectrum innovation and management [33, 34]. Value plays pivotal roles in showing and confirming the technology's capacity to meet stakeholder demands [32] and guide the development of technology in a more beneficial, ethical, and sustainable direction [35], particularly when adopting a service design thinking for the transformation of healthcare systems [36].Understanding needs and value from stakeholder perspectives on developing 6G and metaverse in hospitals further strengthens the value creation, benefiting not only businesses but also society [37]. It enables a shift from big tech to big democracy as well as delivers and captures the value of deploying 6G and metaverse in the future for sustainable healthcare and societal development.

[35] have developed a 6G visioning framework that enables stakeholders to communicate their needs, aims, and visions in future 6G development and ensure the successful innovation and commercialization of the future 6G network as society wants shown in Fig. 1.

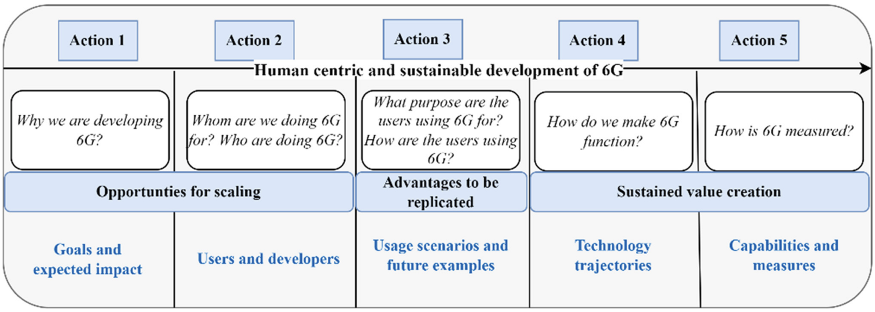

Fig. 1. Adapted from the 6G visioning framework in [35].

This framework addressed the essential questions to develop 6G from a human-centric and sustainability perspectives, such as: "*why we are doing 6G, who we are doing it for, who are doing it, what purposes users will use it for, how users will use it, how we will make 6G work and how we will measure*" [35]. In this paper, we will utilize the questions addressed in the framework proposed [35] to analyze our empirical inquiries in Sect. 3. The focus will be on the analysis of 6G-enabled metaverse use cases to understand stakeholders' needs, usage scenarios, technological capabilities, expected outcomes, impacts in local hospitals, and their importance in offering local 6G infrastructure setup and services.

3 Data and Materials

3.1 Research Approach

This study opted for a qualitative research method allowing us to explore the future envisioned Metaverse and wireless solutions and their application in a hospital context. Understanding the value of 6G and metaverse in-depth requires a conversation with different stakeholders to seek expertise in technology development [38].

For this study, we used a purposeful sampling strategy [39] by focusing on the experts who understand health technology and its development and adoption process in hospitals. Because this study is future-oriented, and the topics are not well-known for everyone, our sampling process needs to make sure that selected participants will be capable of sharing their expertise on the question asked and meet the aim of this study [40]. The experts invited consist of stakeholders involved in hospital operational processes, development functions, solution vendors, and service providers, including hospital managers, health professionals, developers, researchers, and company representatives. We anticipate that a diverse portfolio of experts will approach 6G and metaverse from different angles and perspectives, enabling our understanding of future 6G and metaverse in various areas of hospitals (Table 1).

Table 1. Data collection summary.

No.	Workplace	Field, Profession and Position	Duration
1	Hospital	Surgeon, manager of future hospital development	56 m
2	Hospital	Surgeon	40 m
3	Hospital	Surgeon	45 m
4	University	Biomedical sensing and instrumentation, Adjunct professor	52 m
5	University	Phycologist, health education development, Professor	50 m
6	Company	Metaverse for construction design	54 m
7	Company	Metaverse for pain management solution	46 m
8	University	Engineering, senior research fellow	30 m

We use open-ended questions as an interview strategy. Since 6G and metaverse are future-oriented technologies, the open-ended question allows interviewees to express their thoughts, experiences, and perspectives without being limited by predetermined response options. Open-ended questions provide an opportunity for interviews to shape the direction of the conversation and might lead to unexpected insights and uncover new information. The discussion topics fall into five themes: current digitalization situation in hospitals, 6G in hospitals, metaverse in hospitals, stakeholder, service, and infrastructure, as well as regulatory impacts.

