Healthcare with Machine Learning

Healthcare with Machine Learning:

The Ease of Listening and Learning

Edited by

Rajeev Kumar and Abhay Bhatia

Cambridge Scholars Publishing

Healthcare with Machine Learning: The Ease of Listening and Learning

Edited by Rajeev Kumar and Abhay Bhatia

This book first published 2025

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-0364-4943-8
ISBN (Ebook): 978-1-0364-4944-5

TABLE OF CONTENTS

PREFACE

Healthcare is a core portion of human well-being; now, it is undergoing astonishing changes, almost impossible to understand in the digital age. The coming revolution is machine learning and artificial intelligence, which can ultimately change medical results or conditions, processes, and accessibility to an extent. The book, **An Ease of Listening and Learning: Healthcare with Machine Learning** takes very complex subjects and makes them comprehensible or actionable for readers.

The book is intended to raise awareness about machine learning in the minds of people working in healthcare and motivate techno-crazy individuals to find ways to use it in domains of medical sciences. By way of exciting examples, live cases, and a peek behind the scenes of how algorithms are impacting patient care, we want to build a bridge between theoretical models and their practical applications.

While writing this book, simplicity was kept at the top of our minds without compromising on depth. Therefore, if you are a healthcare professional who is interested in trying to apply machine learning into practice, or even a data scientist interested in what can be done in healthcare, this book contains quite a broad scope. Other principal topics are predictive diagnostics, personal treatments, enhancements in medical imaging, and ethical issues involved.

It is supposed, as the title indicates, that it would be mostly by very easy and inviting ways that the learning process would acquire an approach. With simple explanation and relatable scenarios, we allow the reader to travel the journey across which humanity meets technology. By the end, it is hoped that you will have knowledge and inspiration for contributing to this evolving discipline.

You will ignite curiosity, understanding without forgetting the amazing potential of machine learning in transforming healthcare, one patient, system, and innovation at a time-with this book.

And now, into the future of healthcare. May this book serve as a beacon, a guide, and a spark on your way.

CHAPTER 1

6G INNOVATIONS: ADVANCING HEALTHCARE AND MEDICAL TECHNOLOGIES

HARSH RASTOGI, SHIKHA AGGARWAL, ANIL KUMAR, ARTI CHAUDHARY

Department of Information Technology, Ajay Kumar Garg Engineering College, Ghaziabad

Abstract

What follows 5G? Now that 5G has been deployed, this has become the most pressing question for researchers. As technology advances, we must also upgrade our health-related domain. This chapter covers applications of 6G in healthcare, including telesurgery, remote monitoring, nanomedicine, neurotechnology, and health wearables. As we all know, the population is rapidly increasing. We need to upgrade our health system to deal with such a vast population. Due to a shortage of physicians, medical resources, and connections in rural regions, many medical cases in India currently result in death. When serious medical situations occur at higher elevations, the patients are forced to face the sobering fact that they will not receive assistance from plains. But that will all change soon as the network is upgraded to 6G, which will aid with remote therapy in addition to removing limitations on time and space in medical scenarios. Wireless health must be put into practice to track and manage every citizen's health journey while achieving community-wide economic viability. In addition to enabling wireless healthcare, 6G is anticipated to enable the Internet of Bio-Nano-Things, so enabling the human body to become a part of the" Net". We shall use bio-nanomedical devices in our daily lives to enhance our quality of life. A real-time report for a critical patient or someone suffering from a critical

injury will be updated thanks to advancements in bio-nano medical devices and a high-speed 6G network. Additionally, it will assist in managing pandemic scenarios like as COVID-19.

Keywords: 6G; Telesurgery; Remote monitoring; Nanomedicine; Neurotechnology; Bio-Nano-Things.

Introduction

A remarkable path of revolutionary transformation in science and culture may be traced through the development of smartphone communication networks from 1G to 5G. This development illustrates how quickly communication technology has advanced, greatly improving our capacity for connection and information sharing.

- **1G:** The early 1980s saw the introduction of the first generation of mobile networks, defined by analog signals and simple voice services (1). 1G networks have several drawbacks, including poor speech quality, security flaws, and non-interoperability, despite being groundbreaking at the time.
- **2G:** The 1990s saw the introduction of digital mobile communications with the switch to 2G. 2G networks had enhanced voice quality, more security, and the addition of SMS text messaging. They also started to offer basic data capabilities.
- **3G:** Data rates and network capacity increased significantly with the introduction of 3G networks in the early 2000s. This ushered in a new era of mobile internet access, multimedia messaging, and video calling, turning the phone into an all-purpose instrument for amusement and communication.
- **4G:** When fourth-generation networks first appeared in the 2010s, mobile technology had advanced significantly. 4G networks, which were based on LTE technology, offered high-speed internet access, smooth HD video streaming, and improved network dependability. These developments have made it easier for mobile apps and services—which characterize contemporary digital life—to be widely adopted.
- **5G:** With its global release presently underway, the fifth generation marks a significant advancement in mobile technology. The Internet of Things (IoT), driverless cars, and smart cities are expected to see new uses because of 5G's promise of incredibly fast data rates, low latency, and universal access. Its purpose is to transform industries

and generate never-before-seen prospects for advancement and expansion.

- **6G:** Next-generation cellular technology is called sixth-generation wireless, or 6G. Compared to 5G networks, 6G networks will be able to use higher frequencies while offering significantly larger capacity and considerably lower latency. One microsecond latency for communications is one of the objectives of the 6G internet. This is 1,000 times faster than a millisecond throughput, or 1/1000th of the delay.

