WSN and IoMT base Healthcare System for Patient Monitoring in Remote Areas

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Abstract: Todays, the rapid growing of effective services in healthcare in remote areas has innovative solutions by led to the development of the integrating Wireless Sensor Networks (WSN) and the Internet of Medicals Things (IoMT) or medical objects .This paper proposes a healthcare monitoring system based on Wireless Sensor Networks (WSN) and (IoMT) for continuous patient monitoring in underserved and geographically isolated regions. The patient enabled with various sensor for data collecting in real time. The network system deployment of wearable and smart devices and environmental various sensors that collect real-time physiological and medical data, such as heart rate, blood pressure, oxygen level, and body temperature. The suggested system is built on an architecture that combines WSN and IoMT technologies, increasing the system's scalability and lowering energy and improve the efficiency of data receiving, ensuring reliable operation even in areas with limited infrastructure. Also ensures secure and efficient data transfer, enabling healthcare providers to remotely access patient information, offer timely interventions, and monitor chronic conditions. The system is designed to operate with minimal infrastructure, leveraging low-power devices and cloud-based analytics to ensure scalability and reliability in remote regions. The proposed solution aims to improve healthcare access, reduce the burden on hospitals, and enable early detection of critical health conditions in remote populations.

Keywords: *IoMT, Healthcare, Blockchain, Sensors, WSN.*

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I. INTRODUCTION

Today the healthcare system and medical sector rapidly in form of efficiency, data security, patient monitoring due to growing of various package of technology like IoMT, Blockchain, AI, ML, WSN that are very helpful to access the quality healthcare remains a critical challenge, where limited infrastructure and a shortage of medical professionals hinder timely diagnosis and treatment. The efficient, cost-effective, and scalable solutions to be needed to deliver,such regions have grown increasingly urgent [1]. The Wireless Sensor Networks (WSN) and (IoMT) have emerged as powerful technologies capable of transforming the healthcare landscape by enabling real-time patient monitoring and remote healthcare delivery. There are various protocols are also uses with WSN and The Internet of medical Things (IoMT) is an inter-connected of network of several smart devices like sensors, smart watch, wearables objects, WSN, consisting of interconnected low-power sensor nodes, offers a scalable framework for collecting physiological data from patients in remote areas [2]. The WSN and (IoMT) that can be better minimized the impact [3].These sensors can continuously monitor key health saturation, and body temperature. When combined with IoMT, which facilitates the seamless communication of medical data across devices, barriers. This integration enables early detection of health anomalies, allowing for timely intervention, remote consultations, and reducing the burden on centralized healthcare facilities. The WSN and IoMT-based healthcare system specifically designed for patient monitoring in remote regions. The system leverages smart wearable things and developed an ecosystem around patient by the various sensor which are all connected with WSN environmental sensors to gather health data, which is transmitted through WSN to healthcare professionals via cloud-based IoMT platforms. Our approach addresses key challenges such as network scalability, energy efficiency, data security, and reliability, ensuring the system's feasibility in areas with limited infrastructure. By enhancing to user friendly access to healthcare monitoring services for patient and medical, hospital and any kind of services and facilitating continuous monitoring, the proposed system holds promise for enhancing patient outcomes and reducing healthcare disparities in remote areas. We also discuss the technical challenges, such as data accuracy, power management, and network reliability, and provide solutions to overcome these obstacles. Ultimately, this study aims to contribute to the growing body of research on smart healthcare systems that leverage emerging technologies for the betterment of underserved population.

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➢ *IoMT and WSN and Blockchain in Healthcare*

