The Role of Wireless and Information Technologies in Healthcare: IoT-based Customized Applications

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Article Info

Article history:

Received Apr 5, 2025
Revised May 7, 2025
Accepted Jun 6, 2025

Keywords:

Wireless and information technology
Internet of Things
Network Communication technologies
Personalized healthcare
ICT

ABSTRACT

Conventional healthcare systems have faced historic challenges trying to meet the varying needs of large groups of patients that have been far too inefficient and suboptimum as an outcome. With advances in machine learning (ML) and deep learning (DL) models, we are entering an exciting time in healthcare where hospitals and healthcare systems can begin to deliver value-based care by providing highly personalized and effective treatment for patients. The healthcare systems of the future are expected to provide patients with affordable, high-quality treatments using a range of applications made possible by information and communication technologies. This is because these wirelessly enabled medical systems are able to remotely and continually check on the health of patients in both indoor and outdoor environments, which makes patients feel more at ease and allows them to accomplish more things. The healthcare industry is increasingly being shaped by advancements in information and communication technologies (ICTs). The purpose of the research is to clarify the relationship between ICTs and healthcare by defining the most widely used ICT-based healthcare paradigms and the primary ICTs that support them. The main ICT-based healthcare models that have surfaced recently as a result of ICT breakthroughs are described below. We can also determine the technological foundations of the innovative uses of these developments by examining the scientific literature. The study ends by outlining significant unresolved research questions and concerns, many of which are particularly connected to future IoT-based healthcare systems.

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1. INTRODUCTION

Information and communication technology's (ICT) role in bringing about revolutionary change, especially in advancing women's empowerment, is being recognized more and more. [1]. ICT is facilitating health care in the information age. It is feasible to view medical information technology as a tool for achieving the goal of offering the greatest possible healthcare. Devices that are used to access information or communication networks over the Internet can include computers, phones, and other electronic resource. In recent years, informatics has become a major medical field, and it has drastically altered the capacity to create communication systems that facilitate the delivery of healthcare [2]. The potential for ICT use to aid rehabilitation is significant, thus it is worthwhile to investigate the advantages and consequences for clinical practice as well as the supporting data.

The use of ICT in healthcare is referred to by a variety of terminology. The frequent interchangeability of these phrases may lead to misunderstandings or misconceptions. ICT in healthcare has demonstrated significant promise in enhancing elderly adults' quality of life by supporting their independent living while they suffer from illnesses like Alzheimer's disease and stroke. Additionally, ICT has shown promise in enhancing patient-provider communication [3]. The coordinated effort to collect, analyze, document, and utilize medical data and information to influence investigation, program steps and policy-making is referred to as ICT in healthcare. It also explains that ICT is critical to the efficient operation of health systems across the world. Additionally, ICT supports the growth of global health knowledge by facilitating research, connecting systems, and enhancing healthcare communication and capabilities [4].

Billions of connected gadgets that may be utilized in a range of everyday situations and industries have been produced as the Internet of Things (IoT) concept has gained traction throughout time. IoT-enabling technology has been employed by researchers and industry participants to create intelligent surroundings, including smart homes, smart factories, and smart cities. Wearable technology is becoming more and more popular in the healthcare and wellness sector due to a number of factors, including the growing need for individualized treatment, developments in small, flexible sensor devices, and the widespread usage of IoT technologies in contemporary culture [5].

The significant expansion in the use of Internet of Things (IoT) innovation across several industries is not exclusive to the medical sector. Because it enables real-time patient data collection and analysis, the Internet of Things has the potential to drastically change the healthcare sector. Remote health monitoring, individualized treatment plans, and more accurate diagnosis might result from this. A key goal of the Internet of Things in the medical sector is the secure verification of patient health information, which calls for cloud-based IoT settings [6]. This article's goal is to suggest an Internet of Things (IoT)-based medical data system that can be used both indoors and outdoors and that approaches its development methodically. The way this approach integrates the needs and perspectives of the contracting authority and potential users into most design stages is one of its unique features. In addition, the creator of the proposed approach needs to take into account every possibility for integrating human and technology constraints and requirements [7].