These days, there are a lot of wearable medical gadgets on the market that are built on the foundation of 4G/5G networks. However, because of increased latency and other technical advancements, these devices are unreliable, and their accuracy deviates excessively from the initial findings. Many of these problems will be rectified with the introduction of the 6G network, along with technological breakthroughs and more sophisticated healthcare systems that will undoubtedly be more reliable, accurate, and easily operable.

Although the 5G systems in use now are smart, the 6G systems will also be intelligent and smart. The sixth generation of mobile networks, or 6G, is about to arrive and is expected to outperform its predecessors in terms of capabilities, spurring previously unheard-of innovation and completely changing the digital world. 6G, which is anticipated to launch in the 2030s, intends to expand on the groundwork established by 5G by increasing connectivity, speed, and intelligence (33). With 6G, the Internet of Everything (IoE) will replace the Internet of Things (IoT). 5G only partially enables tactile Internet, however 6G will fully support it. The Internet of Skills (IoS) has made the tactile Internet in healthcare more accessible by facilitating bi-directional immersive human-to-virtual world connections (33). The Internet of Thinking (IoTk) aims to incorporate intelligence into medical sensors and devices so that they can think, learn, and adapt to enable seamless human-machine communication (33).

This chapter delves into the technological advancements, key features, and societal impacts of each generation from 1G to 6G. By understanding this evolution, we not only appreciate the milestones achieved in mobile communications but also anticipate the transformative potential of future innovations in the realm of connectivity. This chapter will mostly address the use of 6G networks to enable technological improvements in healthcare. We can see the ladder being reached in the domain of healthcare from first generation to the last generation via Figure 1.

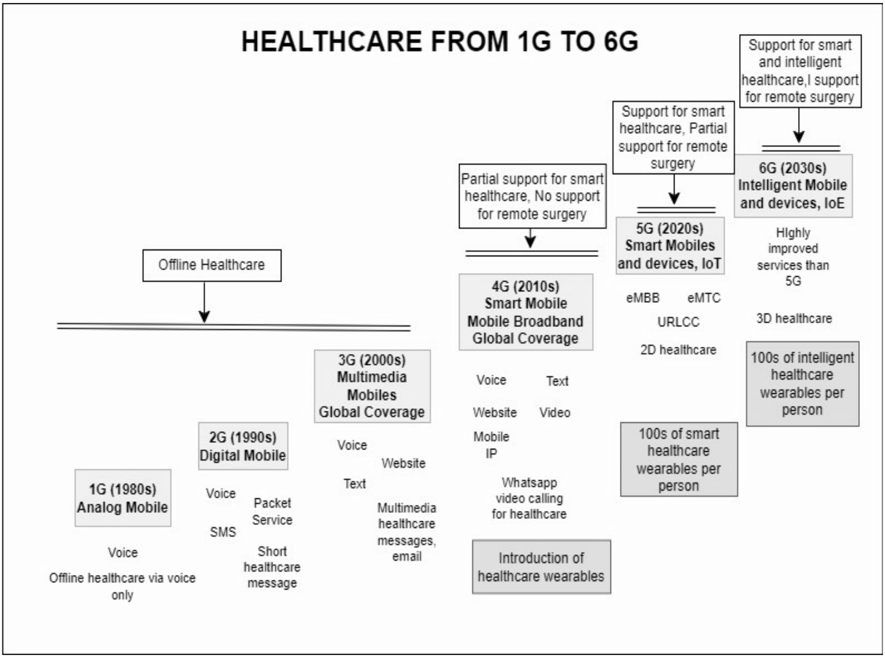

Figure 1. Healthcare from 1G to 6G: Intelligent healthcare driven by technology in 6G (33).

Healthcare Network Challenges

The needs of patients in healthcare are ever-changing. These institutions are utilising cutting-edge technology, which has fundamentally altered the industry landscape, to meet these expectations. Bandwidth-intensive applications are digitally connecting healthcare systems, from IoT devices to Electronic Medical Records to Picture Archiving Systems.

While the continuous addition of new apps can significantly enhance patient care, it can also pose network issues (3). Some of them are listed below:

- **System interoperability**

  In healthcare deployments, the average number of operating systems is greater than 20. The assumption is that the value of IoT in the healthcare industry will reach $534 billion by 2025.1. It gets harder to share and understand the data that is obtained from each application when more devices are added to these networks. These devices need to be able to communicate in the same language in order to guarantee the effective transmission of real-time data acquired.

- **Security**

  In the two most frequently targeted industries by hackers is the healthcare sector, where since 2009, over 190 million patient records have been compromised.

  Healthcare has become a target for hackers because of the volume of patient data that is continuously being gathered. Applications like electronic health records (EHRs) not only hold sensitive patient data, but also important financial data. As a result, the sector faces particular security and compliance issues. Facilities that violate the Health Insurance Portability and Accountability Act (HIPPA) may be subject to fines of up to $1.5 million for any kind of security violation. Healthcare facilities must abide by certain regulations governing health-related transactions and procedures in order to guarantee the security of patient records. Every healthcare organisation is required under the HIPPA security requirement to develop a backup plan to guarantee that, in the unlikely event of a disruption, business operations continue as usual.

- **Connectivity**

  In the healthcare industry, connecting devices to the internet and making sure they are getting the strongest signals possible are ongoing challenges. It's critical to realise that not every mobile and connected device can be handled in the same manner. These devices need a steady and dynamic network connection in order to operate correctly.