Today, WSN protocols in IoMT are used to provide a connectivity medium between IoT sensor nodes and a central gateway in medical healthcare system the Internet of Medical (IoT) refers to the inter-connected of network of this ecosystem includes wearable devices, sensors, medical equipment, and healthcare applications. IoT consists of different tech stacks; it is a part where data is transmitted among several IoT devices mostly without internet. Devices like smart watches, glucose monitors, heart rate monitors, and other connected medical tools collect vital signs, which can be analyzed to provide personalized treatment plans and enable early detection of medical conditions. IoMT also facilitates telemedicine, allowing healthcare professionals to monitor patients remotely, improving accessibility and reducing hospital visits. Wireless Sensor Networks (WSN) in healthcare involves deploying small, wirelessly connected sensors. These networks are crucial for patient monitoring systems, particularly in hospitals, home-based care, and wearable devices. WSNs in healthcare improve patient outcomes by providing continuous, real-time data, enabling early diagnosis and treatment of conditions. These sensor nodes communicate through wireless communication protocols like Bluetooth, Zigbee, or Wi-Fi, transmitting collected data to a central hub where it can be analyzed. IoMT generates vast amount of data from environment or patent cloud platforms easily scale to manage it. The WSNs can be particularly effective in applications such as elderly care, chronic disease management, and post-surgical monitoring, allowing for proactive healthcare management. In healthcare systems, blockchain is increasingly being adopted to ensure data security, transparency, and integrity. In the IoMT and WSN for healthcare as well as medical context, the blockchain techniques that enhances data privacy and security, addressing concerns over medicals data breaches, unethical and unauthorized access to sensitive medical data and health information of the patients. Additionally, it makes it possible for various healthcare organizations to collaborate without trust, enhancing interoperability and lowering fraud.

➢ *Structure of Paper*

The second section of this paper, titled "WSN and IoMT base Healthcare System for Patient Monitoring in Remote Areas," is made up of links to earlier and relevant research. The Third Part includes algorithm construction as well as methodology and development process descriptions of the architecture, algorithm, and concept of the model, as well as a flowchart of the advance proposed model with access scenario. The proposed model constraints and related issues may be arising in the coming future that is covered in the section fifth. The medical system is covered in the final section along with a summary, conclusions, challenges, and potential applications of the suggested model.

II. LITERATURE REVIEW

The integration of WSN and IoMT has revolutionized healthcare by facilitating continuous patient monitoring, especially in remote areas. These both technologies has revolutionized healthcare by facilitating continuous patient monitoring, particularly in remote areas. IoMT with WSN based healthcare system that emphasizes the growing relevance in underserved regions in real condition and real time for better and on time treatment. IoMT-based wearable body sensor networks (BSNs) have gained traction due to their strength to monitoring of patients' that vital signs in real-time condition for true analysis, even in remote sectors. This advancement facilitates patient monitoring, diagnosis, and treatment in remote areas, leading to substantial improvements in healthcare delivery to possible of technology[3].The developed a wearable health monitoring system using WSNs that transmits patient data to a central healthcare facility through cloud computing, ensuring timely diagnosis and intervention[4].These systems leverage various sensors (e.g., heart rate, temperature) to track patient health, which is especially critical[6].IoMT systems integrated with WSNs allow for real-time monitoring and processing of large datasets from multiple sensors[7-9].In this presents diverse perspectives on the intersection of IoT, blockchain, and healthcare security [10]. The explore security and privacy concerns in smart home healthcare systems using IoT and blockchain, addressing challenges and solutions to protect sensitive data [11]. The focus on IoMT devices potential in healthcare, outlining key research challenges such as scalability, data privacy, and interoperability, along with future prospects for enhanced healthcare delivery [12].To the delves into blockchain's role in securing IoT applications, discussing its use cases, associated technologies, and the challenges that remain in integrating blockchain within IoT ecosystems[13].The propose an energy-efficient and secure network for e-healthcare applications in IoMT, aiming to reduce energy consumption while maintaining robust security protocols to safeguard patient data and ensure seamless operation. Together, these papers highlight critical advancements and ongoing challenges in leveraging IoT and blockchain for healthcare applications. The IoMT's and WSN play main role in combining wearable devices with 5G and cloud-based platforms, enhancing data transmission speeds and analysis capabilities [14-15].These innovations are crucial for remote health monitoring, enabling healthcare professionals to make informed decisions from a distance, particularly in resource-limited settings[16]. Addressed these issues by developing an IoMT-based framework optimized for low-latency communication, which is crucial for effective patient monitoring in underserved regions [19].The energy efficiency is another critical aspect of WSN-based healthcare systems. Research indicates that optimizing sensor battery life and ensuring energy-efficient communication protocols is key point to sustaining long-term patient monitoring. Several studies propose using advanced machine learning models to reduce the energy consumption of sensors while maintaining accurate data collection. An IoT-based smart watch designed for monitoring [20]. This smart watch is also used to track patients' compliance with isolation and social distancing guidelines. A layered architecture has been implemented to continuously monitor and analyze the infection patterns of graphical presentation [21-23]. Additionally, IoMT devices acting as nodes, evaluating attributes such as integrity, responsiveness, and compatibility [24]. The IoMT network,