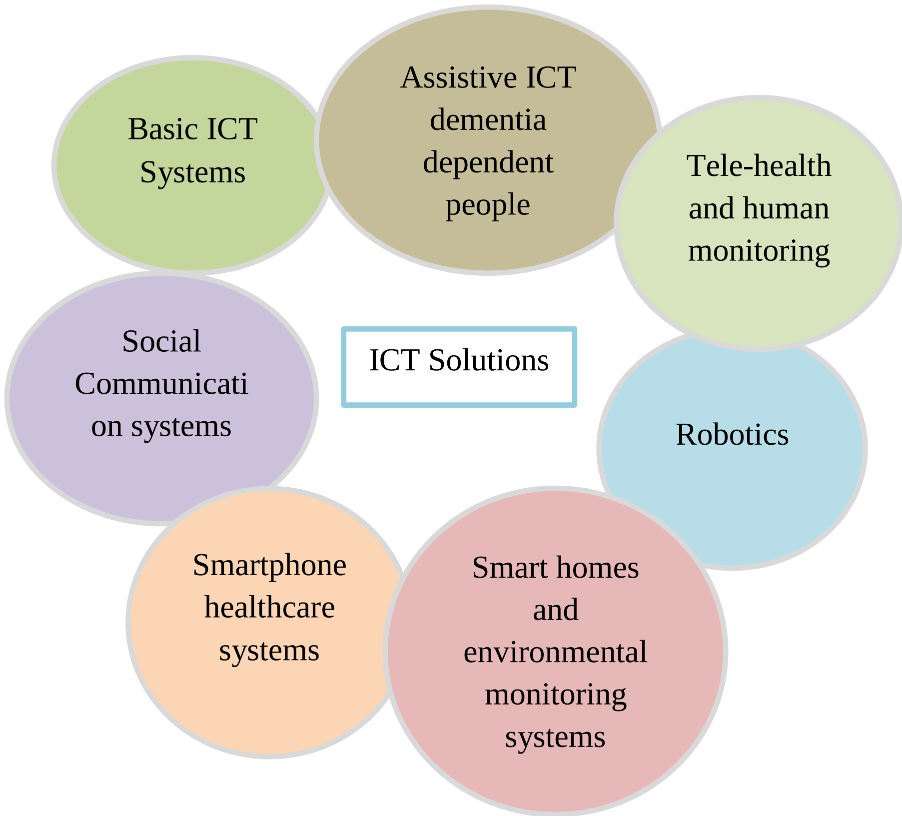

Figure 1. ICT Healthcare solutions

The various types of ICT solutions are shown in Figure 1. Improving the quality of life for the aged population is the aim of all ICT technologies, from the most basic to the most sophisticated. Smart home systems, telemedicine apps, fall detection/prediction/prevention systems, cell phones, and reminder features are a few examples of such ICT solutions. Many different ICT solutions are already used by individuals in their daily lives. Home-based ICT solutions like microwaves and televisions, as well as computer-based tools like email and the internet, are referred to as basic ICT technologies. Simple ICT solutions improved the quality of life for senior citizens who remain in their homes. It is predicted that, despite the advantage of facilitating remote social interactions, ICTs may make elderly people feel more alone in their surroundings. [8].

ICT systems that provide video conferences are also regarded as social communication systems. Physical objects can see, hear, think, and perform a wide range of jobs thanks to the Internet of Things, which enables them to "speak" to one another, share data, and make decisions. By utilizing the wide variety of technologies available through the Internet of Things, such as sensor technology, distributed systems, wireless connections, and applications that make use of the Internet protocol and apps, these items are transformed from conventional to intelligent [9]. IoT technologies provide several benefits for creating intelligent healthcare systems, including accessibility, patient comfort and safety, and lessening hospitalized patients' burdens. IoT facilitates networks of smart devices, cloud apps, and solutions, which in general makes data storage and transportation simpler. In the field of medicine, gadgets for wearing, smart homes, intelligent health products, and remote surveillance are some of the most creative uses of IoT. The Internet of Things might make it easier to quickly confirm insurance coverage and prescribe affordable IoT self-monitoring devices for homes [10].

Benefits of information technology in healthcare

- Reduced Test and Procedure Redundancy
- Reduced Costs
- Improvement of Patient Treatment
- Improved Medication Safety
- Quality of Care
- Minimized Operational Cost

2. LITERATURE REVIEW

Matayong et.al [11] proposed a comprehensive study of IoT-based healthcare apps and systems for the elderly. The proposed method seeks to accomplish many goals. Its main objective is to categorize the research subjects and medical categories covered in the reviewed publications. In order to provide direction for future research directions, it also looks at current trends in terms of important ideas, contributions, and limitations. The last thing it shows is how the research articles are distributed by healthcare types, area studies, publication years, and publishers. By following the guidelines set forth by the Systematic Reviews and Meta-Analyses (PRISMA), the approach guarantees a comprehensive examination of the selected articles. Covering 54 academic papers published in peer-reviewed journals between 2018 and 2022, the review was the first of its kind. According to the research, Internet of Things (IoT)-based solutions are essential for creating applications and systems that help the elderly in a variety of healthcare areas, including wellness, treatment, recovery, and health promotion. The topic of Internet of Things-based systems and applications for elder healthcare is better known overall because of this thorough study. The results of this study can help direct future research and the creation of IoT-based elder healthcare solutions.

Khanh et.al [12] introduced IoT Wireless Communication Technologies in 5G: Overview, Uses, and Difficulties. People, gadgets, software, platforms, and solutions may all connect over the Internet thanks to the Internet of Things. The growth of IoT technology has led to the creation of several applications and approaches that help humanity, such as IoT ecosystems, smart cities, smart agriculture, smart retail, and intelligent transportation systems. One of the most intriguing and challenging topics in wireless research is the introduction of 5G, or fifth-generation wireless communications networks, as suggested by the suggested technique. The capabilities of 5G allow it to establish extremely high throughput and extremely low latency connections with hundreds of billions of devices. The Internet of Things (IoT), made possible by 5G, is a fully digital society in which everything is connected to the Internet.

Park et.al [13] developed Youth experiencing homelessness' usage of ICTs: correlations with their behavior in obtaining online health information. The suggested technique Although studies show that YEH utilizes ICT at a surprisingly high rate, less is known about the factors influencing ICT use and how ICT use relates to YEH's behavior when accessing online health information (OHISB). Within the theoretical structure of Andersen's behavioral model of medical care utilization, the study examined the frequency of

ICT usage and its association with OHISB among YEH. The characteristics associated with ICT use and the connection between each ICT use and OHISB were examined using a multivariate logistic regression method. The results of the study demonstrate how well ICT use may address the medical-related demands of YEH and enhance their medical results. The creation of technology-driven measures especially those that utilize ICTs, might provide YEH with access to a range of health-related tools and information, thereby increasing their OHISB.