All of the aforementioned difficulties can occasionally be considered a curse on lives; for those who pass away, the cause is the greatest evil they will face for the rest of their days. The technology's most popular usage, remote health monitoring, faces numerous difficulties, including limited network capacity (2).Remote health monitoring depends on connectivity, just like other remote monitoring systems (such predictive maintenance in manufacturing) to guarantee data syncing between sensors and the devices doctors use to get those insights (35). Additional significant obstacles consist of:

- Data synchronization latency (35).
- Patient education and onboarding regarding how to use and care for the new gadget (35).
- Data duplication and inconsistency (35).
- Remote device configuration and troubleshooting (35).
- Data intake from gadgets with various output formats (35).

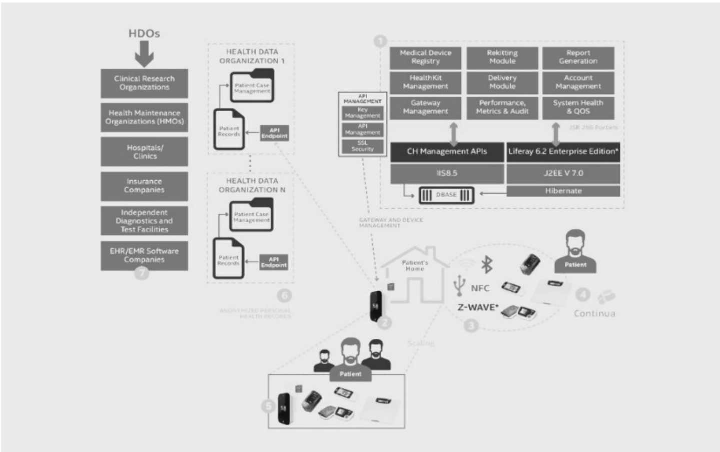

Figure 2. An integrated architecture of a remote patient monitoring system (image credit: Intel)

We have upgraded our network from 5G to 6G in order to provide a better solution and eliminate all of these issues. This will significantly improve the reduction of issues related to the network in the healthcare industry.

Sixth Generation Intelligent Healthcare Conceptual Framework

Sensible and Pervasive Medical Care

There will be intelligence in the 6G healthcare system. The intelligence will be integrated at the sensing, processing, communication, computing, and analytical levels on the network side (33). The intelligence at the level of disease diagnosis, prognosis, and prescription will be at the doctors' disposal.

The wireless body area network **(WBAN)** will enable intelligent in-body (implantable) and on-body (external) wearables to anticipate health indicators like glucose levels in the blood, strain, cardiovascular rate, nervousness, blood pressure, temperature, disorders of the brain, etc. in order to provide timely preventive treatments at the sensing level (Figure 2)(33).

These days, there are smart wearables for practically every bodily area that can sense or identify a wide range of illnesses and conditions. Making the tiny sensors intelligent through the use of intricate algorithms is a challenge. The wearables' energy and memory limitations could make it difficult to integrate intelligence. The health data that has been sensed is analysed, recorded, and sent to the cloud for analysis via smart and intelligent devices. Doctors use the data analysis to make decisions about appropriate therapies and medications. Through the use of optical wireless communication (OWC) or short range radio frequency (RF) technologies, the sensed health data is locally transmitted to smart and intelligent devices(2). 6G will offer the least (ultra-low) latency for long-distance communication tasks from edge devices to the Internet cloud. This delay can be further decreased by enabling processing on the electronic health records (EHR) at the dew, edge, and fog levels (Figure 2). Computing can be categorized into four groups based on the stage at which the data becomes available and processed: cloud, edge, fog, and dew. Cloud computing paradigm is where words like dew, edge, and fog computing in information technology stem from (Table 1). (5) Internet servers utilise cloud computing; local servers or access points use edge computing; gateways or faraway servers use fog computing; and user-end devices, such as mobile phones, use dew computing. Applying intelligent algorithms at various computing levels comes with a number of difficulties and problems. Let's explore these technologies in more detail to gain a better understanding.

- **Dew computing**

  DC is intended to be very heterogeneous, vertical, and distributed, with a reliance on the "micro-services" concept. It creates a new computational window that is free of centralized virtualization, allowing multi-typical data to be dispersed across low-end devices. It thus provides a novel approach to data access without continuous internet connectivity. Consequently, DC needs to cover all facets of the existing network technologies together with a broad spectrum of basic features (such mobility, autonomous data aggregation, collaborative apps, etc.) and hybrid network behaviour. Its selfhealing ability, autonomic self-augmentation, self-adaptiveness, transparency, user-programmability, super user experience, and extreme scalability are believed to be the main benefits of DC. Even with so many different gadgets at its disposal, DC is still capable of

Table 1. The challenges posed by cloud, edge, fog, and dew computing in healthcare (33)

Computing	Utilisation in Medical	Benefits	Negative aspects	Obstacles
Dew	Continuous monitoring of health metrics and patient data (33)	least latency, mostly close end customers can use it locally , and it doesn't need the Internet	restricted computer resources	security, lowering the amount of computational offloading
Edge	keeping track of and disclosing health metrics, analysing patient medical records, and using a decentralised method for providing healthcare services (33)	Low latency, accessible close to the endpoint devices	Restricted computational resources	Cost and energy efficiency are traded off.
Fog	In the healthcare industry, prompt and enhanced personal data security, very precise disease prediction, automated prescriptions, and high-quality video streaming apps are all available (33).	average latency	Distanced from endpoint devices	Solve compatibility problems with disparate resources.
Cloud	Effective use of virtualization techniques to provide healthcare services with computing resources (33)	maximum computational resources	The furthest from end users, with the highest latency, and requiring Internet	Cutting down on latency and energy usage, security

handling challenging tasks close by. To achieve such capabilities, DC needs a sophisticated modular architecture that adheres to all DC-ecosystem criteria. Dew computing (DC) (4) nodes are located at the sensing level, which is the closest to the endpoint devices and where the data is generated. Short-range RF/OWC technologies are used to transfer data from endpoint devices to the dew computing nodes, and they don't require Internet access to do so. The benefits of dew computing include faster data processing and local data availability for analysis. The limitations of dew computing include the power at the endpoint devices, CPU capacity, and data storage.