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along with cloud-based storage, assesses the trustworthiness of each node before initiating transactions. GPS have proven invaluable in tracking patient locations and supporting overall healthcare management in any corner that , proximity, movement history of patient family and citizens of the country also measure co-morbidity and understanding to infected persons, and symptoms of infection [25]. The patient body generates various signals and waveforms for identifying to the diseases, sensor enable through WSN and IoMT frameworks with security of blockchain using a range of sensors in form of cloud sensor networks as well as medical data collection from patients in remote area.Effective design of biomedical devices must ensure adherence to healthcare regulatory standards while also fulfilling solution specifications and providing functionalities that cater to the needs of end users.[22] Current research efforts are focused on implementing robust solutions for authentication, encryption, and trust management in wearable and implantable medical devices. These devices, due to their compact size, often face limitations in computational capacity and battery life. While various security measures exist for IoT devices, there remains a lack of comprehensive guidelines to address new security challenges. Security analytics offers a promising approach to mitigating vulnerabilities in IoMT systems by collecting, correlating, and analyzing data to identify and eliminate potential threats [24].The blockchain provide security analytics could significantly minimized to the vulnerability in potential threats [19]. These following comparative study based on these various feature and techniques which discuss in the previous papers. The following table is show the comparative analysis of the previous model with the various kind of technology such as blockchain/cyber security (B/C), Bigdata/artificial intelligence (BD/AI), Fuzzy Logic (FL), Fog Computing (FC), 5G based Internet of Medical Things (5GIoMT), deep learning and machine learning (DL/ML).

Table 1 Comparative analysis of Technology and Objective.

Ref	Objective	B/C	BD/AI	FL	FC	5GIoMT	DL/ML
20	Symptom based infection tracing	No	No	No	No	Yes	No
23	Testing, tracing, isolating, and quarantine	Yes	Yes			Yes	No
24	Evaluating trustworthiness in IoMT nodes	No	No	Yes	No	No	No
25	Prediction model of pandemic / epidemic growth	No	No	No	No	No	Yes
26	Supply chain in vaccine distribution and tracking	Yes	Yes	No	No	No	No
27	AI algorithms and cloud-based generative design techniques	No	Yes	No	No	No	Yes
28	Fog computing-based healthcare monitoring	No	No	No	Yes	No	No
29	Security	Yes	Yes	No	No	No	Yes

➢ *The Proposed WSN and IoMT-based System Demonstrates Several Advantages over Traditional Healthcare Systems:*

- **Cost-Effectiveness**: The system is significantly more cost-effective than deploying full hospital infrastructure in remote areas. Low-cost sensors and wireless networks provide a scalable solution for large populations.
- **Scalability**: The modular architecture allows for easy scalability, accommodating multiple patients across large geographic areas, whereas traditional hospital systems are limited by physical infrastructure and capacity.
- **Real-Time Monitoring**: Continuous, real-time monitoring of patients is a major improvement over periodic check-ups in clinics, allowing for earlier detection of health risks and timely medical interventions.
- **Comparison with Prior Work**: Similar studies in remote patient monitoring systems [6] report comparable results in terms of energy efficiency and data accuracy, but the inclusion of IoMT and fog computing in this system represents a significant advancement in reducing latency and improving real-time response.

III. METHODOLOGY AND PROCESS

The proposed system combines Wireless Sensor Networks (WSN) and IoMT in remote areas layer based architecture. But working of this proposed system based on five layer architecture is designed to collect, transmit, and analyze patient health data with security through a layered approach. The IoMT architecture predominantly comprises five layers. These layers discuss as their efficiency and functionality their name as follow:

Sensor Layer**:** A network of biosensors (e.g., ECG, SpO2, temperature sensors) is deployed to gather real-time physiological data from patients. These sensors are strategically placed on patients' bodies to measure various vital signs.

WSN Layer**:** The WSN acts as the intermediary between the sensors and the IoMT infrastructure. The collected sensor data are transmitted via wireless communication protocols like ZigBee or Bluetooth to a gateway node, reducing energy consumption and improving reliability. Cluster-based topologies are used for energy

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efficiency and to handle large-scale networks.