Holderried et.al [14] introduced Viewpoints and possible advantages of using telemedicine and contemporary ICT in cross-sectoral solid organ transplant care. We use statistics to evaluate the possible impact and use of modern information and communication technology (ICT) in solid organ transplantation (SOT) patients. We administered a cross-sectional, structured, questionnaire-based research to patients who had received a kidney, liver, pancreas, or combination transplant. The proposed method examined the following topics: patients' eHealth literacy, their general attitude toward eHealth, their current usage of digital tools for health and daily life, and socioeconomic information. The primary reason why SOT recipients embrace the usage of modern ICT is for health reasons. Improved cross-sectoral care might result from a stronger integration of eHealth, regardless of the donated organ. To successfully incorporate eHealth methods into cross-sectoral care, future research should concentrate on information security, information safety, online physician-patient contact, and the components of care quality and safety.

Patel et.al [15] developed A Secure Blockchain-Based Internet of Things Smart Medical Tracking Evaluation. Intelligent medical surveillance systems are being radically altered by blockchain-enabled Internet of Things (IoT) technology. Blockchain technology's distributed ledger ensures the safety and accuracy of health data, avoiding breaches, and the Internet of Things makes it simple to collect health data. This symbiosis fosters a patient-focused and dependable monitoring system while addressing contemporary healthcare concerns by improving security, transparency, and efficiency. The Medical Internet of Things (MIoT) has made tailored and affordable healthcare options more available through technologies like Machine Learning (ML), which efficiently analyses massive datasets, and Wireless Body Area Networks (WBAN), which enhance data quality. Improvements in Software-Defined Networking (SDN) and Network Function Virtualization (NFV) provide more straightforward, flexible networks for healthcare, while fog computing has played a significant role in guaranteeing effective data transfer with lower latency. But as data volume grows, privacy and security issues become more pressing, leading to a move toward blockchain for better data security and transparency.

Kumar et.al [16] proposed Smart Health Care ATM System Powered by IoT to Enhance Life Quality. The suggested approach is the creation and implementation of an Internet of Things-Based Integrated Smart Healthcare Monitoring System, which makes use of IoT technologies to facilitate precision medicine. The system combines a variety of wearable technology and sensors to continually track important health metrics, giving a thorough, up-to-date picture of a patient's condition. The system's design is discussed, with particular attention paid to its key elements: wearable technology and sensors for health monitoring, data collecting systems, communication infrastructure, tools for data administration and analysis, and security mechanisms to safeguard patient privacy and data. Utilizing the system for tracking patients remotely, managing chronic illnesses, and predicting health analytics demonstrates its potential to significantly improve patient outcomes, reduce medical expenses, and advance precision medicine.

Shetty et.al [17] introduced A Comprehensive Examination of Health Monitoring Systems Based on the Internet of Things. It looks at IoT-based health monitoring systems, stressing the benefits and limitations of the available solutions. IoT is a brand-new internet ecosystem that is quickly developing in research, particularly in the medical field. This research article presents a suggested approach that uses an Internet of Things (IoT)-based remote patient monitoring system to enable authorized personnel to access and monitor patients in remote locations. The report provides a thorough look at the trends and difficulties related to Quality of Service (QoS). According to this study, an Internet of Things-based theoretical architecture for tracking cardiology and chronic illnesses may be implemented using devices like blood pressure, ECG, pulse, and blood saturation sensors. Microcontrollers are used in conjunction with them to gather and send data to a local server. A significant step forward in raising awareness of health issues, this system—which can be accessed through an Android application—allows for the remote management of medicine infusion and the virtual exchange of data with users and clinicians.

3. METHODOLOGY

Using a variety of applications made available by information and communication technology, future healthcare systems are anticipated to offer patients high-quality, reasonably priced treatments. To shed light on the link between ICTs and healthcare, the study will identify the most popular ICT-based healthcare paradigms and the main ICTs that underpin them. The primary ICT-based medical systems that have emerged in recent years are outlined below as a result of ICT advancement. Additionally, by examining the scientific literature, we identify the technological underpinnings that enable the creative applications of these advancements. Finally, the poll identifies significant outstanding research questions and concerns that are particularly relevant to future Internet of Things-based healthcare systems.

3.1 Wireless information technologies in healthcare Internet of Things

The Internet of Things (IoT) for medical applications is a quickly developing sector that combines internet-connected devices, software, and sensors. By providing real-time data, predictive analytics, and remote monitoring, it seeks to improve patient outcomes, save costs, and boost efficiency. Wearable technology, telemedicine, smart healthcare facilities, and patient tracking from a distance are just a few of the uses of the Internet of Things in the healthcare sector. By combining AI and machine learning to give individualized and effective care, the Health IoT has the potential to completely transform the way healthcare is delivered. However, maintaining data security and confidentiality may be a problem that has to be resolved in order to ensure the safe and efficient usage of H-IoT technologies [18].

Recent statistics indicate that the Internet of Things is one of the greatest promising technologies in the medical industry. In light of this, a thorough introduction to IoT in healthcare—or IoT in healthcare—was given. Additionally, this report highlights the technological advancements in H-IoT as well as the associated challenges that must be addressed. To overcome the present difficulties that H-IoT is facing also proposed that more study in this area is necessary. To improve IoT healthcare, researchers, IT experts, healthcare professionals, and the general public will find our thorough review to be a valuable resource [19]. Based on the performance analysis, the study's proposed cryptosystem is incredibly safe and can be effectively incorporated into the healthcare IoT space to transmit medical photos securely. As shown in Figure 2, the use of IoT for medical applications is gradually gaining traction as a means of improving patient outcomes, increasing efficacy, and reducing expenses.