Electronic Health Records (EHR) security is critical at all computing levels when it comes to healthcare. Therefore, at the dew, edge, fog, and cloud levels, intelligent and secure federated learning (FL) of health data will be conducted in concert (33).

- **Edge computing**

Edge computing is the practice of putting data storage and processing power near to the devices that generate the data and the users that access it. Smart device applications have been sending data to a central data centre for processing from sensors and smartphones on a regular basis. However, the enormous volume and complexity of data has outpaced the capacities of networks. Edge computing solutions bring processing power closer to users and devices, resulting in speedier real-time insights, reduced bandwidth needs, and significantly improved application performance (5). Because edge computing makes it possible for businesses to gather and evaluate their raw data more effectively, it is growing in popularity. Organisations now more than ever require immediate access to their data in order to make well-informed decisions regarding the operations and business functions of their company. Edge computing may help businesses increase productivity and safety, streamline operations, and enhance user experience when applied properly.

Nodes for edge computing (EC) are situated farther away from the Internet but closer to the sensing locations (1). These nodes include autonomous ambulances, routers, firewalls, gateways, and tiny neighbourhood clinics, labs, and hospitals. Low network traffic and latency are the outcome of the specialised service that the edge computing devices at the edge computing layer provide. Sensors and storage located closer to data sources improve computing. Edge nodes are used for caching, data encoding, data copying, and data calling. The data routing devices in edge computing are situated in closer proximity to the endpoint devices (33). By customising security hardware and software, data security and privacy can be enhanced at the edge computing layer (33).

Among the advantages of edge computing are:

- Speed gain and decreased latency
- Enhanced protection of data
- A rise in output
- remote gathering of data
- Lower expenses
- dependable performance

- **Fog computing**

A type of distributed computing known as fog computing moves data processing and storage closer to the network edge, which is home to many Internet of Things devices. Fog computing does this via lowering latency, increasing speed, and decreasing dependency on the cloud for some resource-intensive operations. Mist computing is an extension of cloud fog computing, bringing computation and data storage closer to the edge. In this approach, mist computing servers—low-power servers that may be set up in large quantities—are often employed. When real-time reaction is required, fog computing is frequently utilized in situations like driverless cars, video monitoring, and industrial control systems (8). It can also be used to offer redundancy and backup in the event of a network outage, or to offload computationally demanding jobs from centralised servers.

Fog computing works well because the source nodes are near together and do not rely solely on the network, which is beneficial in the context of healthcare. A network outage that could create buffering during medical procedures could potentially endanger lives (33). Fog computing (FC) nodes, such as antennas and cellular base stations, are found in a wide range of relatively large clinics, hospitals, labs, ships, aeroplanes, submarines, and flying base stations. They are also present on mobile ambulances, in isolated valleys, and on UAVs that are farther from the sensing places but closer to the Internet. In the absence of cloud centres, end users (patients, physicians, medical staff, and carers) are served via Cisco's fog computing technology.

FC provides installations that are highly scalable, cost-effective, and energy-efficient (33).

In addition to the lower-edge and upper cloud computing layers, FC creates a medium-scale layer that corresponds to IoT gateways, which are tiny data-communicating clinics, hospitals, offices, and rooms. The healthcare sector makes extensive use of FC because of its superior cost, availability, scalability, security, and efficiency (8). One of FC's challenges is managing inexpensive, low-cost installations and interoperability across diverse resources at the fog level. High computational resource provision, security, and dependability maintenance present challenges (33). It also supports telemedicine, and other cutting-edge medical technology, including remote patient monitoring.

- **Cloud computing**

Cloud computing streamlines back-end operations and makes telemedicine app development and administration easier and more secure. The cloud reduces expenses and boosts productivity in the healthcare sector.

The sector is expected to grow at an exponential rate, and by 2027, total global spending on cloud computing is expected to reach a market value of over $89 billion. Moreover, Infrastructure as a Service (IaaS), a cloud computing paradigm that was used to move healthcare infrastructures to the cloud, is currently the cloud service with the fastest pace of growth, with a projected CAGR of 32% by 2027.

Highly dependable and scalable components that can be scaled both vertically and horizontally depending on the need make up cloud computing (CC) (10).(33) Data computing is made possible by the databases, load balancers, and virtualized server instances it has constructed. Cloud storage is an efficient and geo-resilient way to store large amounts of data (33). Thus, the likelihood of data loss is reduced. Features of cloud computing allow for safe data access and storage. Cloud data security is achieved by the deployment of mobile device management (MDM) servers. Cloud computing nodes are usually situated at a considerable distance from sensing places, therefore a dependable and secure bandwidth conduit is required. For data analytics reasons, healthcare systems use extracts from the DC, EC, and FC layers of the data that is collected on cloud storage. Because of the data security policy settings for sensitive patient information, cloud computing presents significant challenges to the healthcare sector (12).

When discussing the usage of cloud computing in the healthcare industry, latency is the most important consideration because high latency can interfere with online medical services and cause delays in data transfer, both of which can be dangerous for the patient's life. Furthermore, as electronic health records hold patients' sensitive and private information, data security and privacy are particularly critical. Hence cloud computing is dependent on the bandwidth of the network.

