ISSN: 2182-2069 / E-ISSN: 2182-2077

A Comprehensive Review on 6G Advanced Techniques and Challenges for Rural Health Care System

Arun Kumar[1], Nishant Gaur[2], and Aziz Nanthaamornphong[3*]

[1]Department of Electronics and Communication Engineering, Sikkim Manipal Institute of Technology, Sikkim Manipal University, Majitar, Rangpo, India. arun.kumar1986@live.com, https://orcid.org/0000-0001-7640-8975

[2]Department of Physics, JECRC University, Jaipur, India. nishant.gaur@jecrcu.edu.in, https://orcid.org/0000-0002-2819-1465

[3*]College of Computing, Prince of Songkla University, Phuket, Thailand. aziz.n@phuket.psu.ac.th, https://orcid.org/0000-0002-1618-6001

Received: August 29, 2025; Revised: October 06, 2025; Accepted: November 14, 2025; Published: November 28, 2025

Abstract

Focusing on the associated research issues, this article provides a thorough examination of the sixth-generation (6G) technology and its ground-breaking uses in smart healthcare. With its lightning-fast data rates, low latency, and constant connectivity, 6G represents a significant breakthrough in wireless communications. Advances such as telemedicine and real-time patient monitoring are possible with 6G integration in healthcare owing to cutting-edge technologies such as edge computing, massive (multle-input multiple-output MIMO (), and terahertz frequencies. These advancements have made it easier to connect quickly and efficiently, which is essential for delivering high-tech healthcare services. The rollout of 6G will create several issues, such as security, adoption of advanced technology in the healthcare system, and monitoring of data. However, 6G communication ensures reliable coverage in both rural and urban areas, making healthcare possible in underdeveloped locations. The use of 6G in the healthcare system demands extensive protocols and trained technicians, which is regarded as a serious issue in the integration of 6G with conventional hospitals. The present work outlines the major technology that will play an important role in future smart hospitals and the challenges associated with the utilization of these techniques in health care. Furthermore, the article also highlights the revolutionary change that may be possible in healthcare services by enhancing the standard of health quality by analyzing and solving the challenges associated with the integration of advanced techniques and conventional hospitals.

Keywords: 6G Communication Technologies, Rural Healthcare Systems, Telemedicine and Remote Monitoring, Intelligent Health Networks, Healthcare Connectivity Challenges.

1 Introduction

As the demand from users regarding healthcare systems increases, there is a need to integrate advanced technologies with conventional healthcare systems. In the present scenario, technologies such as 4G and 5G are being utilized in hospitals, which has made a drastic change in the quality of health services and

Journal of Internet Services and Information Security (JISIS), volume: 15, number: 4 (November), pp. 693-708.
DOI: *10.58346/JISIS.2025.I4.050*

*Corresponding author: College of Computing, Prince of Songkla University, Phuket, Thailand.

administration. The patient can book an appointment with the best doctor and seek medical advice from experts by staying at home, which saves the time and cost involved in travelling. The patient's data can be stored electronically and easily accessed by the corresponding user. Therefore, even if a prescription is lost or misplaced, it can be easily tracked by accessing the electronic files of the patients. It is also seen that most of the diseases can be perfectly healed and managed by sitting at home under the monitoring of expert health care through video and audio (Azmi et al., 2020). However, it requires a high data rate, low latency, good capacity of the framework, and the ability to connect to millions of devices, ensuring multilevel security. Access to better health services is mostly affected in rural areas, as there is a deficiency in better health services and infrastructure. Patients from the village have to go to town seeking proper healthcare support, which increases the cost of treatment, and most of the time, the patients need to wait for the appointment. The concept of telemedicine was introduced when a primary healthcare center in any rural area was connected with the best hospitals and medical experts in the town. Remote surgery can be performed with the support of experts in healthcare. However, a lack of infrastructure and technical facilities can hamper the concept of telemedicine. However, the present 5G technology cannot fulfil the demand for standard smart healthcare services. Hence, it is important to explore advanced technologies that can fulfil the demands of smart hospitals (Arsad et al., 2019). Advanced radio communication, such as 6G, has huge potential to integrate with hospitals and other advanced technologies, which can improve the standards of health services across the globe. The utilization of 6G in healthcare can make it possible to diagnose patients remotely, provide the best medical advice, and, if required, call the patient for other health checkups. This process saves time, provides the best health care, and even refers to other experts. The integration of wearable devices through 6G also properly monitors chronic patients, continuously sending the data to medical experts and alarming the patients in case of any emergency. The attention of medical experts during medical emergencies can boost the standard of health services, which can be achieved using 6G. Medical experts in rural areas can continuously send patients' medical imaging, tests, and other important data to the best healthcare hospitals in urban areas. This will ensure that the patient receives constant advice from the best medical professionals across the world, bridging the gap in healthcare quality between urban and rural areas. The use of 6G in medical training and education can also help experts analyze patient data more accurately and precisely (Liet al., 2019).

2 Literature Review

In this section, we analyze articles related to the use of 6G and other advanced technologies in conventional hospitals. This indicates the significance of smart hospitals and the progress related to the use of advanced methods in the conventional healthcare sector. Further, it also addressed different parameters, such as high data speed, latency, deployment of advanced infrastructure in rural areas, and use of advanced methods such as AI and robotics for medical diagnostics. It outlines several major issues, such as scalability, cost, and infrastructure capacity. For effective, long-term rural healthcare delivery, a multi-technology hybrid framework is suggested. The articles published in the 6G field are listed in Table 1 (Kumar et al., 2021; Chowdhury et al., 2020; De Alwis et al., 2021).

- Research articles have the potential to advance the state of the art by facilitating the development of innovative technologies and approaches to improve healthcare outcomes.
- Evaluating the effectiveness of new technologies: Research papers can evaluate the effectiveness of cutting-edge methods and technologies in real-world settings.

- Delineating challenges and limitations: Research articles can outline the difficulties and limitations of new technologies and methodologies, which can help guide future research and development.
- Promoting interdisciplinary collaboration: Research articles that combine knowledge from computer science, engineering, and healthcare can help foster interdisciplinary collaboration, which is essential for developing effective solutions in smart hospitals. By bringing together experts from various fields, research articles can encourage the development of innovative solutions to challenging health care issues (Gui et al., 2020; Kumar et al., 2024).