To begin our data analysis, we initiated desk research, examining existing literature, documents, and transcripts. After a comprehensive study of the data, we observed that each interviewee had envisioned a use case based on their field of work and knowledge. These use cases correspond to each stage of the hospital care pathway, from emergency and treatment to rehabilitation. Additionally, there is a use case for building smart hospitals by applying 3D modeling now and integrating the metaverse in the future. We decided to describe and analyze these use cases to synthesize the key values of each case to explore the future 6G-enabled hospital metaverse.

3.2 Findings and Discussions

The Current Level of Digitalization. The discussions of the digitalization of hospitals, in general, indicated that a huge step was taken in the development and use of digital services and platforms during pandemics. Due to social distancing, people learned to use digital service portals, which advise maintaining well-being with personal actions and activities or guide self-diagnostics as preliminary care action. "*Individuals are progressively becoming accustomed to utilizing sensors and wearables to manage their well-being and acquire the skills to analyze health data for self-care*". *(Interviewee 4). Moreover*, many tasks like discussions with chat service, video consultancy, or renewing prescriptions happen now based on individuals' own activity.

Considering the digitalization of medical actions, "*the biggest benefits have been reached, in imaging and various analysis tasks when high data volumes can be analyzed and transferred in a minimum time.*" *(Interviewee 4)* Imaging patients produce high volumes of data, which needs to be analyzed powerfully in a short time for diagnostics. Often, masses of data are sent to other locations, which assumes high data transfer capabilities. Another remarkable advantage of digitalization has been "*in the analysis of biosignals, where digitalization of analysis methods has enabled the detection and identification of some rare illnesses.*" *(Interviewee 4).* Analysis and comparison of patient data with a vast amount of reference cohort data enables, e.g., to recognize deviations from normal trends of health data. More generally, the high increase in computing power making, e.g., real-time 3D video analyses, has been a crucial change in the patient care processes. For future improvement, doctors propose "*to develop a system which enables real-time situational awareness e.g. in urgent cases, when the operation room needs to be prepared for a patient arriving with an ambulance.*" *(Interviewee 1).* The increase of edge computing capability of 5G and beyond technologies will help to achieve a real-time situational picture based on patient data. Subsequently, instead of processing high volumes of data in VR glasses, the data can be transferred wirelessly to the surrounding 6G network i.e. "*implementation of edge computing can be used for off-loading. The glasses' weight will be dramatically reduced, thus increasing the usability of the metaverse.*" *(Interviewee 8).*

Another aspect where digitalization helps is the serious lack of professionals, specialists, and other resources, which even challenges the delivery of public health care services as statutory debts. This is further "*challenged by the demographics, which show the number of elderly to be in high growth, resulting in an increasing need for health services.*" *(Interviewee 2)* Subsequently, some advancements are rather easy to develop like "*simple practical improvement would be to minimize the time used for manual data collection from patients being still today a frequently repeating activity, which has even caused cons in false medication due to human errors. (Interviewee 1)*" All this could be probably decreased by the integration of devices and instruments with improved data management processes, though, considering all the privacy rules. Moreover, developing data management practices by adopting increasingly more artificial intelligence technologies would help in the decision-making of operational patient processes.

Digitalization has considerably streamlined hospital workflows, enhancing the efficiency of clinical work. The digital care pathway not only reduces the time health professionals spend on filling out patient forms but also simplifies data retrieval. Appointment bookings can be effortlessly managed through digital protocols, while patient interactions, including pre-surgery preparations, can now be seamlessly conducted through mobile apps.

The Current Processes and Stakeholders. Typical stakeholders of hospital operational and development processes are based on both internal and external functions. Each organizational unit is the process owner of its special medical focus area or support function, and it needs to present plans and reasoning for its activity, procurement, and investments to the cost control function. When it comes to hospital patient care processes, the interviews revealed that there exists some room for development. Often the evaluations of processes are conducted internally, which often does not disclose all the process deficiencies. The hospital management oversees processes and needs to take action when shortages are detected. The process developers have co-operated with external specialists and researchers when targeting improvements.