On the other hand, cloud computing is a prize for the administration of patient medical records if the system is completely safe and dependable. For example, a patient may complain of coughing, chest pains, and headaches. The doctor would then take note of any pertinent data and use their knowledge to determine the problem.

However, only the primary diagnosis—possibly accompanied by a secondary or tertiary one—would be shown on the patient's chart. This is when cloud-based data analysis is used to extract information that would otherwise stay buried.

- **AI in healthcare**

The healthcare business has undergone a transformation thanks to artificial intelligence (AI), which has altered patient identification, treatment, and follow-up. This technology is greatly improving healthcare research and outcomes by offering more personalized therapies and precise diagnoses. AI is currently being used by medical professionals to improve healthcare by rapidly discovering illness markers and patterns through the examination of massive volumes of clinical data (7). AI has several potential applications in the healthcare sector, ranging from early detection image analysis to outcome prediction using electronic health records. Millions of patients worldwide can be treated more quickly, intelligently, and effectively by healthcare systems using artificial intelligence in hospital and clinic settings. In the healthcare sector, artificial intelligence is without a doubt the way of the future. It will transform the way patients receive high-quality care, save providers money, and enhance patient outcomes.

The first artificial intelligence system of its kind was IBM’s Watson, which was created to respond to queries quickly and accurately. Articles about artificial intelligence in healthcare bring up IBM’s healthcare-focused Watson, which debuted in 2011 and focused on natural language processing, or the technology that understands and interprets human communication. These days, IBM is not the only digital giant investing more in AI for the healthcare sector; Apple, Microsoft, and Amazon are also major players in this space (7).

Large amounts of medical data can be processed and analysed much more quickly in the healthcare industry thanks to artificial intelligence (AI). This ability was essential for diagnosing diseases, predicting outcomes, and recommending courses of therapy. When it comes to evaluating medical images like MRIs and X-rays, for instance, AI systems outperform human radiologists in speed and accuracy and may oftentimes detect diseases like cancer at an early stage.

Artificial intelligence has several important uses in the medical field. Google’s DeepMind Health project, which demonstrated that it could diagnose eye disorders from retinal scans as precisely as human specialists, was a remarkable breakthrough in addition to IBM’s Watson Health. These creative initiatives show how AI can revolutionize personalized medicine and diagnostics.

AI is slowly but steadily making its way into the healthcare sector thanks to advancements in technology and the growing demand for better healthcare delivery. Thanks to AI’s paradigm-shifting entry into the healthcare sector, treatment is now more efficient, accurate, and customized. As AI technology advances, it is anticipated to have a greater and greater impact on healthcare, solidifying its place as an essential tool in modern medicine. AI is a technical revolution that has the potential to improve everyone’s health, having evolved from a novel concept to an essential part of healthcare.

There is a significant impact of 6G on AI because, while systems were intelligent before, they will become even more so with the introduction of AI. To achieve this, they require an extremely intelligent and quick environment, which is supported by the 6G vision.

In a few milliseconds, AI algorithms are able to process a far larger volume of images with greater precision than humans or medical professionals, allowing them to identify even the smallest characteristics in imaging. With an accuracy rate of over 90%, Zebra Medical Vision developed Profound, a revolutionary platform that can analyse different types of medical data and identify osteoporosis, aortic aneurysms, and breast cancer (12). Artificial intelligence eliminates the need for human drug testing. The successful communication of the blind, deaf, and dumb will also be greatly aided by AI in the 6G-based brain-abstracted Internet of Thinking (IoTk) (33).

Challenges for AI in 6G

As an increasing number of healthcare businesses invest in implementing AI for various roles, it is imperative that the issues this technology presents be addressed. Many ethical and legal concerns might not be relevant in other situations.

Data security and privacy, patient safety and accuracy, teaching algorithms to identify patterns in medical data, integrating AI with existing IT systems, educating doctors about the use of AI, and guaranteeing compliance with federal regulations are some of the most urgent issues facing AI in healthcare. AI systems collect a great deal of personal health data, which is especially important to protect data privacy because it could be misused if not managed properly. To further stop sensitive patient data from being abused or misused, suitable security measures must be put in place.

Accuracy and patient safety are major problems when utilising AI in healthcare. Artificial intelligence (AI) systems need to be trained to recognise patterns in medical data and comprehend the connections between various diagnoses and treatments in order to deliver precise, patient-specific advice. Furthermore, medical practitioners may find it more difficult to integrate AI with current IT systems because doing so requires a thorough understanding of how current technology functions in order to assure a flawless operation.

Lastly, gaining the respect and confidence of medical professionals is crucial to the successful application of AI in healthcare. Medical professionals must have faith that the AI system is providing sane advice and won't mislead them. This implies that openness is crucial; in order to ensure the utilisation of reliable, current medical research, doctors need to comprehend the reasoning behind the AI system.

Furthermore, in order to guarantee that AI systems are applied morally and do not endanger patient safety, compliance with regulatory standards is essential (13).

Due to 6G device limitations, edge, fog, and cloud computing overcome the challenge of supplying huge computational training resources for AI. Because doctors are unwilling to release their patient records due to serious ethical and regulatory concerns, data analysts do not have access to entire healthcare datasets. Hospitals are therefore unable to accept foreign patients due to security and privacy concerns.