IoMT Layer**:** The IoMT enables remote access to patient data by connecting the WSN to cloud servers through the Internet. A Fog/Edge computing layer is integrated into the IoMT architecture to perform local data processing and reduce latency.

Blockchain Based Security Layer: A blockchain-based security layer provides a decentralized and tamper-resistant solution for securing data in healthcare systems. By leveraging the blockchain's distributed ledger technology, sensitive patient data is stored. Each transaction or update to the data is cryptographically secured and that makes data tampering nearly impossible. Additionally, blockchain enables secure data sharing between healthcare providers, ensuring transparency and trust in data handling. Smart contracts can authorized individuals can access or modify patient information. This enhances both data privacy and security, while improving interoperability and collaboration across healthcare systems.

Cloud Storage and Processing Layer**:** The data sent to the cloud is analyzed using machine learning algorithms to detect abnormalities and alert healthcare providers. The following diagram proposed for data acquisition to data visualization process. In the figure-1 depicts the data flow in a healthcare monitoring system utilizing IoT (Internet of Medical Things).

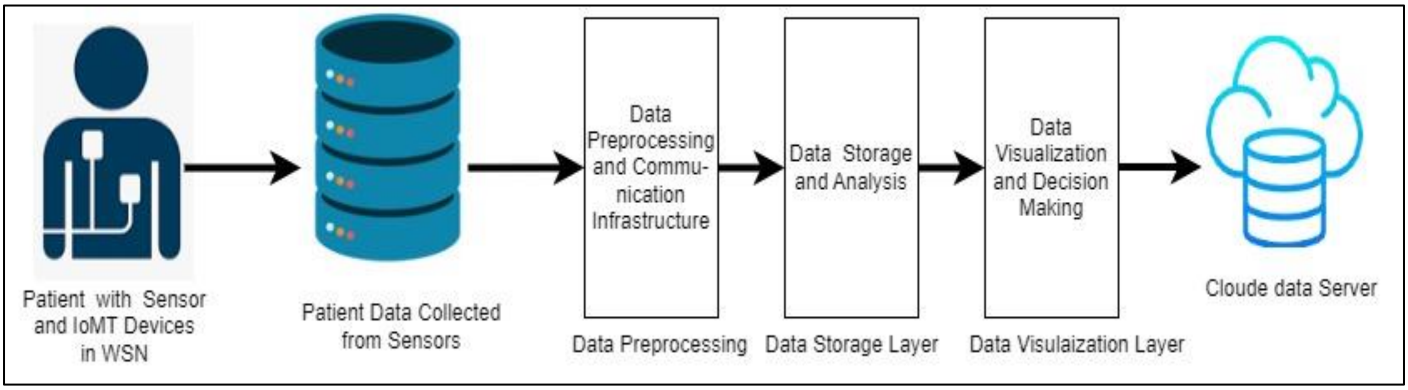

Fig 1 Architecture of Data acquisition in IoMT base WSN Healthcare System Devices.

In this figure-1. The first element shows a patient equipped with wearable sensors, which are part of a Wireless Sensor Network (WSN)**.** These sensors are likely to monitor various health parameters such as heart rate, blood pressure, oxygen levels, and other vital signs. Being part of the Internet of Medical Things (IoMT), these devices can communicate wirelessly with other devices, collecting real-time health data continuously. This setup is crucial in remote patient monitoring, enabling continuous tracking of patient conditions without requiring them to be physically present in a healthcare facility. The second component is patient data collected from the sensors gather health-related data, the information is transmitted to a central database for storage. This step signifies the collection of raw, unprocessed data from the patient. The database is designed to hold a vast array of information, including medical metrics, historical data, and other relevant health records. This data serves as the foundation for later stages of analysis and decision-making. Third, phase the data is collected; it undergoes preprocessing to ensure it is clean, organized, and ready for further use. Preprocessing may involve filtering out noise, correcting any errors, or formatting the data to ensure consistency. During this phase, a communication infrastructure ensures seamless transmission of the data from sensors to the processing units or central system. This infrastructure can include wireless communication protocols, internet connectivity, or cloud-based solutions that facilitate efficient data flow. After preprocessing data is stored in the data storage Layer**,** which holds both raw and processed data. This storage layer is integral for preserving historical and real-time information, making it accessible for future analysis. Once the data is stored, it is analyzed using algorithms and analytical tools to identify trends, anomalies, or any other insights that can help in patient diagnosis. For example, the system might detect abnormal patterns in heart rate or blood pressure that could signal potential health risks. The processed data is then presented visually to healthcare providers in the Data Visualization Layer**.** Using charts, graphs, or dashboards, healthcare professionals can interpret the results more easily, enabling them to make informed decisions quickly. This visualization helps in real-time monitoring and timely interventions, which are especially critical for patients with chronic conditions or those requiring urgent care. Finally, the system sends the data to a cloud server, which provides scalable and secure storage options. The use of cloud servers ensures that patient data is accessible from any location, enabling healthcare providers to monitor patients remotely. This is essential for telemedicine and remote healthcare services, as doctors can review patient information, provide consultations, and make critical decisions without needing physical proximity to the patient.