Table 1: Comprehensive study of published works

References	Remarks
(Albreemet al.,2020)	The article focused on reducing the latency in 5G network by utilizing the advanced hybrid detection algorithm, Substantial improvement in throughput were obtained (Albreem with increase in complexity.
(Albreem et al., 2021)	The article focused on the research and challenges in 5G based smart hospital and also provide a comprehensive investigation on the advanced techniques of 5G.
(Ahmed et al., 2020)	A few challenging problems are introduced together with the anticipated 6G coming technology. Furthermore, the prerequisites, potential technologies, and projected applications are discussed.
(Benniset al., 2020)	This article speculates on the futuristic visionary technologies that could deliver the significant advancements needed to allow 6G, extending the 5G vision to more ambitious future scenarios.
(Adachi et al., 2020)	An outline of the main 6G issues, including core services, use cases, needs, enabling technologies, architectures, typical use scenarios, obstacles, and research paths.
(Gaoet al., 2020)	This article examines measurements and models for 6G wireless channels across all frequency bands, use cases, and worldwide coverage.
(Habibiet al., 2021)	There is thorough research that presents the drivers, use cases, usage scenarios, requirements, key performance pointers, architecture, and supporting technologies of the 6G system.
(Alwiset al., 2021)	A thorough analysis of current 6G developments is conducted.

3 6G Radio System

As shown in Figure 1, 6G mobile technology represents the next step forward in wireless communication, building on the advancements in 5G. Experts anticipate that 6G mobile technology will transform communication across various industries by providing faster speeds, reduced latency, and advanced features. The rollout of 5G is completed globally, and it is deployed in different wireless applications for education, automation, industries, and so on. Although 5G has made an incredible change in the health sector, the demand for digitizing the health sector has increased due to the pandemic situation and unavailability of a workforce and infrastructure that can accommodate a large number of patients at a time. 6G is a promising technique that can fulfil the requirements of the healthcare industry and ensure low latency, gigantic speeds, reliability, and better coverage than 5G. Orthogonal frequency division multiplexing (OFDM) is currently utilised in 5G, which has its own advantages and constraints. The 6G radio system anticipates the use of advanced waveforms, such as NOMA and OTFS. The advanced waveforms improved the throughput of the framework and ensured a compatible large-scale connection with multiple devices. 6G also ensures real-time experience by reducing the latency to less

than 1 ms and uploading and downloading the data at a faster speed, which will benefit the health sector to a greater extent. The integration of AI with 6G can significantly enhance automation in the health care sector. It can diagnose problems accurately and rapidly. The data can be interpreted at a significant level of understanding in a much easier and more sophisticated manner. The multiple authentication layer in 6G also secured the medical data of the patients. 6G also enhances the capacity 10x as compared with the 5G network, as it utilizes the terahertz band, providing an enormous amount of bandwidth, which is beneficial for millions of wearable devices and their data storage. The role of 6G is to provide uninterrupted services that assist in deploying smart hospitals in both rural and urban areas, as well as improving the quality of healthcare, infrastructure, and continuous monitoring. One of the most important features of 6G is its enhanced access to, and utilization of, the spectrum, which increases the capacity of the framework. 6G can incorporate sensing methods of the spectrum to optimize its use. Therefore, we conclude that 6G will provide unparalleled services to various sectors, significantly transforming the economy, workforce, and efficiency.

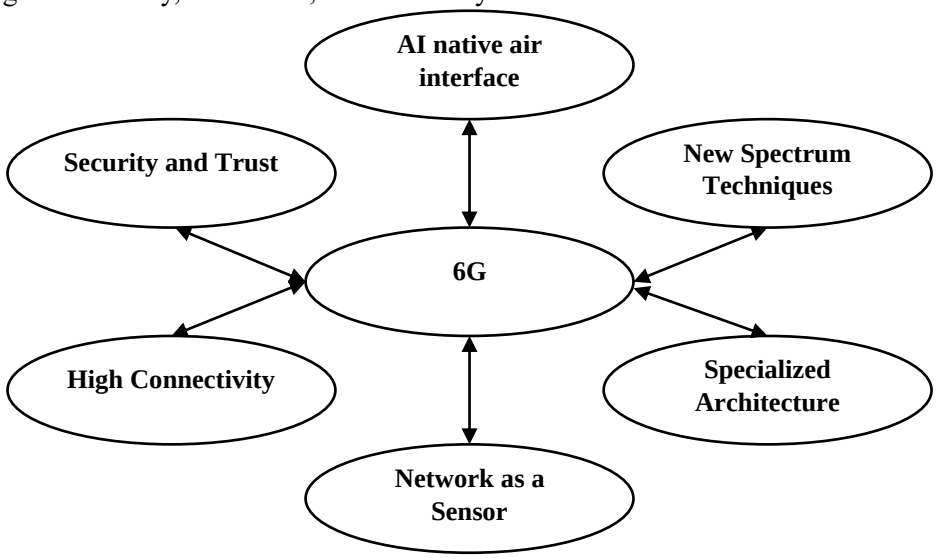

Figure 1: Architecture of 6G

3.1. Augmentations in 6G

With the increase in demand from different sectors, such as industries, education, academics, etc.. There is a need to improve speed, latency, coverage, and other technical aspects. 6G alone cannot fulfil all the requirements. Hence, it is important to integrate all technologies, such as 4G, 5G, and short-range wireless communications, with 6G. It is important to design a standalone architecture, where 6G alone provides service in an efficient manner. However, it is also important to design a dual-mode radio architecture in which both 5G and 4G provide services according to their availability. The selection of multicarrier waveforms is important for achieving optimal service. However, the advanced carrier method also introduces problems such as the peak-to-average power ratio (PAPR), which severely affects the performance of the amplifier and reduces the battery performance of the framework. Some advanced methods can reduce the peak power of the framework and degrade the system throughput. Hence, it is important to design an advanced PPAR scheme that reduces peak power and improves the throughput of the framework. Advanced methods should be compatible with 6G systems (Bennis et al.,2020). The integration of 6G with AI can enhance the healthcare framework and improve the quality of healthcare services effectively. However, it is also noted that the ongoing integration of AI in health

systems also demands several trained and skilled service providers, which can be a huge challenge for the rollout of smart hospitals.