Federated learning (FL) improves data privacy in the healthcare industry. In FL, collaborative training of shared AI/ML models across various devices and compute tiers takes place without jeopardizing data security. FL uses a decentralized approach to locate the healthcare data in the learning models. To protect the security of the patient health data, it collectively applies deep learning to the unpooled data. All things considered, FL is utilized to improve data privacy and conserve network capacity.

By analysing patterns in a patient's prior medical history and current health data, artificial intelligence (AI) in healthcare is able to predict potential health issues (13). This predictive power allows healthcare practitioners to provide proactive, preventative care, which ultimately improves patient outcomes and reduces the cost of healthcare.

Healthcare Applications of Sixth Generation (6G) Technologies and Their Difficulties

Optical Wireless Communications

Without any question, wireless communication has become a necessary tool for daily living. These days, the majority of wireless communication devices employ radio frequency (RF) technologies to transport data. All agree, however, that the RF spectrum will not be sufficient to future-proof wireless communication due to the constantly growing demand for wireless data, driven by new paradigms such as machine-type communication for autonomous systems as well as new devices like intelligent glasses using augmented reality and virtual reality (VR) (14).

Unguided visible, infrared, or ultraviolet light is used in optical wireless communications (OWC), a type of optical communication, to deliver a signal. Usually, short-range communication uses it. Oftentimes, systems that function inside the visible spectrum (390–750 nm) are called visible light communication (VLC) systems. Light-emitting diodes (LEDs), used in VLC systems, have the ability to pulse at extremely high speeds without significantly changing the illumination output or the experience of the human eye. Wireless local area networks, wireless personal area networks, and vehicle networks are just a few of the numerous potential uses for VLC.

Conversely, free space optical (FSO) systems, or terrestrial point-to-point OWC systems, function in the near-infrared (NIR) frequency range of 750–1600 nm (14). The backhaul bottleneck may be lessened by these systems, which frequently employ laser transmitters to provide a protocol-transparent link with a high data rate (10 Gbit/s per wavelength) at an affordable price. The various 6G technologies are included in the table.

- **VLC**

  Visible light communication, or VLC for short, is the use of visible light, particularly light with a wavelength of 375 nm and a frequency of 400–800 THz, as a transmission medium. Optical wireless communications methods include VLC as a subset. In addition to providing fast wireless connectivity and a substantial unlicensed bandwidth, VLC can also be utilized for localization. The sixth generation (6G) of mobile communication targets—low power consumption, high data rate, high dependability, huge user connectivity, low latency, and high security—may be more easily attained with the employment of VLC technology in conjunction with RF communication (15). Using VLC-based smart and intelligent light sensors, 6G networks are highly dense in the healthcare industry. The human body may suffer from flickering consequences resulting from the widespread usage of VLC in healthcare. Overcoming these impacts using ML techniques will be difficult (16).

  Healthcare applications such as gestures, wheelchairs, tracking the blind, reporting images from MRI scanners, healthcare on ships, in the ocean, and in hospitals, lighting as a service (LAAS), VLC for surgery, and VLC-based health monitoring in intensive care units (ICU) are listed in Table 2 (16).

- **FSO (Free Space Optics)**

Free-space photonics, often referred to as free-space optics, is the process of guiding altered visible or infrared (IR) beams through the atmosphere to create broadband communications. Although non-lasing sources like light-emitting diodes (LEDs) or infrared-emitting diodes (IREDs) can also be used, laser beams are typically used.

The treatment of cancer patients is one of its main applications (17). One of the deadly diseases is cancer. There are several different approaches used in the treatment of cancer. Initial treatment involves radiotherapy if metastases is evident. It is adhered to by performing clinical surgery and, if necessary, radiation. An average course of treatment takes roughly two months to fully cure the patient. Therapists are then expected to propose the prescription medications. Chemotherapy is done if the number of cancerous cells is not too high (15). Brachytherapy can occasionally be beneficial for malignancies that are close to the prostate or pelvic. In brachytherapy, a few applicators are placed in the afflicted area and allowed to break down the tissues that cause cancer. In cases of brain cancer, breast cancer, and other cancers, the affected area is exposed to external radiation. In order to totally destroy the impacted cell, a radioactive isotope may occasionally be positioned next to it within the body. In this sense, the person becomes radioactive for a predetermined amount of time.

Typically, all cancer treatments are carried out in a room with some light so that X-rays may be seen. Different masks should be applied to different body sections in order to achieve varied angles when doing radiotherapy. Therapists locate tattoos and marks in order to treat patients appropriately (19). An X-ray simulation is performed prior to the start of treatment. Selective internal radiation is used if liver cancer is discovered. Some claustrophobics experience difficulties while undergoing therapy. Hair loss could occur. People who don’t reproduce also tend to have lower libido.

- **OCC (Optical camera communication)**

  The visible light communication (VLC) development method is known as OCC, which uses photodiodes and LEDs as transmitters and receivers. OCC employs a camera as the receiver rather than photodiodes, and a variety of devices, including LEDs and even digital signs, can be utilised as the transmitter (20).