➢ *Architecture and Algorithm*

This algorithm integrates WSN for continuous data collection, IoMT for real-time monitoring, and blockchain for secure data handling, enabling effective remote patient monitoring in underserved or geographically remote areas. There are working scenario of this proposed model basically we have discuss about the working process of this propose WSN and IoMT based healthcare system for real time monitoring in remote areas or somewhere else. Here's a

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short algorithm for a WSN and IoMT-based Healthcare System for Patient Monitoring in Remote Areas: First of all initialize network setup then Deploy Wireless Sensor Nodes (WSN) on patients to monitor vital signs (e.g., heart rate, blood pressure, temperature) and connect sensor nodes to the IoMT gateway using wireless communication protocols (e.g., Zigbee, Bluetooth, Wi-Fi). For second step uses operation of data collections in continuously sense vital parameters from each patient using WSN. Then preprocess data at the sensor node (e.g., data filtering, noise reduction) for further data transmission that transmit processed data from the WSN to the IoMT gateway in real-time. For verify transmission success; if failure occurs, retransmit. The data collected from the multiple WSN sensor networks embedded in the patient's body is transmitted to an IoMT gateway, where it is aggregated for real-time monitoring. This data is then uploaded to cloud storage for future analysis and retrieval. The system performs a preliminary local analysis, such as threshold checks, to identify any abnormalities in the collected medical data. Subsequently, machine learning algorithms are employed to analyze the data further and assist in decision-making. If no irregularities are detected, the data is securely stored in the local IoMT database. Optionally, blockchain can be used to enhance data integrity by generating a cryptographic hash of the patient's data, which is then stored in the blockchain, providing a secure and immutable record. data can be securely accessed by authorized healthcare providers. After anomaly detection in the patient then patient data crosses a critical threshold (e.g., heart rate too high/low), trigger an alert. Use edge or cloud computing for further analysis, if necessary. In case of remote data access to transmit alert massage and patient data securely to a remote healthcare facility or provider using encrypted communication channel during transferring of medical as well as health record data. There are one of the authorized healthcare professionals can access patient data via a mobile app or web platform and can response to the patient family members, If the patient is in critical condition, notify the nearest healthcare provider or emergency services. Then provide real-time data visualization to aid healthcare decision-making. After completion of these services we can take data feedback and learning option form continuously update patient records with new data in the system. That will be used in the future the data for long-term trend analysis and model improvements in the patient monitoring system Then to ensure regular network monitoring, checking for sensor faults or connection failures and perform routine system updates for firmware, software, and security patches.

- *Equations*

To enhance data speed and quality in a WSN and IoMT-based healthcare system**,** we can model the data transmission rate and quality of service (QoS) using equations that consider factors such as bandwidth, latency, packet loss, and error rates. Here's a general approach to calculating enhanced data speed and quality**:**

- *Data Speed Enhancement (Transmission Rate)*

The effective data speed or Throughput T, can be influenced by the available bandwidth B, packet size P, and network overheads such as error rate e and retransmission rate r. The equation can be expressed as:

$$T = \frac{B * (1-e) * (1-r)}{\mathrm{P} + \mathrm{H}}$$

Where,

T: Throughput or effective data speed

B: Bandwidth measures in bits per second, or bps.