Most of the medical units have specific devices and instruments, which are taken care of by the maintenance unit. This team is crucial to keeping the operations functional and in continuous completeness. Some of the processes, devices, and instruments are sensitive to environmental conditions like temperature or humidity, which need to be stable and constant. For that purpose, the hospital property management controls particular premises to maintain optimal circumstances of patient processes in various use cases. Through the patient care processes high volumes of data are generated constantly. Collection, protection, analysis, and safe sharing of data are assumed to have high-capacity computing and data transfer capabilities. The ICT department is responsible for operating, maintaining, and developing the data infrastructure. Moreover, various other support functions as stakeholders exist in the hospital. Logistics is responsible for the delivery of numerous things that are needed in the processes. Another support function is the security office to maintain overall security in the hospital premises.

Constraints. The constraints on digitalization and developing the 6G-enabled metaverse fall into different categories. Both the telecommunication and health industries are highly regulated. At the societal level, the current regulation appears bureaucratic and does not enable new businesses or innovations to enter hospitals due to the long clinical trial period and heavy process of preparation for certification and documentation, which is applied to medical innovations.

At the organizational level, the regulation of medical procurement also limits the potential for innovation adoption. Few resources with potentially insufficient competence are allocated to the purchase of future-oriented technology and equipment, such as the necessary VR glasses, or infrastructure for a virtual simulation environment. "*It took a long time for us to get permission from the research management group to buy more advanced and expensive VR and head glasses for our VR project.*" *(Interviewee 5).* Safety for sensitive health data is obviously seen in hospitals. The interoperability among different technological solutions is not compatible, and collaboration between data-driven solutions is not sufficient, so innovation solutions are dead without sufficient investment from external investors.

At the individual level, technology resistance has been cited by most of the interviewees. Our empirical finding indicates that digitalization simplifies the processes of documenting, archiving, and searching for patient data, and it benefits the process of treatment. However, digitalization also increases the workload, e.g., time spent on inserting patient information into different systems. A common statement is that technology cannot replace human contact with patients. This is not the aim of developers either, but they are developing solutions for routine tasks e.g. to decrease time spent with computers when manually exporting and importing information between data systems. Also, remote or virtual consultation with doctors or nurses is often resisted by the customers. This can be potentially decreased when positive experiences about the virtual meetings are gained. A favourable experience can be e.g. quick digital appointment with the doctor on the next day instead of queueing for one week for a physical meeting with the professionals and the result of the consultation is the same in both cases. Many physical meetings could be replaced by virtual negotiations. Due to outdated infrastructure, errors often occur in documenting processes, sometimes, just simply because of e.g., "*the shortage of computer memory, or an unreliable network and bad connection*" *(Interviewee 3).* These administrative tasks prevent doctors from concentrating on treatment and clinical work.

Need for 6G and Metaverse in Hospital: Use Cases. Although the current digitalization has brought benefits to clinical treatment, processes, and services, further development is expected to improve the efficiency and effectiveness of clinical work. Considering the emerging technologies such as 6G and the Metaverse, detailed specifications or well-defined expectations are still lacking. However, based on our interviews, there is a strong demand for connecting physical objects, people, locations, and services to optimize work processes, which may lead to saving costs and improving the quality of care. Based on the interviewees' backgrounds and knowledge, they identified the use cases for the Metaverse and 6G.

Use Case 1 (Designing Smart Hospital). When constructing or renovating smart hospitals, 3D models can be generated within the metaverse to visualize prototypes and designs. This enables stakeholders to immerse themselves in the design phase, providing them with the ability to experience and convey their ideas. "*…to understand how to make that location work better. E.g., how to place certain operation models and blocks, see if there are enough spaces around them to be able to move around and how to place the different displays and devices there. Then maybe renovating a whole room for totally* *different use cases or new types of operations*" *(Interviewee 6).* This proactive approach helps in identifying design flaws and facilitates essential modifications.

The metaverse can be used to simulate various room configurations and dynamic aspects of hospitals, such as combining different rooms, to enhance planning and decision-making. "*Metaverse goes even one step further because you can actually go inside the space with other people and visualize the way how to utilize.*" *(Interviewee 6).* The huge benefit of the metaverse is that simulates different situations in a faster way and brings more capabilities to enable you to move around to get a more realistic situation.