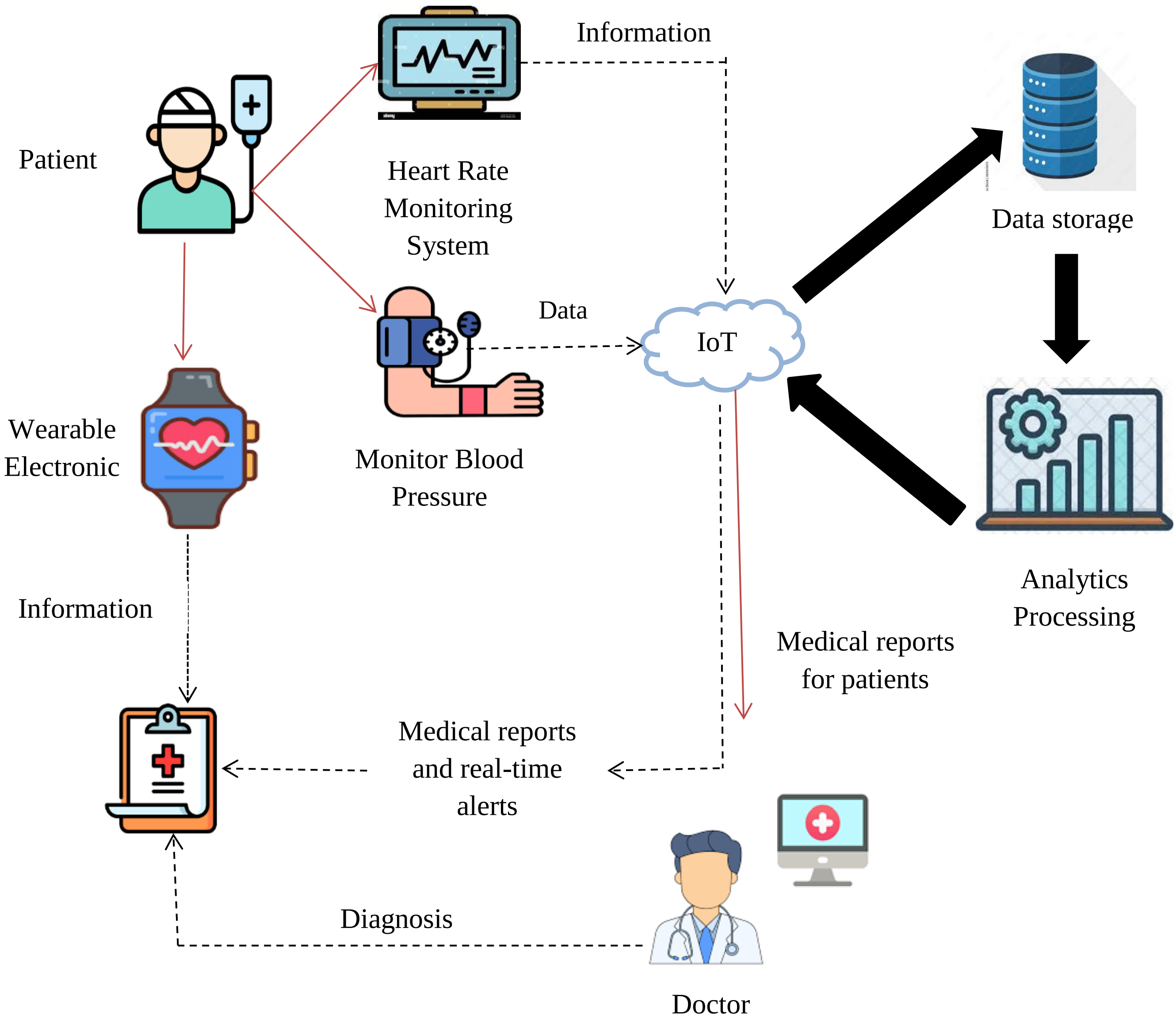

Figure 2. The proposed Internet of Things in healthcare

3.2 IoT Design for Smart Healthcare

Ensuring the operation and stability of connected medical devices is crucial since they gather essential parameters from patients. Depending on the specific IoT application, any performance deterioration and loss of dependability might raise the danger to patient safety and result in possibly fatal situations. Several technical problems with the design and execution of these devices need to be fixed before they are put on the market. One area that has drawn a lot of interest is the security and privacy of healthcare IoT data. Medical equipment, for instance, gathers and sends extremely private data [20]. If hackers are given access, they might use this information to falsify a patient's medical records, submit a false claim to the insurance company on the patient's behalf, or endanger the patient (for example, with insulin pumps). This problem is made more difficult by the fact that the majority of IoT devices lack basic data protection methods, which forces suppliers to significantly reduce the time required for production from the prototype to the finished product in a market that is extremely competitive [21].