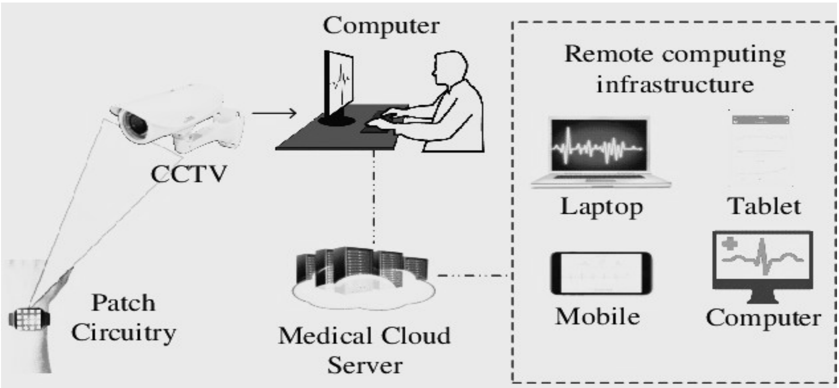

Figure 3. Remote health monitoring

In recent decades, there has been interest in research on an emerging technology called optical camera communication (OCC). In contrast to earlier communication methods, OCC transmits data from receivers and cameras using visible light. OCC offers a number of benefits that can be used in a variety of ways. Nonetheless, a technology with enormous promise has emerged: the Internet of Things (IoT) (23). Several research projects back up the potential of IoT technology, which may be applied in a number of industries, including healthcare.

The medical industry is one of the IoT's uses, as was previously mentioned. Notably, IoMT encompasses a wide range of specialised subjects. Nonetheless, the creation of a Wireless Body Area Network (WBAN) is one of the hottest IoMT research initiatives (22). With the help of WBAN, medical professionals will be able to monitor patients continuously and automatically, as well as get insights and knowledge that will speed up response times and action plans. Moreover, WBAN is intended to collect many data points directly from the patient's body, including temperature, oxygen saturation, and tension (22; 23). This improves the accuracy of the medical diagnosis. WBAN can be connected to local or edge server systems in indoor settings, such as clinics or hospitals, to build an IoMT. At the moment, RF-based signal communication technologies like Bluetooth, Ultra-Wideband (UWB), and ZigBee are used to transfer data from body-area sensing devices to the upper layer of the IoMT system (36).

- **LI-Fi**

An infrared or LED light can be used to transfer data in a bidirectional wireless system called LiFi (light fidelity). Unlike Wi-Fi, which uses radio frequency, LiFi technology was initially introduced in 2011 and employs light waves to transmit a signal for the internet. A light source with a chip is all it needs (34).

This represents a significant improvement over current wireless networks. LiFi multiplies the bandwidth and speed of Wi-Fi, 4G, and 3G. Due to their limited capacity, the latter eventually become saturated with many users browsing at once, which can lead to crashes, slower speeds, or even connection interruptions (34).

Li-Fi has the potential to be the answer to every issue listed above. Li-Fi technology makes use of LED lights, which can transfer data at a rate of 800 Mbps by using light. Since Li-Fi is user-friendly, it cannot impair the functionality of medical equipment or patient health. Li-Fi offers superior data rates, increased security, and a more affordable option when compared to conventional wireless technologies such as Bluetooth and Wi-Fi (30). Since Li-Fi relies on visible light, its available spectrum is ten times greater than that of other RF technologies. With the aid of LEDs and photodiodes, the Li-Fias prototype seen in Figure 1 is simple to create and provides an incredibly affordable solution (29).

There have been reports of using Li-Fi to monitor the health of babies in incubators (28). The babies' heart rates and oxygen saturation levels are measured. For communication purposes, phase shift keying, or PSK, was employed. This method has bandwidth limitations and involves sophisticated message recovery concerns. A generalised Li-FI-based hospital health monitoring system has been suggested in this paper. The patient's temperature and heart rate have been recorded in this work, and Li-Fi has been used to transfer the data.

Conclusion and Future Directions

The implementation of 6G technology is expected to improve remote health monitoring, hence mitigating the challenges encountered by individuals residing in remote places in relation to hospital access and treatment. The distance will be largely eliminated as a factor in the quality of care and surgeries thanks to remote surgery.

The 6G-intelligent healthcare is the foundation for the suggested conceptual framework. A variety of cutting-edge technologies are discussed, along with their uses and difficulties in the healthcare industry. Based on 6G, the viability of 3D healthcare is established. We anticipate that 6G will significantly assist several 5G technologies in order to achieve the objective of real-time remote healthcare. 6G enables ubiquitous, intelligent healthcare by supporting enhanced services, newer technology, and full intelligence (1). A number of obstacles must be overcome in order to achieve 6G-intelligent healthcare. Meeting the demands of the healthcare industry in 6G networks requires the integration of multiple technologies, which presents a difficulty. It is necessary to find solutions for the integration of intelligence difficulties in every part of the healthcare framework.

Future technological advancements will allow us to monitor a patient's quality of health and create an internal monitoring system inside their body, which will greatly reduce the need for intensive care units.

References

[1] Kharche, Shubhangi & Kharche, Jayshree. (2023). 6G Intelligent Healthcare Framework: A Review on Role of Technologies, Challenges and Future Directions. Journal of Mobile Multimedia. 19. 603-644. 10.13052/jmm1550-4646.1931.

[2] P. Yang, Y. Xiao, M. Xiao and S. Li, ”6G Wireless Communications: Vision and Potential Techniques,” in IEEE Network, vol. 33, no. 4, pp. 70-75, July/August 2019, doi: 10.1109/MNET.2019.1800418. keywords: 5G mobile communication; Wireless communication; MIMO communication; OFDM; Time-frequency analysis; Wireless sensor networks; Internet of Things; 6G mobile communication,

[3] https://opengear.com/blog/top-healthcare-network-challenges/

[4] P. P. Ray, "An Introduction to Dew Computing: Definition, Concept and Implications," in IEEE Access, vol. 6, pp. 723-737, 2018, doi: 10.1109/ACCESS.2017.2775042.