Metaverse simulates hospital capabilities and navigation e.g., covid 19 brought a huge number of patients into the hospital, metaverse can simulate the situation at the design stage by knowing the capabilities of the hospital and for building dynamics, like pop-up hospital rooms. Metaverse provides a higher-level understanding of the whole hospital building behaviors and environments by data coming from sensors at objects and people. "*You can track the patients and instruments, like fleet management.*" *(Interviewee 6).* Data produced by sensors from the rooms in the hospital environment and its connection to the virtual environment gives a real understanding of the situation. "*They have glasses for data, obviously the same thing for real-time. And this way you can maybe much, much more efficiently kind of handle the situations. Inventories can be handled more efficiently by floating from many angles*" *(Interviewee 6).*

*Use Case 2 (Improvement of Medical Workflow)***.** A common use case involves the urgency of preparing for a critical surgical procedure, especially when there is preliminary information about a severely injured patient arriving via ambulance. "*When a patient is coming to an ambulance, it's a big mess in the hospital because they are calling to each other and we need to be prepared. It's coming, it's coming. And then where do we have free space and where are the needed instruments and equipment?*" *(Interviewee 1).* The efficient planning and coordination of essential medical devices, equipment, operation rooms, and estimated arrival time at various locations are crucial but often challenging to accomplish on short notice.

Use case 3 (Surgery Modeling). Some initial experiences about metaverse have been gathered, e.g., through 3D modeling of the skull, which is seen as a huge benefit in specific processes of diagnosing head-related illnesses. "*Doctors could be with VR glasses on with zero latency connection in real-time seeing how the operations work and capture the movement seeing what happening. With pictures from the machine, you cannot see and move.*" *(Interviewee 7).* VR technologies, e.g. latest video device can get realistic images on VR that add value to telemedicine. The treatment will not solely rely on pictures and videos but allow doctors to see real situations in VR. Data safety and security are very important for metaverse usage in hospitals, "*I think the networks were closed so that you had black on service and hope on data handling inside of buildings.*" *(Interviewee 2).* Therefore, the indoor and local network of 6G is needed.

Use Case 4 (Situational Awareness of Patients/Hospital - Mobility/Location/Navigating/Tracking). Remote monitoring of a patient in a remote location, e.g., at home, whose real-time vital data is available, and the doctor needs to make decisions for the care actions of local professionals beside the patient. "*Some visions foresee hospital beds at homes, increasing the need for situational awareness. The response will be much faster when we see this happening in real-time, e.g., by metaverse*" *(Interviewee*

7). 6G will enable the positioning of various objects. This can be utilized in prompt indoor navigation of personnel, patients, or visitors. With 6G capabilities, data is sent and processed in real time, allowing for immediate alarms if a critical event occurs. Tracking is essential to determine the locations of machines and equipment, as well as doctors and patients. Wireless solutions enable not only the mobility of patients and doctors but also allow machines and equipment to be positioned, tracked, and moved to the required locations. Instead of wasting time fetching instruments along long corridors, the personnel could call the autonomously navigating instruments to arrive in the operations room.

Use Case 5 (Pain Management and Mental Therapy). Experiments show good results in the treatment of chronic pain or mental illness with virtual technology like VR because with chronic conditions, patients are not willing to travel to the hospital all the time when they need to talk with doctors, particularly for some patients with serious illness and disabilities. "*Building services for those patients who are at home almost 24 h per day, would be a huge potential. In the metaverse, those people will be able to travel around the world and see different places, engaging in various activities, as technology advances and realism improves. It's beneficial for pain management and mental health.*" *(Interviewee 7).*

Use Case 6 (Training and Education). Metaverse can provide training not only for health professionals but also for healthy individuals and patients. Metaverse supports preventive health and provides guidelines to prevent, reparation e.g., surgery in the virtual situation that can replace health care professionals for counseling. "*We should support healthy people to stay healthy…I think the metaverse is an excellent example of where we can encourage people to exercise, build virtual agents to be their friends, and guide them in their daily lives to improve their health*" *(Interviewee 5).*

The hospital-tested metaverse environment will guide prevention in the correct direction because the internet is full of information regarding diseases, but not all the information is valid and represents the true situation "*metaverse we can even develop these kinds of new tools of screening evidence, you know, making sure that what we present to our patients is correct information*".