Another problem that impacts not only the medical field but the whole Internet of Things ecosystem is compatibility. It may be characterized as the interoperability of an ICT system. Device manufacturers' disagreement over common communication protocols and standards is the main reason this problem still persists. Figure 3 shows an interconnection model. The model's several levels, as can be seen, each represent a need that must be satisfied in order for the system to be completely compatible with other systems:

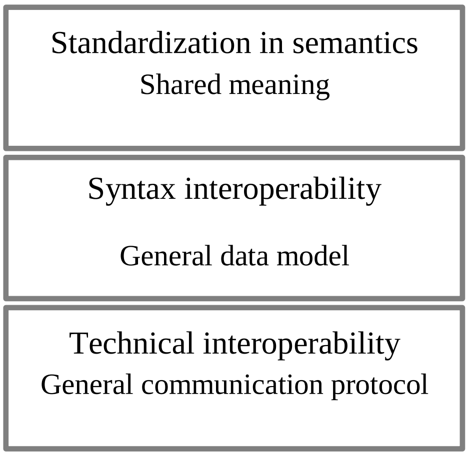

Figure 3. Interoperability layers.

3.3 Application of IoT in healthcare

IoT-based applications are developed using various IoT-based services and concepts. For the benefit of humanity, researchers in the aforementioned fields have put forward many ideas. Put simply, applications are more focused on the user, whereas ideas are more focused on the developer. The rapid development of IoT technology has led to the development of sensors that are worn, compact electronics, and easier to access and use medical devices [20]. Figure 4 illustrates how these systems may be used to collect patient data, diagnose conditions, monitor patients' health, and sound alerts in case of an emergency. A few of the newest commercially available gadgets have been covered in the section that follows.

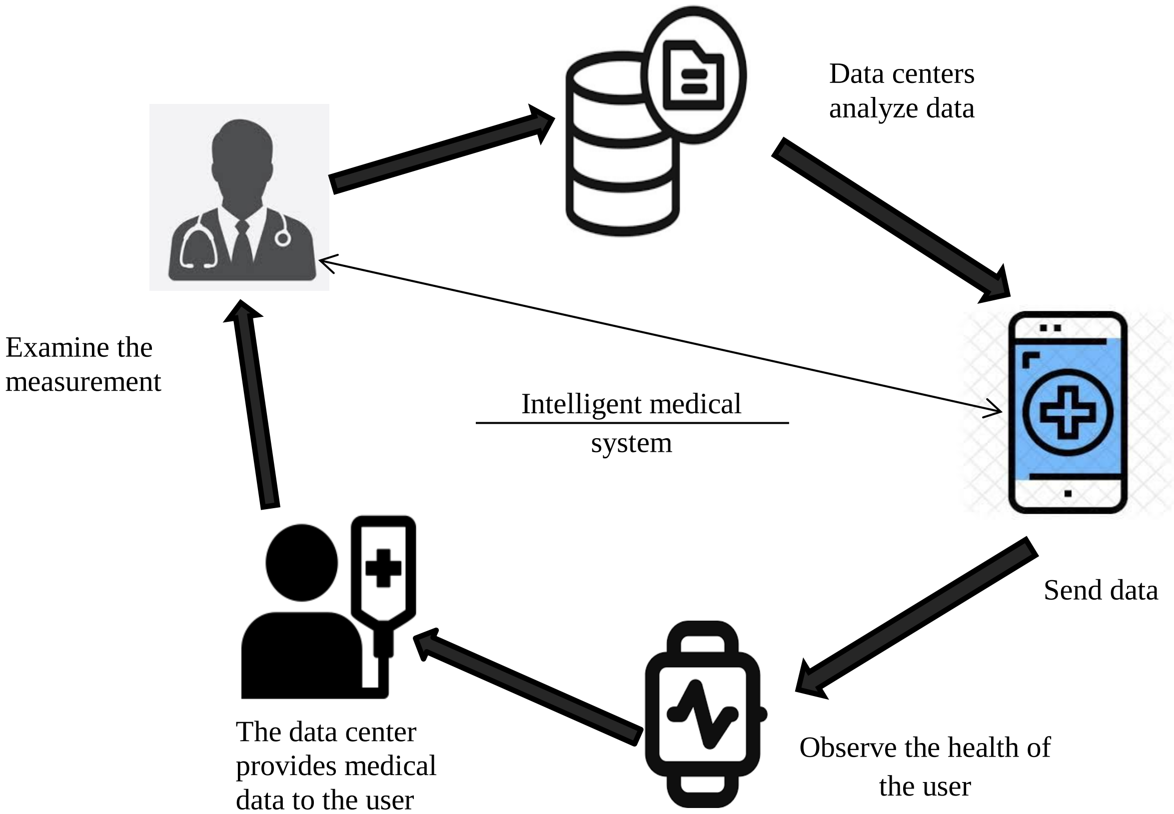

Figure 4. Application of IoT in healthcare

In general, the Internet of Things demands that all devices produce enormous volumes of data, which calls for efficient processing and storage. However, to enhance performance and lower latency, real-time processing of data from healthcare apps is required. Intelligent sensors and Internet of Things devices are used across several facets of life, such as company, monitoring, medical care, travel, communication, and many more industries. Numerous sensors and gadgets generate vast amounts of data, which healthcare organizations may benefit from and value if they conduct additional research on the data.

3.4 ICT Integration Challenges in Smart Healthcare

While the merging of digitally-enabled Internet of Things (IoT) and Information and Communications Technologies (ICT) into the healthcare sector have many benefits, there are a number of real-world obstacles that reject widespread application. The first major barrier is the lack of robust digital infrastructure in rural or underdeveloped areas. In many cases, rural facilities have unreliable internet services, unstable electricity supply, and limited skilled staff to operate any digital-focused services. For this reason, telemedicine and remote monitoring services can either be disrupted or they do not provide real-time care.