3.2. Need of 6G Radio

In the present scenario, the increase in the number of wireless applications and different demands from the different sectors make academics and scientists explore the different technologies that can fully satisfy the requirements of the users. The roll-out of 5G is still in process in several countries compared to developed nations. Hence, the services promised by 5G are still not provided in several areas. However, the integration of a large number of machines with 5G requires a large amount of power, and connectivity is a serious concern. However, some sectors are taken care of by providing private 5G networks and cloud-based services. There are several sectors where 5G has not fulfilled requirements, such as high bandwidth, ultra-fast data rate, low latency, ubiquitous connection, and integration of non-radio devices with radio devices. The implementation of 6G will overcome the hurdles faced in the present scenario in different sectors. The implementation of 6G will give rise to different technology-driven scenarios, such as boosting tourism, the automation sector, agriculture, and, most importantly, it can improve the quality of health services. A high level of connectivity can boost the standard of services and the integration of primary healthcare centers and healthcare experts with the best hospital across the world. The advancement in IoT, where millions of devices are connected and data are shared instantly with a high level of security, standardizes the technical process of different sectors. Hence, it is important to analyze the different uses of 6G and its applications in different sectors. AI-driven automation, real-time data analytics, and precise control systems can enhance processes, reduce waste, and reduce their environmental impact. There is no denying 6G's importance to sustainability. The development of dynamic power management and energy-efficient network topologies aligns with global efforts to reduce carbon emissions and to create environmentally friendly technological solutions. However, the importance of developing 6G goes beyond the simple technological advancements. This highlights the importance of funding research, innovation, and industry-academia collaboration (Adachi et al., 2020).

3.3. Scenarios of Usage

The implementation of 6G covers all untouched applications of wireless standards. This creates an environment that can effectively improve the performance of every sector. The 6G in healthcare framework will combine with different frameworks, such as AI, IoT, and ML, to upgrade the quality of services in the medical sector. The rollout of 6G can generate several new areas and subscribes, as shown below (Gao et al.,2020):

I. Advancements in 5G technology, known as Enhanced Mobile Broadband (eMBB), offer much higher data rates, lower latency, and greater capacity for continuous streaming, gaming, and content sharing on mobile devices.

II. It is expected that the latency in the 6G standard will be less than 1 ms, creating real-time scenarios for any health service. Health experts can be connected with patents anywhere and can perform several medical procedures.

III. 6G will be designed in such a way that it can be incorporated with any technology or device. d2d communication is an important application in which a connection is ensured to transmit and receive information. However, data storage is regarded as an important issue.

4 Architecture of 6G Smart Hospital

The design of 6G radio communications ensures reliability, adaptability, and compatibility with different wireless standards and applications. The main focus of 6G is to ensure a better and simpler connectivity at every location. Thus, users can access different services at any location. One of the critical criteria of a smart hospital is low latency; thus, remote health services can be achieved. Even emergency medical procedures, such as remote surgery and remote guidance to medical experts, are possible when communication delay in the process is minimal. 6G ensures real-time experience by minimizing the latency to less than 1 ms, which is not possible in the present scenarios. Patients can use several wearable devices to continuously monitor their health. Wearable devices regularly send health data to medical experts, which can be monitored to analyze patient conditions. This will ensure that health is regularly monitored, and regular prescriptions are provided to users. If any emergency conditions exist, the device can alert users and send a signal to the nearest healthcare center. Figure 2 shows the architecture of 6G. The architecture mainly focuses on the connectivity offered by 6G by integrating IoT and other radio systems. The 6G-centred future smart hospital is designed in such a way that the patients do not experience difficulty in making appointments with the best experts, getting opinions from different experts around the world, and prescribing medical options. Hence, 6G smart hospitals offer seamless, real-time analysis of different applications. To ensure continuity of care, authorized personnel have access to patient information, medical histories, and treatment plans. Steps in cybersecurity: Owing to the sensitive nature of medical data, strict cybersecurity protocols are necessary. This design incorporates intrusion detection systems, encryption, authentication methods, and privacy-enhancing technologies to safeguard patient data and guarantee adherence to data protection (Klonidis et al.,2020).

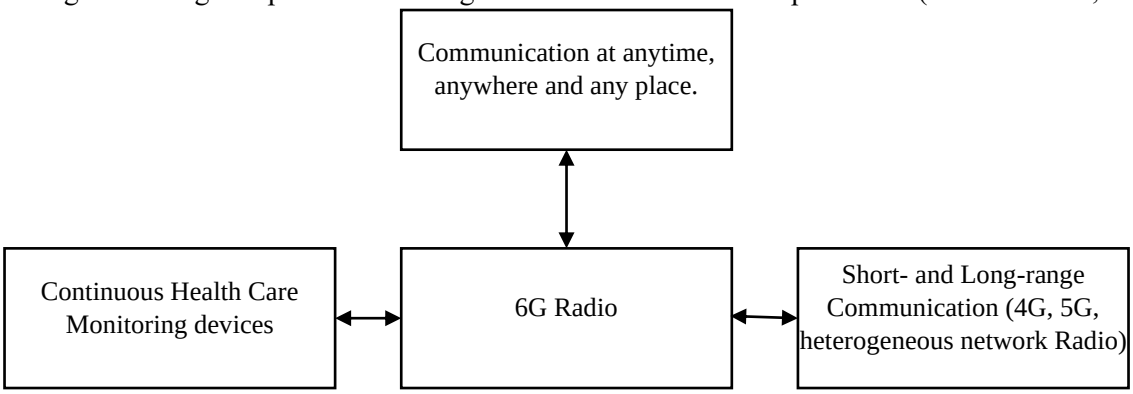

Figure 2: Architecture of 6G with healthcare

5 Advanced Technologies in 6G

6G radio's advanced technologies include a number of ground-breaking advancements that will revolutionize networking and wireless communication. Building on the foundations laid by earlier generations, 6G aims to deploy revolutionary technologies to satisfy the growing demands of an increasingly interconnected society. Many important cutting-edge technologies in the field of 6G radio are listed below. Terahertz Frequencies: 6G is expected to operate within the terahertz spectrum, offering a significantly larger bandwidth than the lower frequency bands used in previous generations. In the Internet of Things (IoT) era, terahertz frequencies support a vast array of connected objects and offer ultrahigh data speeds (Gao et al.,2014). Massive multiple-input multiple-output (MIMO): Building on 5G MIMO technology, 6G incorporates much larger antenna arrays for improved massive MIMO performance. This method improves signal quality, capacity, and coverage by broadcasting and

receiving data simultaneously using multiple antennas. This increases network efficiency and data rates. With the use of beamforming technology, radio signals can be precisely targeted and directed towards specific objects or areas. Dynamic beamforming advances 6G, adapting in real time to improve the signal quality and strength for different users and scenarios. The technology known as "spatial modulation" uses a large number of antennas to encode information and transmit data using the spatial properties of the signal. The utilization of these methods can effectively increase spectrum usage and utilization of the null spectrum, which will improve the overall efficiency of the framework (Fettweis, 2020; Fettweis, 2014; Zong et al., 2019; Negrillo-Cárdenas et al., 2020). The main focus of this advanced method is to analyze the performance of the framework, which is essential for remote applications. Energy Efficiency and Sustainability: 6G radio technology aims to optimize energy use through techniques such as advanced sleep modes and dynamic power allocation. This is necessary to ensure sustainability and accommodate a wide variety of devices. Several users and services can dynamically share the same frequency channels thanks to 6G the advanced spectrum sharing algorithms. This increases network efficiency and makes better use of the spectrum (Bennis et al., 2020).