For patient training, a similar example is also mentioned by Interviewee 7: "*(For first pregnancy), training for delivery is common in Finland. With metaverse, it can bring pregnant women to reality and get realistic ideas and understanding in the real, specific local hospital how things will be work and what kind of preparation would be and how the delivery will be done there.*"

Education of new healthcare professionals in immersive environments supports learning of medical tasks and processes after which working in the real environment is more familiar without having worked there before. "*A good example is training in the automotive industry by VR, the accident rate dropped like 60% after training with VR solutions.*" *(Interviewee 4).*

Analyzing KVs of Identified Use Cases. We apply the adapted 6G visioning framework by answering the fundamental questions of actions to be taken for building 6G future networks proposed by [35]. The related questions in [35] help to identify value addressed by use cases described in interviews. Since this study focuses on the healthcare context, the usage scenarios will be based on the hospital patient care pathways and their situational usage. The study results are presented in Table 2.

Table 2. Analysis of use cases: expected outcomes, usage scenarios, capabilities and impacts.

Use Cases	Expected Outcomes	Usage Scenarios	Capabilities	Impact
1 Designing smart hospital	*Why are we developing 6G?*	*What purpose are the users using 6G for? How are the users using 6G?*	*How do we make 6G function?*	What is the impact on future hospital)
	Hospital room usage optimization	Smart hospitals	Connectivity	Efficiency
	Matching and positioning hospital rooms, equipment, and human resources	Room positioning	Positioning	Saving
		Simulation of different combinations and purposes of uses of hospital rooms	Flexibility	Local services
		Development of processes	Mobility	
		Acquisition of instruments		
		Education		
2 Improvement of medical workflow	Patient Safety	Emergency	Mobility	Efficient usage of resources
	Hospital work process optimization	Moving wards	Tracing, Tracking, Navigating	Situational awareness
	Precise location	Location sharing	Sensing	
		Patient monitoring	Real-time data and computing	
3 Surgery modeling	Patient safety	Surgery process development	Flexibility	Sensing
	Patient monitoring	Remote surgery	Mobility	Data capabilities
	Decreasing errors		Information security & privacy	Wireless solutions
	Quick		Reliability	Local network
	Emergency response		Local services	Reliability

(*continued*)

Table 2. (*continued*)

Use Cases	Expected Outcomes	Usage Scenarios	Capabilities	Impact
4 Situational awareness	Remote monitoring, tracing, and tracking in local hospitals	Emergency	Real-time data	Sensing
	Moving wards	Ward transfer	Local services	Positioning
		Hospital transfer		Real-data capabilities
5 Pain management and mental therapy	Pain management	Rehabilitation	High-speed, Connectivity	Data capabilities
	Mental therapy			
6 Training and education	Preventive health and patient training	Accurate information	Simulation and visualization	Connectivity
	Research, training, and education	Education and hospital, nursing homes	Sustainability	Sustainability

The crucial link between the metaverse and 6G lies in real-time data connection and analysis, focusing on the effective utilization of diverse data sources such as patient information, environmental factors, sensors, and medical devices. In this context, connectivity facilitates connections among people, physical objects, and virtual realism through data. The illustrated use cases indicate that mobility is important in hospitals to connect patients, doctors, nurses, and needed medical equipment and machines, particularly during emergencies, and for remote patient monitoring. Mobility, e.g., mobility in ambulances and its connection to hospital environments, is critical to ensuring patient safety. Seamless data transmission across department boundaries will enhance mobility in ambulances, streamlining and seamlessly coordinating people, equipment, and facilities in a hospital environment, leading to situational awareness and more effective and timely responses to emergencies.

Situation awareness is one of the key values identified from use cases. To support situation awareness, a seamless wireless connection is required for real-time communication among different objects, e.g. sensors from patients, real-time data from medical instruments and equipment, and location and positioning of health staff. Flexibility allows optimized usage and combination of hospital wards and rooms without having to move around the equipment. Due to the sensitive medical and treatment data and safety operations, a secure, closed indoor network is needed to ensure the stability and safety of data.