Another major area of concern is the gap in digital literacy for both health care providers and patients. While a younger generation of users may be able to take advantage of these systems right away, elderly patients and less-trained staff may not be able to effectively utilize mobile health apps or wearable IoT devices. Device interoperability is also a major challenge. IoT healthcare systems are often made up of devices from different manufacturers, each of which has its own data formats, communication protocols, and software platforms. This results in siloed data, increased integration costs, and variable system performance. Finally, security and privacy risks associated with sensitive medical data are ongoing areas of risk.

As patient data transfers wirelessly or stored in the cloud, the threat of attacks, unauthorized access, or data breaches will increase, and the issue of abiding to global privacy laws, such as HIPAA in the US, or the General Data Protection Regulation (GDPR) in Europe, remains prominent and requires protection measures such as encryption, authentication, and access control. Last, but not the least, legal and policy challenges have not been resolved in many locations. Regulatory approval of new devices and technology can be slow, and the lack of global jurisdiction and framework can reduce functionality and impede deployment of healthcare IoT systems. These barriers demonstrate the continued need for a collaborative and transdisciplinary approach to online and digital solutions, as well as the need for safe, inclusive, and sustainable methods for the implementation, acceptance, and use of ICT-enabled health care systems.

4. EXPERIMENTAL RESULT AND ANALYSIS

The ECG signal collected at 1000 Hz is initially used to derive the R-R series. Once the ECG data has been downsampled to 100 Hz, R-R intervals are once more calculated. Although there is far less diversity in the second R-R time series—just seven distinct frequency values—the two identical R-R signals seem to be comparable. Only seven different numbers in the data provide a shorter amount of information. Variable coding is particularly undesirable since more than 6% of adjacent samples would have the same value. ECG signal sampling should be standardized to provide similar results and should have a high sample frequency in case interpolation is not possible.

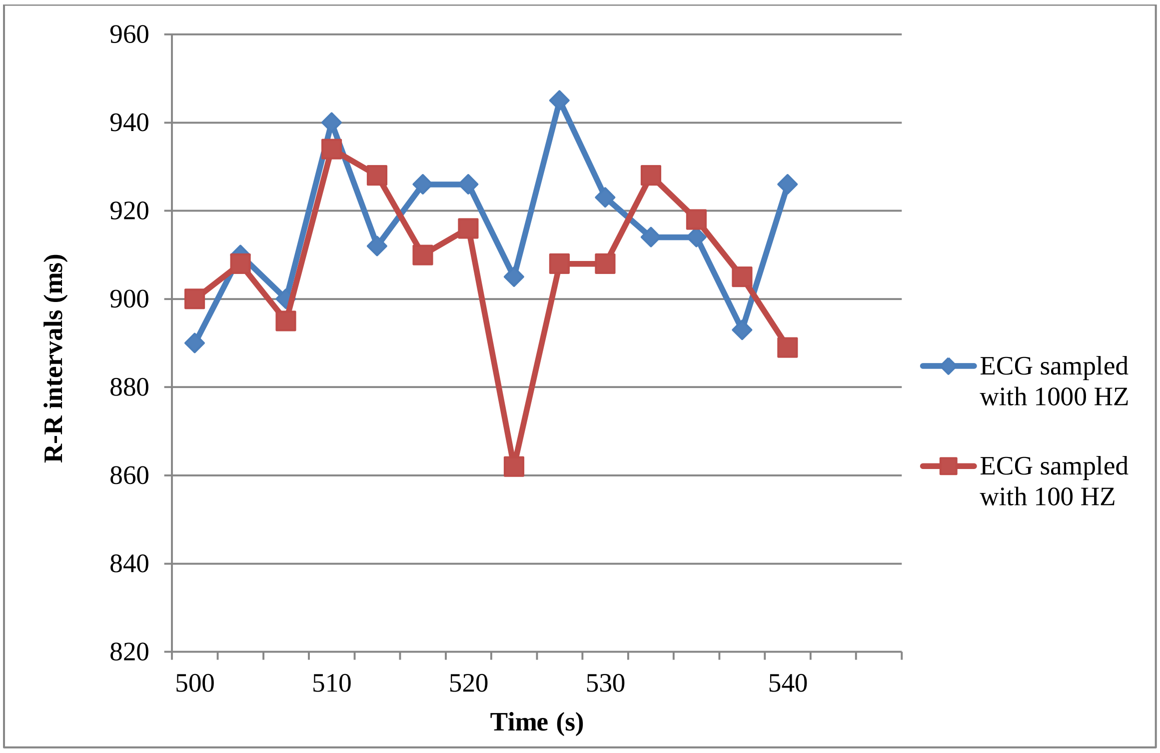

Figure 5. Time series of R-R intervals derived from the electrocardiogram (ECG) signal

The computed R-R intervals from the low frequencies and a high level of ECG data are displayed in Figure 5. When the ECG measurement rate is set to 100 Hz, the R-R values (shown by horizontal lines) are just seven different. To illustrate the decrease in R-R wave resolution, the ECG was downsampled from a 1000 Hz sampling frequency to 100 Hz instead. A healthy participant provided the signal after signing an informed permission form to take part in the study. Visual examination identifies residual faults. However, this filter is not appropriate for other waveforms in the cardiovascular system. Almost all analytical tools require stationarity, which is guaranteed by a filter made specifically for medical signals.

Vertical lines represent an input signal measured at 200 Hz; dA is the equivalent amplitude change; and dT represents the error shift of 2 ms between the measurement maximum (red line) and the signal maximum (dashed line). Cardiovascular acquisition equipment frequently provides first-phase results, or signal samples. Its objective is to locate a signal's highest point with a time dimension of $\Delta t = 0.1$ ms. The samples acquired without approximation provide the error shift dT, or the time distance between the sample highest locations and the proper peak positions. The example's frequency is fixed at 200 Hz (Figure 6). dT is equivalent to 2 ms in this instance.