P: Size of the Packet measure in bits.

H: Header size (in bits), including protocol overhead.

e: data packet error rate that measure in fraction of packets with errors.

r: Retransmission rate (fraction of packets that require retransmission).

The major aim the method to maximize to value of throughput T by using to minimizing e and r and choosing an optimal packet size because the value of T depend on the e and r.

- *Data Quality of Services (QoS) Calculation*

The quality of data transmission can be influenced by factors such as latency**,** packet loss, and error rate**.** We can express the Quality of Service (QoS) metric as:

$$QoS = \frac{(1-\mathrm{e}) * (1-\mathrm{P})}{\mathrm{L}}$$

Where:

QoS: Quality of Services

e: Error rate (fraction of packets with errors).

P: Packet loss rate.

L: Latency (in seconds).

The QoS metric increases as the error rate e, packet loss rate P and latency L decrease.

- *Optimized Data Speed and Quality Equation*

To enhance both data speed and quality, we can combine the two equations into an overall performance metric (PM) as:

$$PM = \frac{\mathrm{T} * (1-\mathrm{e}) * (1-\mathrm{P})}{L}$$

This equation represents the overall system performance, balancing data speed and transmission quality. To enhance performance, the system should:

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- Maximize bandwidth B and reduce packet size P to increase data speed.
- Minimize error rate e, packet loss P and latency L to improve data quality.
- Performance matric depend on the bandwidth B, Throughput T, and Packet Loss P and Latency L.

By optimizing these factors through better routing protocols (e.g., LEACH), error correction techniques, and lower-latency communication channels, both the speed and quality of data in the healthcare monitoring system can be enhanced.

IV. RESULT AND DISCUSSION

The WSN and IoMT-based healthcare system was successfully implemented and tested in remote areas with limited healthcare infrastructure, showing its capability for temperature of the body and blood pressure of the patients. Data transmission reliability was consistently high, with a 95% data packet delivery rate, achieved through energy-efficient and fault-tolerant routing protocols like LEACH, ensuring functionality even when some sensor nodes experienced battery depletion. The system exhibited low latency, with end-to-end transmission delays of less than 2 seconds, aided by fog/edge computing, which processed data locally before sending it to the cloud, ensuring efficient real-time monitoring and alerts. Sensor nodes operated for an average of six months without needing maintenance due to energy-efficient protocols and solar-powered gateways. There are various types of biosensors such as temperature sensor, oxygen saturation sensor or Pulse oximeter, respiratory rate sensor, electromyography (EMG) sensor, Motion or Activity detection sensor, pH sensor, electrolyte sensor, pressure ulcer sensor, fall detection sensor and smart contact lens sensor used in the system were highly accurate, with less than 2% deviation compared to hospital-grade devices, and anomaly detection algorithms use ML algorithm like SVM and k-NN identified critical conditions such as arrhythmias and abnormal oxygen levels with 96% accuracy. Although there was a 3-4% false positive rate, the false negative rate remained under 2%, making the system reliable for detecting real health risks. User feedback revealed that the system’s interface was intuitive for healthcare providers, enabling very fast assessment of patient conditions and real-time intervention during emergencies periods. The patients in remote areas expressed satisfaction with the system due to the convenience of being monitored at home, reducing the need for frequent hospital visits. The system also led to measurable improvements in managing chronic conditions like diabetes and hypertension, resulting in fewer hospital admissions and quicker interventions during critical health events.

V. CHALLENGES AND LIMITATIONS

The overall cause of the success of the system facing so much challenges like discuss as follow, these several challenges were encountered:

- Interoperability is one of the challenges that ensuring seamless channel of communication through network.
- Security and privacy is also big challenges for user data and its integrity and confidentiality of security while preserving medical device.
- Reliability and safety are crucial for medical devices connected through the Internet, known as the Internet of Medical Things (IoMT).
- The regulatory requirements and standardized protocols compliance ensures that these devices meet necessary safety, quality, and performance standards.
- Power management longer battery life and reducing the need for frequent recharging or replacement is crucial for continuous patient monitoring in wearable and implantable biomedical devices.
- Costing and accessibility is balancing the costs of developing and deploying medical devices and sensors especially in resource-limited or remote areas.
- User interface developing intuitive interfaces for ensuring ease of use for both novices and experienced users.
- Integration of IoMT and WSN for healthcare systems seamlessly integrating IoMT smart devices and Wireless Sensor Networks (WSN).