6 AI in Health Care

The term Artificial Intelligence (AI) in 6G Healthcare refers to the application of advanced AI technologies in the healthcare industry, enhanced by the quick, low-latency communication capabilities of sixth-generation (6G) networks (Figure 3). In the future, the use of AI in different sectors can enhance the throughput of the framework. The utilization of AI can lead to a revolutionary change in the medical field. AI can be used in data analysis, prescription writing, and patent treatment (Fan et al., 2019). The medical data of the patent can be run on an Ai algorithm, and the AI can predict the different types of illness after studying and analyzing the data. The role of AI in 6G smart hospitals is to help medical experts make better decisions and provide good services to subscribers (Fan et.al 2025). One of the most important benefits of AI is early prediction of the disease, which leads to early medical treatment. Based on the medical data of the user, the AI can suggest the best doctor and treatment. It also helps users keep track of their health. Furthermore, the prediction of data will be accurate, which makes the medical service more robust and efficient (ITU-R M.2083 report, 2023). AI can also help in real-time analysis of patients and can provide suggestions to users 24/7 based on the size and nature of wearable devices. The combination of AI with 6G provides wearable medical devices with a huge potential in the medical sector (Chakravarthy et al., 2024; Liu et al., 2015; Krilavičius et al., 2025). AI in IoT can depict more information in a fraction of time than the conventional method. Hence, it reduces the time and accuracy of the framework. However, the security of AI-based health care systems is an important concern. Effective and practical guidelines should be framed before digitizing the healthcare sector (Chen et al., 2020; ITU-R, 2015; Shafi et al., 2024; Jia et al., 2024).

6.1. Challenges in Artificial Intelligence in 6G Health Care

With the many advantages of AI in healthcare, there are several challenges such as security, infrastructure, and skilled medical experts and so on (Ma et al.,2019). The difficulties of integrating AI tools with legacy healthcare systems and resistance to change are the main barriers to integration and adoption. Interoperability in a 6G environment may also be hampered by the lack of standardization of communication protocols among AI devices (Liang et al.,2019). Delineating ownership, access rights, and responsibilities for data sharing requires strong governance. Finally, regulation and validation are crucial because AI models need to be thoroughly tested for safety and dependability, but the rapid development of 6G healthcare may outpace current regulatory frameworks (Jain et al.,2024). Using AI

in a 6G-enabled healthcare ecosystem, Figure 3 illustrates how AI technologies, made possible by 6G's ultra-low latency, high data rates, and wide-ranging connectivity, are revolutionizing a number of areas of modern healthcare. While wearable IoT devices continuously monitor vital signs and use AI to detect abnormalities and sound alarms, medical imaging and patient data are sent to cloud-based AI systems for real-time diagnosis. AI supports clinical decision-making and symptom analysis, whereas high-definition, low-latency telemedicine systems enable remote consultations. AI makes individualized treatment planning easier by analyzing large amounts of patient data and optimizing it through smooth 6G data transfer (Yin et al., 2020; Hagiwara et al., 2014; Lai et al., 2017). The AI-driven accuracy and responsiveness of the 6G connection improve remote robotic surgeries. Furthermore, AI algorithms are trained with a large number of datasets, and AI can make quick decisions on patent health and accelerate the process of providing treatment. AI can also be used in researching new drugs for different diseases owing to its high computational efficiency (Jia et al.,2024; De et al.,2025).

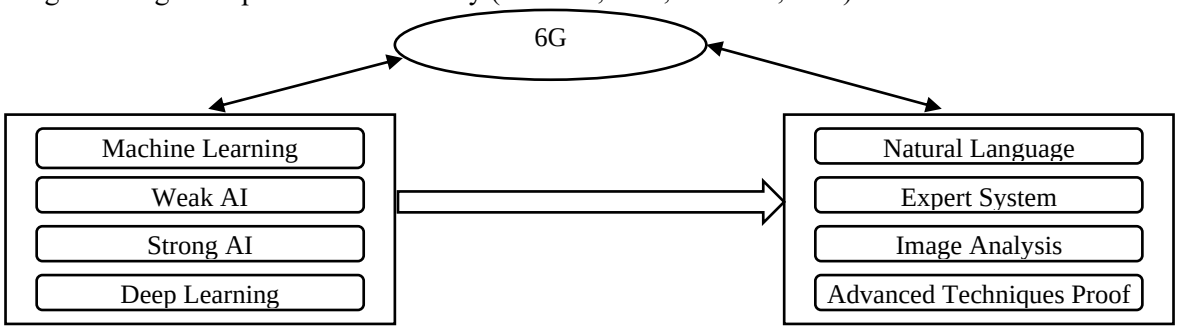

Figure 3: AI with 6G based health care

6.2. Architecture layers of AI in smart health care

The AI architecture should incorporate all other technologies, and it should be feasible in terms of infrastructure and cost. The design should be robust to ensure proper safety of the data. (Wang et al., 2017; Wang et al., 2020; Wang et al., 2014). The AI structure consists of several layers responsible for the particle task. The initial task was to divide the raw data and transmit them to the second layer. The second layer performs encryption and selects the routing through which the data is transmitted. At the destination, it is ensured that the data are received with zero error, and the de-commutation of several packets is performed. Finally, the data are transmitted to the receiving terminal. (Feito et al., 2020). AI consists of several ML methods that help to implement a robust layering system for the architecture. The design consisted of robust validation and authentication. This means that the data are highly secure, and two-way authentication is required to access the information by users and administrators. One design is validated; the design can be utilized to make several key decisions regarding healthcare and monitoring of the framework (Homik & Rachamin, 2025). Users can easily access the information through different facilities, such as messages, alerts, or the dashboard to view their medical history. The interaction between users and stored medical history is provided by the interaction layer (Eisemann et al., 2016; Stengel et al., 2016). Finally, it is very important that the proposed design can interact, and it should be compatible with the 6G radio, which acts as the backbone of the framework. Regular monitoring and training of the layer enhances the system performance and accuracy of the framework (Choi et al., 2014; Kaplanyan et al., 2019; Xu et al., 2014; Raviteja et al., 2018; Raviteja et al., 2019; Jiang et al., 2021).