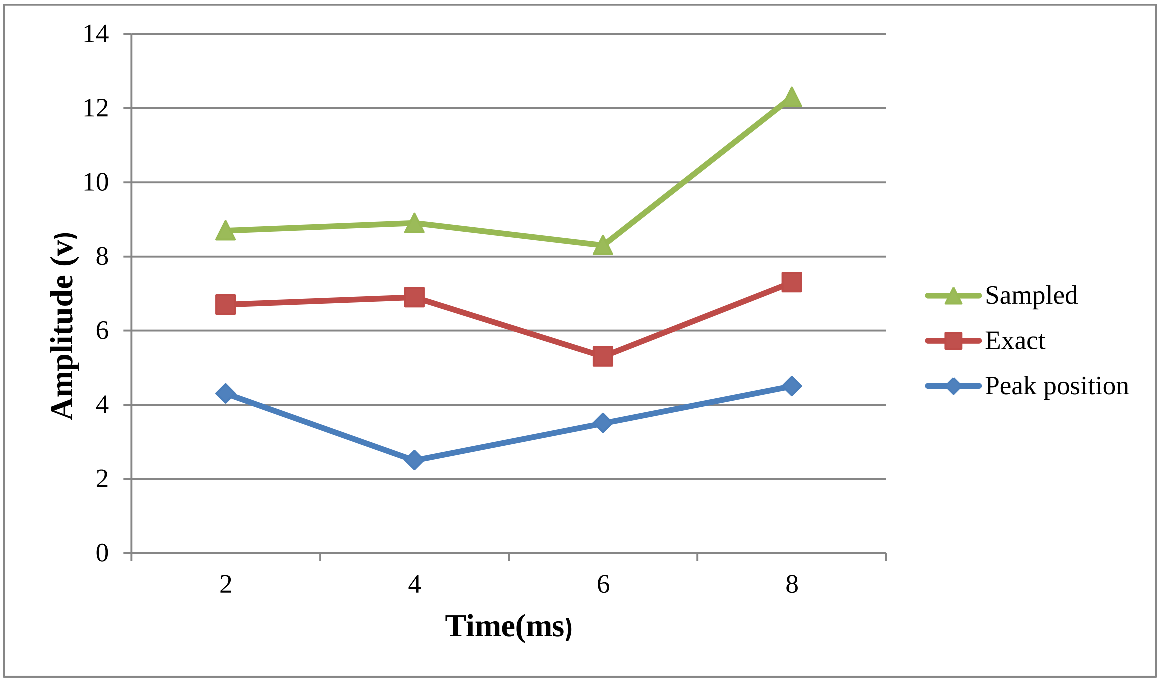

Figure 6. Peak Position estimation source signal

As healthcare continues to advance, future IoT-enabled systems will incorporate even smarter technologies, including artificial intelligence (AI), machine learning (ML), blockchain and next-gen wireless networks. AI and ML will facilitate predictive diagnostics whereby systems can recognize the earliest signs of illness fronfz subtle changes in physiology, potentially lowering hospital admissions and actively promoting preventive care. Blockchain is rapidly becoming an important instrument in securing patient data and guaranteeing data integrity from multiple system stakeholders.

With the development of 6G and terahertz communication technologies, ultra-low latency with near-real-time analytics will become commonplace, replicating challenges like remote surgeries, emergency response systems and continuous care. Additionally, nano-sensors will allow constant monitoring of health including levels happening at the cellular-level and further promote results in precision medicine. The assimilation of edge and fog computing will lessen dependence on networks and streamline processing lthis, supporting quicker decision-making at or near data source. The future is personalized and intelligent, as healthcare systems will be more adequately designed to evolve with the patients and promote safety, efficiency, compliance and appropriately head-using following regulatory frameworks.

Table 1. Emerging trends in IoT-enabled smart healthcare

Trend	Technology Involved	Impact on Healthcare
Predictive Diagnostics	AI, ML	Early detection, prevention, reduced hospitalization
Data Security	Blockchain	Secure and transparent health data sharing
Ultra-Fast Connectivity	6G, THz Communication	Real-time monitoring, telesurgery, emergency care
Precision Monitoring	Nano-sensors	Cellular-level health tracking, personalized care
Localized Processing	Edge/Fog Computing	Faster decisions, reduced latency and cloud load

Table 1 presents the growing technological trends that are expected to shape the future of smart healthcare. This table is necessary due to the complexity and multiplicity of contemporary developments related to care and healthcare technology, including predictive systems based on artificial intelligence (AI), nano-sensors, blockchain technologies etc., delivered via ultra-fast communication technologies (e.g., 6G). By summarizing the technologies, alongside their anticipated implications, we can produce a greater understanding of the trajectory of IoT intelligently driven health in the next few years. We can also signal the shift from identifying reactive solutions to a preventive response, secure patient-based health economies, and enable the reader to capture a view of the strategic direction for attempts toward future healthcare innovations.