Metaverse requires more reliable connections and faster data processing speeds to support the efficient exchange and collaboration of a large network of interconnected devices and sensors for hospitals. The fifth Generation (5G) communication network cannot meet the growing demands and requirements for metaverse use cases that require latency and reliability of short-packet transmission [41, 42]. Therefore, Six-Generation

(6G) Networks are expected to eliminate time and space barriers to optimize healthcare workflow [43] and meet the demand for seamless connectivity and ubiquitous intelligence [15]. The 6G is posited to support massive connectivity, empower AI and ML for real-time data analytics [44], and support the metaverse development for health practices and services with energy-efficient solutions.

Drawing from the use cases identified and analyzed, this paper has identified the key values and related capabilities, usage scenarios, and impact of 6G and metaverse in hospitals shown in Fig. 2.

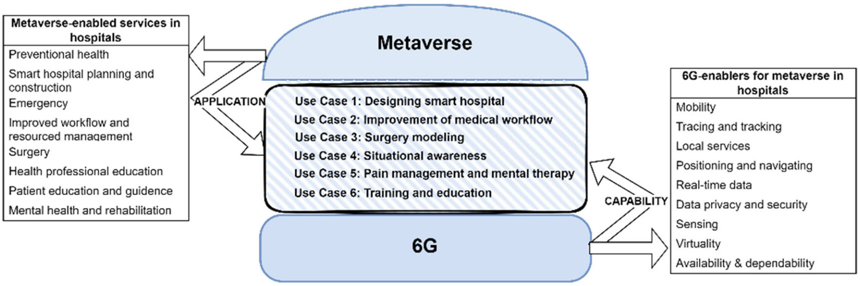

Fig. 2. Services, enablers, and use cases for 6G-enabled hospital metaverse.

The evolution of the metaverse will rely on the network of 6G as core infrastructure and services. 6G, as a general-purpose technology, offers the foundational platform and capability necessary for metaverse enabled services and its development [45] in hospitals. The 6G network alone, in the absence of metaverse as a practical application, would probably lack some key characteristics essential in the healthcare context. Thus, the metaverse, an emerging technology, is integrated within the 6G framework to unleash its capabilities contributing to each stage of the patient care pathway from emergency to rehabilitation. Consequently, the development of both metaverse and 6G will progress in tandem, hand in hand, offering local services in hospitals.

4 Conclusion

Technology advancement helps to develop hospital processes further and more effectively, leading to quality-of-care improvement and cost savings. The 5G and beyond or 6G technologies cannot bring any short-term solutions, but the challenging state of health care surely generates lots of expectations and requirements for the upcoming technologies under development. 6G is expected to play a significant role in telemedicine [46], remote surgery, fast processing of high data volumes, and other healthcare instruments and applications by providing ultra-reliable and low-latency connections for real-time medical procedures and diagnostics.

In the developing process of the 6G-enabled metaverse, it's important to consider key values, stakeholder needs, and healthcare regulations in the early stages of R&D technology projects to prevent future bottlenecks. The existing infrastructure, somewhat antiquated, faces challenges in meeting the demands of new technology, such as computer processing speed and memory capacity, and needs sufficient investment to build and renew the necessary infrastructure.

Understanding the needs and key values of the 6G-enabled metaverse will allow tailored solutions to their specific requirements, consequently diminishing healthcare professionals' resistance to the burdens of adopting new technology, including the associated training, and learning. Local services of 6G-enabled metaverse are needed, e.g. protecting patient-sensitive information and precise positioning of people and objects. The anticipated integration of 6G and metaverse technologies in hospital settings is predicted to create a demand for new roles distinct from the current stakeholders in the hospital. It's projected that the Information and Communications Technology (ICT) departments of hospitals, along with national Mobile Network Operators (MNOs), will not be solely responsible for managing the upcoming local 6G infrastructures. New businesses will emerge, but the current regulations that may slow down the process of healthcare innovation should be reformed to better support their emergence and development.

For managerial implication, the 6G-enabled metaverse should have: (1) support from the government and different organizations for funding; (2) an updated network to ensure connectivity and reliability; (3) investment in hardware and equipment that can fulfill metaverse requirements; (4) strong leadership from hospital management to support its development; (5) stakeholder engagement, especially from end-users, in the development process to guide the direction for building the 6G-enabled metaverse environment; and (6) regulations that do not hinder the development of using AI models and connectivity between different infrastructures for data.

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