7 Role of Industry in 6G Based Smart Health Care

In the last few decades, several theoretical studies have been performed by academicians and engineers, but it is important to deploy theoretical research in applications. Hence, the industry will play a vital role in deploying and manufacturing hardware that can be useful in healthcare systems. The industry can innovate and academic research can effectively deploy a smart hospital framework (Dey et al., 2015). The rollout of 6G will bring several advantages in every field and can enhance the data speed, latency, spectral performance, IoT, etc.. However, the growth of these advanced technologies will depend on the fabrication of smart semiconductors, optimized wireless devices, and smart low-energy wearable devices. Hence, it is crucial for industries to play an active role in the design and implementation of smart healthcare protocols (Guo et al., 2014; Hornik & Rachamim, 2025). Once the technology is ready after several tests, it can be deployed to hospitals, which will make a revolutionary change in the functioning of the healthcare system. The design of the system should be so simple that anyone can use it more easily. While cybersecurity companies safeguard data, regulatory bodies create standards for safe and moral behavior. Medical device certification organizations ensure the safety of integrated devices, while research centers and innovation hubs study new technologies. By teaching healthcare professionals how to use 6G-based technology appropriately, educational institutions can also support the workforce (Cui et al., 2020). These industries collaborate to create a robust ecosystem that advances intelligent healthcare solutions.

8 Research Challenges in Establishing a Reliable Connectivity Between 6G and Remote Health Care

- To guarantee reliable connectivity for effective healthcare delivery, several complex research issues have been raised by the combination of 6G technology and remote healthcare. These issues demonstrate the interdisciplinary nature of this endeavor by encompassing technical, regulatory, and operational aspects (Baldwin et al., 2024). The main research issues are as follows:
- Coverage and Connectivity in Remote Areas: It difficult to provide reliable connectivity in remote and underdeveloped areas. Research is necessary to overcome topographical and infrastructure limitations and develop strategies that extend 6G network coverage to rural areas (Ellis et al., 2017).
- Interference Management: The design of the 6G architecture involves the integration of several short- and long-range wireless applications. Hence, the interference manager plays a key role in the deployment of several technologies for seamless communication (Kagermann & Wahlster, 2022; Tomkos et al., 2020; Yang et al., 2019; Zhang et al., 2019; Zhang, Liang & Niyato, 2019)
- Energy Efficiency: The use of wearable devices in healthcare systems will boost the performance of the medical sector. However, most of these devices are battery-centered; hence, it is important to design an optimized, energy-efficient device for the healthcare industry (Gao et al., 2017).
- Security and Privacy: The medical records of patients should be secured and stored appropriately. This regulation should be implemented for the medical data storage of patients (He et al., 2024; Yang et al., 2019; Zhang et al., 2022; You et al., 2020).
- Network Resilience: In the healthcare sector, it is mandatory to have continuous signal coverage to accommodate different applications smoothly manner (Santos et al., 2017).

9 4G, 5G and 6G Comparison

The deployment of the cellular systems has made a great change in our life style and habits. In the poresent scenario the use wants to access the internet and other services 24/7 without any interruption. The implementation of 4G has satisfied several requirements but it was not sufficient to cope up with the increase in number of demands. Few years back, the 5G was deployed which has satisfied requirements and demands of the few sectors but it has not given an expected performance in health care sector. Hence, it is necessary to design a radio system beyond 5G which can be integrated with conventional hospitals and digitize the health care sector. The 6G deployment will ensure a real-time analysis and can satisfy the requirement of the health care sector (Baldwin et al., 2024). The deployment of 5G has brought about some positive changes in the quality of service, but it is not efficient to be called a smart healthcare system. However, 6G is currently in the design phase, so the necessities of smart hospitals should be taken care of during the rollout of the 6G system. (Fettweis et al., 2019). Table 1 presents an analysis of the efficiency of different radio generations.

Table 2: Performance analysis of 5G, 5G and 6G

Technology	Data Speed	Latency	Connection Density	Network Slicing:	Energy Efficiency
4G	Up to 100 Mbps (download) and 50 Mbps (upload).	Typically, around 30-50 milliseconds.	Limited support for IoT devices (around 1,000 devices per square kilometer).	Limited capability for network slicing (logical network partitioning).	Moderate energy efficiency, suitable for general applications.
5G (Fettweis et al., 2020).	Up to several Gbps (download) and several hundred Mbps (upload).	Reduced to 1-10 milliseconds (or even lower).	Supports massive IoT connectivity (up to 1 million devices per square kilometer).	Introduces network slicing for creating customized virtual networks for specific applications.	Improved energy efficiency, catering to various IoT devices.
6G (Ankarali et al., 2017).	Expected to provide even higher data rates than 5G, potentially reaching tens of Gbps.	(Projected): Aiming for ultra-low latency, potentially reaching microseconds, enhancing real-time interactions.	Expected to further increase IoT connectivity, accommodating even denser device deployments	Expected to advance network slicing capabilities, optimizing resource allocation.	Strives to further improve energy efficiency, crucial for IoT-based healthcare.

10 Block Chain in Health Care System

A schematic of the block chain with 6G integration is shown in Figure 4. The authentication of the services, whether it is a drug, medical device, wearable device, or medical sector, is important in the present scenario, as several duplicate things can be created and given to the users. Hence, it is important to identify the originality of medical items. The blockchain can help to understand the difference between

the original and fake items. Hence, it lowers the risk of medical fraud (Hong et al., 2018). It is observed that fraud can be easily done in medical prescriptions; hence, it is important to pay medical bills and provide a secure environment for users while performing payments and different tasks. The integration of blockchains guarantees a lower risk of fraud and other activities (Aly et al., 2024). It is important to enhance the efficiency of the blockchain and train the technology by securing a large dataset in a secured way. The implementation of a block chain saves time by generating a system that does not require several verifications of the data. The smart features of the blockchain will give the users an empowerment whether to share the data, and the user at any time can extract or change their preference without any hardship. This system provides an efficient framework for importing and exporting medical data and equipment from different countries. Verification will occur at the sender and receiver sides to lower the risk of fraud and scams. Blockchain deployment in smart hospitals requires several infrastructure changes in traditional healthcare services (Hong et al., 2019; Saad et al., 2019)

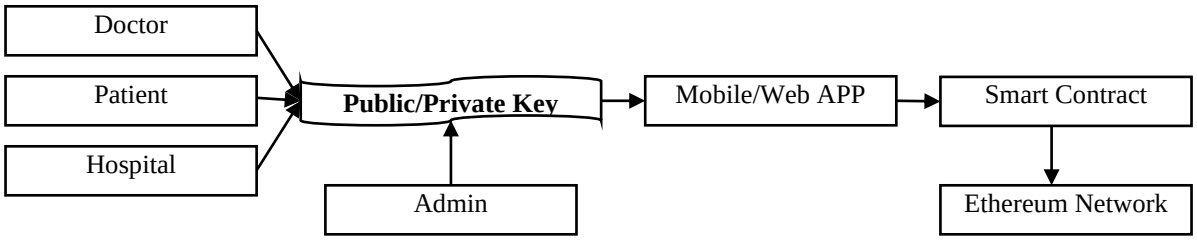

Figure 4: Block chain with 6G smart health care

11 Simulation Results

The proposed section analyzes and compares the role of 6G in healthcare facilities in rural and urban areas. This consists of a summary and case study of several studies in the proposed work. The parameters of the smart healthcare system with 6G are listed in Table 2. According to the analysis, while a number of 6G-enabled solutions are in work, AI-integrated networks and intelligent surfaces are the most efficient means of meeting the latency and reliability requirements for real-time healthcare applications (such as remote surgery and continuous monitoring). However, because of their scalability and ease of deployment, UAV-based and hybrid mesh implementations offer greater practicality in underserved areas Table 3 (Rao & Manvi, 2022).