Table 2. Performance metrics of IoT-based healthcare prototype

Metric	**Observed Value**	**Interpretation**
Average Latency (Wi-Fi)	120 ms	Acceptable for real-time non-critical monitoring
Data Accuracy	98.3%	High reliability in sensor-to-cloud transmission
Battery Life (Wearables)	~28 hours	Suitable for day-long remote care applications
Packet Loss Rate	<1.5%	Minor loss under signal interference, auto-corrected
User Satisfaction Score	4.5/5	Positive feedback from elderly test group

In Table 2, we demonstrate measurable system performance metrics subject to the proposed IoT-based healthcare monitoring framework. Displaying measures for real-time latency, data accuracy, power consumption efficiency, and user satisfaction, the table serves to validate the functionality of the system in real-world scenarios. These metrics provide insight into the system's performance in adherence to health care obligations such as timely data updates, authentic data transmission, sufficient battery life in wearables, and ease of access for patients, especially in home-care and remote settings. These measurable performance indicators provide an evaluation of system feasibility and readiness for real-life implementation.

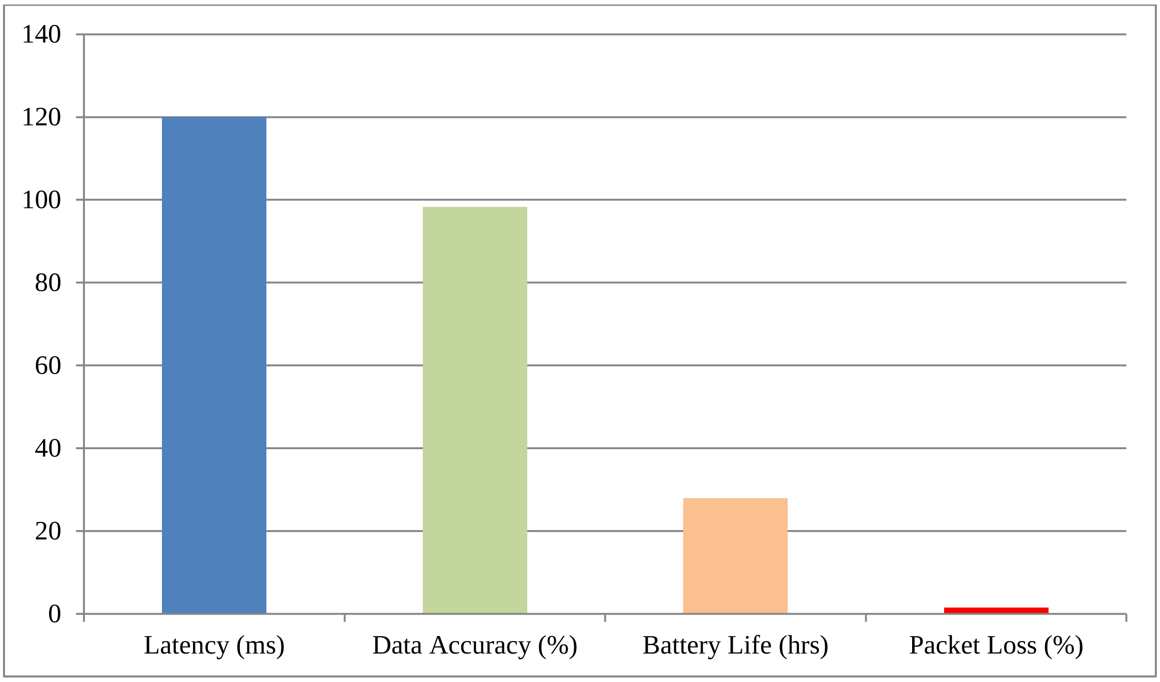

Figure 7. Performance metrics of IoT-based healthcare system

Figure 7 provides a visual representation of the core performance metrics of the IoT-based healthcare system. The low latency of 120 ms shows the system can monitor patients in a near-real-time capacity. The data accuracy metric was high (98.3%), sense the medical data received would be reliable. The analysis of the wearable device shows the system handled battery consumption well and was able to last for 28 hours on a single charge. There was also a minimal packet loss of 0.15% that suggested stable wireless communication. This finding demonstrates that IoT-based healthcare systems are suitable for home or remote healthcare.

5. CONCLUSION

Ensuring user privacy and security has been identified as the primary obstacle to the widespread integration of IoT devices in healthcare systems. Although they were employed to improve security, a number of innovative techniques had drawbacks. The present review examined many facets of the Internet of Things system. Here, extensive information on the components, architecture, and communication between HIoT systems has been covered. This article also offers details on the healthcare services that are currently being investigated using IoT-based technology. Healthcare practitioners have been able to measure several health factors, monitor and diagnose several health concerns, and provide diagnostic facilities at remote locations by utilizing these principles in IoT technology.

Being healthy and obtaining tailored, effective treatment when ill is essential to our individual life and well-being. In addition, we must ensure the long-term viability of our healthcare system and reduce the rising expenses of healthcare, which currently total 4 billion euros daily in Europe alone. There is also a pressing need to abandon traditional healthcare methods, which concentrate most of our efforts on curing illnesses rather than preventing them. The ability to detect illnesses early enough to offer life-saving treatments is crucial. It is consequently necessary to implement a revolution that capitalizes on the latest technological advancements. Furthermore, we must revaluate the future functioning of our healthcare system, including its legal foundation, privacy and security policies, and payment procedures. Our healthcare system is gradually incorporating smart healthcare technology in an effort to provide preventative and personalized therapy. Smart healthcare will be built on top of emerging IoT technology. Future IoT-enabled smart healthcare facilities will integrate more sophisticated communication technologies in terms of data analytics and administration, more powerful and inventive detector types (like nanoscale sensors), and reach, security, resource allocation, safety, and privacy.

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