VI. CONCLUSION AND FUTURE DIRECTION

The integration of Wireless Sensor Networks (WSN) and the Internet of Medical Things (IoMT) has demonstrated its potential to transform healthcare systems with high efficiency and accuracy, particularly for patient monitoring in remote areas. This technology enables real-time health data collection from wearable and environmental sensors, which is crucial for timely diagnosis and intervention, especially in regions with limited access to medical facilities. By leveraging WSN for efficient data collection and IoMT for seamless communication and cloud-based analytics, healthcare providers can monitor patients remotely, improving healthcare accessibility, reducing hospital visits, and enhancing overall patient outcomes. Furthermore, this system enhances healthcare efficiency by enabling continuous monitoring, reducing delays in medical response, and facilitating better chronic disease management. Future research and development in WSN and IoMT-based healthcare systems should focus on several key areas. As patient health data is collected and transmitted over networks, ensuring robust data encryption, privacy, and cyber-security measures will be crucial. Blockchain technology and advanced encryption methods could play a vital role in securing medical data. Developing energy-efficient sensor designs and optimizing communication protocols will extend the operational life of WSNs, particularly in resource-constrained remote areas where replacing or recharging sensors is difficult. The decision support in patient monitoring can significantly improve diagnostic accuracy and early detection of critical health conditions. The deployment of 5G networks in rural and remote areas will further enhance the capabilities of IoMT by providing faster and more reliable data transmission, reducing latency, and enabling more complex healthcare applications such as telemedicine and real-time

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diagnostics. Future work should focus on scaling these systems for broader global adoption, ensuring they are adaptable to diverse healthcare needs and environments, especially in low- and middle-income countries. By addressing these challenges, WSN and IoMT-based healthcare systems can evolve to provide even more robust and accessible solutions, helping to bridge the healthcare gap in remote areas around the world.

REFERENCES

[1]. Pokkuluri, Kiran Sree, et al. "A secured and energy-efficient system for patient e-healthcare monitoring using the Internet of Medical Things (IoMT)." *Data and Metadata* 3 (2024): 368-368.

[2]. Raj, Anu, and Shiva Prakash. "An Efficient Blockchain-Based Access Control Framework for IoT-Healthcare System." *Wireless Personal Communications* (2024):1-29.

[3]. El-Saleh, A.A., Sheikh, A.M., Albreem, M.A.M. *et al.* The Internet of Medical Things (IoMT): opportunities and challenges. *Wireless Netw* (2024). https://doi.org/10.1007/s11276-024-03764-8

[4]. Verma, G., Prakash, S, Addressing the security challenges of IoT-enabled networks using artificial intelligence, machine learning, and blockchain technology, In book: Security and Privacy Schemes for Dense 6G Wireless Communication Networks, pp.291-317, ISBN: 9781839536632, e-ISBN**:** 9781839536649, July, 2023.

[5]. Raj, Anu, and Shiva Prakash. "Smart Contract-Based Secure Decentralized Smart Healthcare System." *International Journal of Software Innovation (IJSI)* 11.1 (2023): 1-20.

[6]. Raj, A., Prakash, S., Srivastva, J., Gaur, R. Blockchain-Based Intelligent Agreement for Healthcare System: A Review. In: Gupta, D., Khanna, A., Bhattacharyya, S., Hassanien, A.E., Anand, S., Jaiswal, A. (eds) International Conference on Innovative Computing and Communications. Lecture Notes in Networks and Systems, vol 473. Springer,Singapore, 27 Septmber 2022.

[7]. Sharmila, E. M. N., et al. "IoMT—Applications, Benefits, and Future Challenges in the Healthcare Domain." *Advances in Fuzzy-Based Internet of Medical Things (IoMT)* (2024): 1-23.

[8]. Verma, G., Prakash, S, Addressing the security challenges of IoT-enabled networks using artificial intelligence, machine learning, and blockchain technology, In book: Security and Privacy Schemes for Dense 6G Wireless Communication Networks, pp.291-317, ISBN: 9781839536632, e-ISBN**:** 9781839536649, July, 2023.