Table 3: Key metrics performance comparison

Technique Used	Latency (ms)	Reliability (%)	Energy Efficiency	Remarks
Telemedicine with AI	1.2	99.9	High	Requires stable edge infrastructure
UAV + 6G Mesh Networks	5.6	98.5	Medium	Suitable for remote terrain
Intelligent Reflecting Surfaces	2.1	99.2	Very High	Low-cost solution but early-stage
Synthesized Best Practices	~2.0	~99.5	High	Hybrid solutions suggested

THz communication and AI-driven diagnostics stand out among the assessed technologies because of their extremely low latency, making them appropriate for vital uses, such as real-time monitoring and telesurgery. However, their high cost and energy consumption pose significant barriers to their deployment in rural or off-grid areas. On the other hand, Intelligent Reflecting Surfaces (IRS) offer

exceptional energy efficiency, which is a crucial advantage in regions with erratic power supplies. However, their practical implementation is constrained by the complex control systems and undeveloped deployment technologies. UAV-assisted 6G mesh networks are practical for deployment, especially in remote areas or emergency scenarios, but their limited flight time and dependence on weather can prevent continuous service delivery. However, hybrid systems that combine AI, UAVs, IRS, and blockchain technology appear to offer the most equitable solution, combining low latency, strong reliability, energy efficiency, and moderate-to-high deployment feasibility, making them especially suitable for the evolving needs of rural healthcare systems. According to the comparison analysis, no single technology currently meets all the requirements in the best possible manner. There is great promise for bridging the healthcare gap in rural areas with intelligent hybrid frameworks that integrate different 6G-enabling technologies. For widespread adoption in underprivileged areas, it is imperative to prioritize flexible, energy-efficient, and secure communication models.

12 Conclusion

6G-based smart hospitals will play an important role in upgrading healthcareers worldwide. During the pandemic, it is noted that most diseases can be cured without visiting the hospital if proper health guidance is provided online, and it is impossible to accommodate a large number of people at a time. The population of the world is aging daily; hence, it is important to update the current healthcare infrastructure. 6G-based smart hospitals will play an important role in upgrading and providing proper health services to people in both rural and urban areas. The proposed article focuses on 6G integrating with advanced technologies and improving health standards. The utilization of advanced techniques in conventional hospitals will enable real-time analysis of health conditions and correctly predict the illness and medication of patients. It is also noted that techniques such as IoT and wearable devices significantly improve patient data analysis in a great way. Furthermore, the deployment challenges of the proposed framework are outlined. The proposed framework can effectively enhance throughput, high data speed, low latency, and coverage to ensure seamless health monitoring in rural areas. The proposed 6G-based smart hospital provides a system in which good health care is guaranteed, regardless of the location where the patient lives. Finally, it was concluded that an enormous amount of research needs to be performed for the proper and efficient deployment of the upcoming healthcare system. The limitation of this work is that the proposed model is not analyzed in real-time scenarios, the cost involved in updating the infrastructure is huge, and stricter regulations should be maintained regarding the patients' medical data.

References

[1] Albreem, M. A., Alsharif, M. H., Gupta, M., Kim, S., & Kumar, A. (2020). Future 5G network-based smart hospitals: Hybrid detection technique for latency Improvement.*in IEEE Access*, *8,*153240-153249, https://doi.org/10.1109/ACCESS.2020.3017625

[2] Ankarali, Z. E., Arslan, H., Pekoz, B. (2017). Flexible radio access beyond 5G: A future projection on waveform, numerology, and frame design principles. *IEEE Access*, *5,* 18295–18309. https://doi.org/10.1109/ACCESS.2017.2684783

[3] Arsad, A., Azmi, M.H., Ergen, M., Han, C.T., Rahman, T.A., Shayea, I. (2019). Spectrum gap analysis with practical solutions for future mobile data traffic growth in Malaysia. *IEEE Access*, *7,* 24910-24933. https://doi.org/10.1109/ACCESS.2018.2890302

[4] Azmi, M.H., Çolak, S.A., Daradkeh, Y.I., Ergen, M., Nordin, R., & Shayea, I. (2020). Key challenges, drivers and solutions for mobility management in 5G networks: a survey. *IEEE Access*, *8,* 172534-172552. https://doi.org/10.1109/ACCESS.2020.3023802

[5] Baldwin, M., Doherty, C., Keogh, A., et al. (2024). Keeping Pace with Wearables: A Living Umbrella Review of Systematic Reviews Evaluating the Accuracy of Consumer Wearable Technologies in Health Measurement. *Sports Med, 54,* 2907–2926, https://doi.org/10.1007/s40279-024-02077-2

[6] Bennis, M., Debbah, M., Imran, M.A., Khandaker, M.R., Tariq, F., Wong, K.K. (2020). Speculative study of 6G. *IEEE Wirel. Commun., 27,* 118-125.

[7] Chakravarthy, S., Gaur, N., Kumar, A., Nanthaamornphong, A. (2024). Hybrid approaches to PAPR, BER, and PSD optimization in 6G OTFS: Implications for healthcare. *in Journal of Communications and Networks*, *26*(3), 308-320, https://doi.org/10.23919/JCN.2024.000027

[8] Chen, S., Liang, Y. C., Sun, S., Kang, S., Cheng, W., & Peng, M. (2020). Vision, requirements, and technology trend of 6G: How to tackle the challenges of system coverage, capacity, user data-rate and movement speed. *IEEE Wireless Communications*, *27*(2), 218-228. https://doi.org/10.1109/MWC.001.1900333

[9] Chowdhury, M. Z., Shahjalal, M., Ahmed, S., & Jang, Y. M. (2020). 6G wireless communication systems: Applications, requirements, technologies, challenges, and research directions. *IEEE Open Journal of the Communications Society*, *1*, 957-975. https://doi.org/10.1109/OJCOMS.2020.3010270