[5] https://aws.amazon.com/what-is/edge-computing/

[6] https://www.frontiersin.org/journals/communications-and-networks/articles/10.3389/frcmn.2020.610879
[7] https://www.foreseemed.com/artificial-intelligence-in-healthcare
[8] Jadeja, Y. and Modi, K., 2012, March. Cloud computing-concepts, archi-tecture and challenges. In 2012 International Conference on Comput-ing, Electronics and Electrical Technologies (ICCEET) (pp. 877–880). IEEE.
[9] Corradini, F., De Angelis, F., Ippoliti, F. and Marcantoni, F., 2015. ASurvey of Trust Management Models for Cloud Computing. In CLOSER (pp. 155–162).
[10] Sharma, D.K., Chakravarthi, D.S., Shaikh, A.A., Ahmed, A.A.A., Jaiswal, S. and Naved, M., 2021. The aspect of vast data management problem in healthcare sector and implementation of cloud computing technique. Materials Today: Proceedings
[11] https://www.eccouncil.org/cybersecurity-exchange/ethical-hacking/fog-computing-everything-to-know/#:˜:text=Fog%20computing%20is%20a%20term,on%20top%20of%2C%20end%20users.
[12] Mintz, Y. and Brodie, R., 2019. Introduction to artificial intelligence in medicine. Minimally Invasive Therapy & Allied Technologies, 28(2), pp. 73–81.
[13] Gulshan V, Peng L, Voram M, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA 2016; 316:2402–2410.
[14] Zhang, Chentao & Liang, Peidong & Jamel, Nebhen & Chaudhary, Sushank & Sharma, Abhishek & Malhotra, Jyoteesh & Sharma, Bindu. (2021). Performance analysis of mode division multiplexing-based free space optical systems for healthcare infrastructures. Optical and Quantum Electronics. 53. 10.1007/s11082-021-03167-5.
[15] Janjua, Muhammad Bilal and Duranay, Ahmet Enes and Arslan, Hu¨seyin. (2020). “Role of Wireless Communication in Healthcare System to Cater Disaster Situations Under 6G Vision”; Frontiers in Communications and Networks; DOI.10.3389/frcmn.2020.610879.
[16] Harrison Kurunathan, R. Indhumathi, Miguel Gutie´rrez Gaita´n, Carla Taramasco, Eduardo Tovar, “VLC-enabled monitoring in a healthcare setting: Overview and Challenges”, 2023 South American Conference On Visible Light Communications (SACVLC), pp.135-140, 2023.
[17] Abhishek Kumar Mandal and Bijayananda Patnaik, Bhubaneswar, India. “Free Space Optics and its Medical Applications” IJSRD -

International Journal for Scientific Research & Development— Vol. 5, Issue 09, 2017 — ISSN (online): 2321-0613
[18] S. Verdu´ and T. S. Han, “A general formula for channel capacity,” IEEE Trans. Inf. Theory, vol. 40, no. 4, pp. 1147-1157, July 1994
[19] https://www.macmillan.org.uk/documents/cancerinfo/foreignlanguagefactsheets/radiotherapyinenglish.pdf
[20] Herfandi, H.; Sitanggang, O.S.; Nasution, M.R.A.; Nguyen, H.; Jang, Y.M. Real-Time Patient Indoor Health Monitoring and Location Tracking with Optical Camera Communications on the Internet of Medical Things. Appl. Sci. 2024, 14, 1153.
[21] Cahyadi, W.A.; Chung, Y.H.; Ghassemlooy, Z.; Hassan, N.B. Optical Camera Communications: Principles, Modulations, Potential and Challenges. Electronics 2020, 9, 1339.
[22] Li, X.; Pak, C.; Bi, K. Analysis of the development trends and innovation characteristics of Internet of Things technology—Based on patentometrics and bibliometrics. Technol. Anal. Strateg. Manag. 2020, 32, 104–118.
[23] Ahmed, Faisal & Hasan, Moh Khalid & Shahjalal, Md & Alam, Md & Jang, Yeong Min. (2020). Design and Implementation of an OCC-Based Real-Time Heart Rate and Pulse-Oxygen Saturation Monitoring System. IEEE Access. 8. 1-1. 10.1109/ACCESS. 2020. 3034366.
[24] Askari, Z.; Abouei, J.; Jaseemuddin, M.; Anpalagan, A. Energy-Efficient and Real-Time NOMA Scheduling in IoMT-Based Three-Tier WBANs. IEEE Internet Things J. 2021, 18, 13975–13990.
[25] Sumathi, D.; Poongodi, T. IoT network architecture and design. In Internet of Things; Prakash, K.B., Ed.; Walter de Gruyter GmbH and Co KG: Berlin, Germany; Boston, MA, USA, 2020; pp. 63–84.
[26] Latha, R.; Vetrivelan, P. Wireless Body Area Network (WBAN)-Based Telemedicine for Emergency Care. Sensors 2020, 20, 2153.
[27] Ruby, D.; Divya, M.; Shaleen, C. Potential of Internet of Medical Things (IoMT) applications in building a smart healthcare system: A systematic review. J. Oral Biol. Craniofacial Res. 2022, 12, 302–318.
[28] Z. A. Khan, “Li-Fi Based Healthcare Monitoring System”, PakJET, vol. 5, no. 2, pp. 177–182, Sep. 2022.
[29] https://www.iberdrola.com/innovation/lifi-technology#:˜:text=LiFi%20(light%20fidelity)%20is%20a,internet%20signal%20through%20light%
[30] Ali, Hasnain, M. Ibtehaj Ahmad, and Anoshah Malik. “Li-Fi Based Health Monitoring System for Infants.”2019 2nd International