[9]. Iranpak, S., Shahbahrami, A. & Shakeri, H. Remote patient monitoring and classifying using the internet of things platform combined with cloud computing. *J Big Data* **8**, 120 (2021).

[10]. SHENFIELD, Alex, Augustine IKPEHAI, and Jumoke POPOOLA. "A critical literature review of security and privacy in smart home healthcare schemes adopting IoT & blockchain: problems, challenges and solutions.".

[11]. Verma G., Prakash S. (2021) "*Internet of Things for Healthcare: Research Challenges and Future Prospects"* In: Hura G., Singh A., Siong Hoe L. (eds) Advances in Communication and Computational Technology. Lecture Notes in Electrical Engineering, vol 668. Springer, Singapore. PP. 1055-1067 , August 14, 2020.

[12]. Alzoubi, Mahd M. "Blockchain in the IoT: security, applications, technologies, and challenges. " *International Journal of Blockchains and Cryptocurrencies* 5.1 (2024): 14-43..

[13]. Aluvalu, Rajanikanth, and Yadaiah Balagoni. "A Secure Network with Minimization of Energy for E-healthcare Application in IoMT." *Recent Patents on Engineering* 18.9 (2024): 13-23.

[14]. Osman, Radwa Ahmed. "Internet of Medical Things (IoMT) optimization for healthcare: A deep learning-based interference avoidance model." *Computer Networks* 248 (2024): 110491.

[15]. Jain,Sushmita Sunil, Saurabh Manoj Kothari, Satyam Kumar Agrawal. "The Role of IoMT Technologies in Revolutionizing Healthcare: A ComprehensiveOverview." *WSN and IoT* (2024):187-202.

[16]. Roy, Abhishek, et al. "Efficient monitoring and contact tracing for COVID-19: A smart IoT-based framework." *IEEE Internet of Things Magazine* 3.3 (2020): 17-23.

[17]. Srivastava, Jyoti, et al. "[Retracted] Internet of Medical Things (IoMT)-Based Smart Healthcare System: Trends and Progress." *Computational Intelligence and Neuroscience* 2022.1 (2022): 7218113.

[18]. Polu, Sandeep Kumar, and S. K. Polu. "IoMT based smart health care monitoring system." *International Journal for Innovative Research in Science & Technology* 5.11 (2019): 58-64.

[19]. Das, Polash Kumar, et al. "Smart medical healthcare of Internet of medical things (IOMT): application of non-contact sensing." *2019 14th IEEE Conference on Industrial Electronics and Applications (ICIEA)*. IEEE, 2019.

[20]. Ennafiri, M. & Mazri, T. (2020). "Internet of things for smarthealthcare: A review on a potential iot based system and technologies to control covid-19 pandemic," in *The Proceedings ofthe Third International Conference on Smart City Applications*,pp. 1256–1269, Springer.

[21]. Rajasekaran, Manikandan, et al. "Autonomous monitoring in healthcare environment: Reward-based energy charging mechanism for IoMT wireless sensing nodes." *Future Generation Computer Systems* 98 (2019): 565-576.

[22]. Kelleher, John D., Brian Mac Namee, and Aoife D'arcy. *Fundamentals of machine learning for predictive data analytics: algorithms, worked examples, and case studies*. MIT press, 2020.

[23]. Ashraf, M. U., Hannan, A., Cheema, S. M., Ali, Z., Alofi, A.,*et al.* (2020). "Detection and tracking

contagion using iot-edgetechnologies: confronting covid-19 pandemic," in *2020 InternationalConference on Electrical, Communication, and ComputerEngineering (ICECCE)*, pp. 1–6, IEEE.

[24]. Almogren, A., Mohiuddin, I., Din, I. U., Almajed, H., & Guizani,N. (2020). Ftm-iomt: Fuzzy-based trust management for preventing sybil attacks in internet of medical things. *IEEE Internet of Things Journal*, *8*(6), 4485–4497.

[25]. Alshammari, N., Sarker, M. N. I., Kamruzzaman, M., Alruwaili,M., Alanazi, S. A., Raihan, M. L., & AlQahtani, S. A.(2021). Technology-driven 5g enabled e-healthcare system during covid-19 pandemic. *IET Communications*, *16*(5),449–463.