[10] De Alwis, C., Kalla, A., Pham, Q. V., Kumar, P., Dev, K., Hwang, W. J., & Liyanage, M. (2021). Survey on 6G frontiers: Trends, applications, requirements, technologies and future research. *IEEE Open Journal of the Communications Society*, *2*, 836-886. https://doi.org/10.1109/OJCOMS.2021.3071496

[11] Fettweis, G. P. (2014). The tactile internet: Applications and challenges. *IEEE vehicular technology magazine*, *9*(1), 64-70. https://doi.org/10.1109/MVT.2013.2295069

[12] Fettweis, G. P., Matus, E., Wittig, R., Hasler, M., Damjancevic, S., Nam, S., & Haas, S. (2019, October). 5G-and-beyond scalable machines. In *2019 IFIP/IEEE 27th International Conference on Very Large Scale Integration (VLSI-SoC)* (pp. 105-109). IEEE. https://doi.org/10.1109/VLSI-SoC.2019.8920308

[13] Fettweis, G., Dörpinghaus, M., Bender, S., Landau, L., Neuhaus, P., & Schlüter, M. (2019, November). Zero crossing modulation for communication with temporally oversampled 1-bit quantization. In *2019 53rd Asilomar Conference on Signals, Systems, and Computers* (pp. 207-214). IEEE. https://doi.org/10.1109/IEEECONF44664.2019.9048794

[14] Fettweis, G., Hassler, M., Wittig, R., Matus, E., Damjancevic, S., Haas, S., ... & Grigoryan, N. (2020, November). A low-power scalable signal processing chip platform for 5G and beyond-kachel. In *2019 53rd Asilomar Conference on Signals, Systems, and Computers* (pp. 896-900). IEEE. https://doi.org/10.1109/IEEECONF44664.2019.9048785

[15] Gao, L., Li, Y., Misener, J., & Patil, S. (2017, September). C-V2X based basic safety related ITS spectrum requirement analysis. In *2017 IEEE 86th vehicular technology conference (VTC-Fall)* (pp. 1-5). IEEE. https://doi.org/10.1109/VTCFall.2017.8288393

[16] Gui, G., Liu, M., Tang, F., Kato, N., & Adachi, F. (2020). 6G: Opening new horizons for integration of comfort, security, and intelligence. *IEEE Wireless Communications*, *27*(5), 126-132. https://doi.org/10.1109/MWC.001.1900516

[17] Hagiwara, Y., Mizuchi, Y., Choi, Y., & Inamura, T. (2014, December). Cloud VR system with immersive interfaces to collect human gaze-controls and interpersonal-behaviors. In *2014 IEEE/SICE International Symposium on System Integration* (pp. 169-174). IEEE. https://doi.org/10.1109/SII.2014.7028032

[18] He, B.,Liao, J., Qi, Q., Wang, J., &Wang, J. (2024). What Is 6G. In: Key Technologies for On-Demand 6G Network Services. *Wireless Networks. Springer, Cham.* https://doi.org/10.1007/978-3-031-70606-6_1

[19] Hornik, J., & Rachamim, M. (2025). AI-enabled consumer digital twins as a platform for research aimed at enhancing customer experience. *Management Review Quarterly*, 1-34. https://doi.org/10.1007/s11301-025-00527-3

[20] ITU-R M.2083 report. IMT vision: framework and overall objectives of the future development of IMT for 2020 and beyond. https://www.itu.int/rec/R-REC-M.2083-0-201509-I/en

[21] Jia, Z., Wang, F., & Li, J. (2024). Construction of SIoT CG virtual reality framework under ubiquitous clouds environment. *International Journal of System Assurance Engineering and Management*, *15*(8), 3612-3619. https://doi.org/10.1007/s13198-023-01858-8

[22] Jiang, W., Han, B., Habibi, M. A., & Schotten, H. D. (2021). The road towards 6G: A comprehensive survey. *IEEE Open Journal of the Communications Society*, *2*, 334-366. https://doi.org/10.1109/OJCOMS.2021.3057679

[23] Kagermann, H. and Wahlster, W. (2022). Ten years of Industrie 4.0. *Sci, 4*(3), 26. https://doi.org/10.3390/sci4030026

[24] Kaplanyan, A. S., Sochenov, A., Leimkühler, T., Okunev, M., Goodall, T., & Rufo, G. (2019). DeepFovea: Neural reconstruction for foveated rendering and video compression using learned statistics of natural videos. *ACM Transactions on Graphics (TOG)*, *38*(6), 1-13. https://doi.org/10.1145/3355089.3356557

[25] Krilavičius, T., De Paolis, L. T., De Luca, V., & Spjut, J. (2025). eXtended reality and artificial intelligence in medicine and rehabilitation. *Information Systems Frontiers*, *27*(1), 1-6. https://doi.org/10.1007/s10796-025-10580-8

[26] Kumar, A., Dhanagopal, R., Albreem, M. A., & Le, D. N. (2021). A comprehensive study on the role of advanced technologies in 5G based smart hospital. *Alexandria Engineering Journal*, *60*(6), 5527-5536. https://doi.org/10.1016/j.aej.2021.04.016

[27] Kumar, A., Gaur, N., Aly, A. A., & Nanthaamornphong, A. (2024). PAPR reduction of OTFS using an automatic amplitude reduction neural network with vendermonde matrix-based PTS and SLM algorithms. *EURASIP Journal on Wireless Communications and Networking*, *2024*(1), 84. https://doi.org/10.1186/s13638-024-02414-z

[28] Lai, Z., Hu, Y. C., Cui, Y., Sun, L., & Dai, N. (2017, October). Furion: Engineering high-quality immersive virtual reality on today's mobile devices. In *Proceedings of the 23rd Annual International Conference on Mobile Computing and Networking* (pp. 409-421). https://doi.org/10.1145/3117811.3117815

[29] Liu, Y., Dey, S., & Lu, Y. (2015). Enhancing video encoding for cloud gaming using rendering information. *IEEE Transactions on Circuits and Systems for Video Technology*, *25*(12), 1960-1974. https://doi.org/10.1109/TCSVT.2015.2450175

[30] Negrillo-Cárdenas, J., Jiménez-Pérez, J. R., & Feito, F. R. (2020). The role of virtual and augmented reality in orthopedic trauma surgery: From diagnosis to rehabilitation. *Computer methods and programs in biomedicine*, *191*, 105407. https://doi.org/10.1016/j.cmpb.2020.105407

[31] Rao, K. P. N., & Manvi, S. S. (2022). Issues and Challenges in Using Electronic Health Records for Smart Hospitals. *Society 5.0: Smart Future Towards Enhancing the Quality of Society*, 131-157. https://doi.org/10.1007/978-981-19-2161-2_8

[32] Raviteja, P., Phan, K. T., & Hong, Y. (2019). Embedded pilot-aided channel estimation for OTFS in delay–Doppler channels. *IEEE transactions on vehicular technology*, *68*(5), 4906-4917. https://doi.org/10.1109/TVT.2019.2906357

[33] Raviteja, P., Phan, K. T., Hong, Y., & Viterbo, E. (2018). Interference cancellation and iterative detection for orthogonal time frequency space modulation. *IEEE transactions on wireless communications*, *17*(10), 6501-6515. https://doi.org/10.1109/TWC.2018.2860011

[34] Saad, W., Bennis, M., & Chen, M. (2019). A vision of 6G wireless systems: Applications, trends, technologies, and open research problems. *IEEE network*, *34*(3), 134-142. https://doi.org/10.1109/MNET.001.1900287

[35] Santos, J., Wauters, T., Volckaert, B., & De Turck, F. (2017). Fog computing: Enabling the management and orchestration of smart city applications in 5G networks. *Entropy*, *20*(1), 4. https://doi.org/10.3390/e20010004

[36] Shafi, M., Jha, R. K., & Jain, S. (2024). 6G: Technology evolution in future wireless networks. *IEEE Access*, *12*, 57548-57573. https://doi.org/10.1109/ACCESS.2024.3385230
[37] Stengel, M., Grogorick, S., Eisemann, M., & Magnor, M. (2016, July). Adaptive image-space sampling for gaze-contingent real-time rendering. In *Computer graphics forum* (Vol. 35, No. 4, pp. 129-139). https://doi.org/10.1111/cgf.12956
[38] Tomkos, I., Klonidis, D., Pikasis, E., & Theodoridis, S. (2020). Toward the 6G network era: Opportunities and challenges. *IT Professional*, *22*(1), 34-38. https://doi.org/10.1109/MITP.2019.2963491
[39] Wang, C. X., Haider, F., Gao, X., You, X. H., Yang, Y., Yuan, D., ... & Hepsaydir, E. (2014). Cellular architecture and key technologies for 5G wireless communication networks. *IEEE communications magazine*, *52*(2), 122-130. https://doi.org/10.1109/MCOM.2014.6736752
[40] Wang, C. X., Huang, J., Wang, H., Gao, X., You, X., & Hao, Y. (2020). 6G wireless channel measurements and models: Trends and challenges. *IEEE Vehicular Technology Magazine*, *15*(4), 22-32. https://doi.org/10.1109/MVT.2020.3018436
[41] Wang, P. C., Ellis, A. I., Hart, J. C., & Hsu, C. H. (2017, June). Optimizing next-generation cloud gaming platforms with planar map streaming and distributed rendering. In *2017 15th Annual workshop on network and systems support for games (NetGames)* (pp. 1-6). IEEE. https://doi.org/10.1109/NetGames.2017.7991544
[42] Xu, L., Guo, X., Lu, Y., Li, S., Au, O. C., & Fang, L. (2014, July). A low latency cloud gaming system using edge preserved image homography. In *2014 IEEE International Conference on Multimedia and Expo (ICME)* (pp. 1-6). IEEE. https://doi.org/10.1109/ICME.2014.6890279
[43] Yang, P., Xiao, Y., Xiao, M., & Li, S. (2019). 6G wireless communications: Vision and potential techniques. *IEEE network*, *33*(4), 70-75. https://doi.org/10.1109/MNET.2019.1800418
[44] You, X. H., Yin, H., & Wu, H. Q. (2020). 6G and wide area Internet. *Chinese J Int Things*, *4*, 12-18.
[45] Zhang, J., Yu, N., Wang, B., & Lv, X. (2022). Trends in the use of augmented reality, virtual reality, and mixed reality in surgical research: a global bibliometric and visualized analysis. *Indian Journal of Surgery*, *84*(Suppl 1), 52-69. https://doi.org/10.1007/s12262-021-03243-w
[46] Zhang, L., Liang, Y. C., & Niyato, D. (2019). 6G Visions: Mobile ultra-broadband, super internet-of-things, and artificial intelligence. *China Communications*, *16*(8), 1-14. https://doi.org/10.23919/JCC.2019.08.001
[47] Zhang, Z., Xiao, Y., Ma, Z., Xiao, M., Ding, Z., Lei, X., ... & Fan, P. (2019). 6G wireless networks: Vision, requirements, architecture, and key technologies. *IEEE vehicular technology magazine*, *14*(3), 28-41. https://doi.org/10.1109/MVT.2019.2921208
[48] Zong, B., Fan, C., Wang, X., Duan, X., Wang, B., & Wang, J. (2019). 6G technologies: Key drivers, core requirements, system architectures, and enabling technologies. *IEEE Vehicular Technology Magazine*, *14*(3), 18-27 https://doi.org/10.1109/MVT.2019.2921398.

Authors Biography

Arun Kumar (Senior Member, IEEE) received the Ph.D. degree in electronics and communication engineering from JECRC University, Jaipur, India. He works with the Sikkim Manipal Institute of Technology, Majitar, Rangpo, India. He has 12 years of teaching experience and has published more than 180 research articles in SCI-E and Scopus index journals. He has successfully implemented different reduction techniques for multicarrier waveforms, such as NOMA, FBMC, and UFMC, and has also implemented and compared different waveform techniques for 5G systems. He is working on the requirements of 5G-based smart hospital systems. His research interests include advanced waveforms for 5G mobile communication systems and 5G-based smart hospitals, PAPR

reduction techniques in multicarrier waveforms, and spectrum-sensing techniques. He is a reviewer for many refereed and indexed journals.

Nishant Gaur has been used in the fields of communications engineering, antennas, wireless communications,5G and 6G, electrical and electronics engineering, MATLAB, telecommunications engineering, spectrum sensing, network science, Simulink, signal processing, image processing, and material science. He is currently an Associate Professor with the Department of Physics, JECRC University, Jaipur, India. He had 23 years of experience in research and was a professor. His research interests include 5G and 6G, numerical analysis, computer programming, classical mechanics, mechanics, binary alloys, quantum mechanics, and cryptography.

Aziz Nanthaamornphong is Associate Professor and serves as the Dean at the College of Computing at Prince of Songkla University's Phuket campus in Thailand. He earned his Ph.D. degree from the University of Alabama, USA. With an extensive academic background, Dr. Nanthaamornphong specializes in empirical software engineering and data science, among other areas. His research significantly contributes to the development of scientific software and leverages data science in the field of tourism. In addition to his core focus, he is also deeply engaged in the study of human-computer interaction, pioneering innovative approaches to foster a beneficial interplay between humans and technology. For correspondence.