Revolutionizing Healthcare: A Comprehensive Analysis of the Impact of Internet of Things

Abubakar Bello Bada
Department of Computer Science,
Federal University Birnin-Kebbi.

Aminu Aliyu
Department of Computer Science,
Federal University Birnin-Kebbi.

Hafsat Mahe Omar
Department of Computer Science,
Federal University Birnin-Kebbi.

ABSTRACT
The Internet of Things (IoT) which refers to a system of interconnected wireless digital devices that have the ability to collect, transmit, and store data autonomously, without the need for human intervention. The Internet of Things (IoT) has affected many fields. In healthcare, it is highly useful in linking professionals, equipment, and sensors to deliver high-quality services anywhere, at any time, and even in remote areas. This is particularly helpful as accessing health facilities can become very difficult in some situations, as witnessed during the Coronavirus (COVID-19) pandemic. The advancement of IoT technology and its application in healthcare has created new solutions and opportunities in healthcare provision, such as the remote monitoring and treatment of patients. IoT in healthcare has reduced the cost of healthcare, improved patient safety, and enhanced healthcare operational efficiency and accessibility. This paper provides in-depth information on the impact of IoT in healthcare, the challenges affecting it, and the current trends in IoT in healthcare. Methods to mitigate security challenges facing healthcare IoT and future recommendations on current trends are discussed in this paper.

Keywords
IoT, Machine Learning, Deep Learning, Data Analysis, HIoT

1. INTRODUCTION
A few years ago, disease diagnosis was limited to the physical examination of patients in hospitals. Most patients must remain in the hospital for the duration of their treatment or for a greater part of it, which results in increased healthcare costs. Recent technological developments have made it possible to use miniature devices to monitor patient's health and also detect a variety of medical conditions. New technologies such as big data analysis, Machine Learning, Internet of Things (IoT), in conjunction with communication services, make remote monitoring of patients and autonomous diagnosis possible [1]. The IoT, a network that connects physical things (uniquely identifiable devices) to the Internet and enables them to sense their environment and communicate with each other [2], has enabled devices to generate huge amounts of medical data. As a result, interest in a variety of health practices aimed at enhancing the health of the population has increased [3]. This huge amount of data generated in combination with advanced machine learning algorithms can play a significant role in the creation of automated systems for gathering medical data, as well as in improving monitoring, diagnosis, and treatment of patients. Internet of Medical Things (IoMT) is a relatively new term that describes connected medical devices [4]. For the purpose of this study, IoMT, Healthcare IoT, (HIoT), and IoT in healthcare are used interchangeably.

Smart watches and sensors (IoT Devices), for example, have been integrated with other physical devices for monitoring and data exchange through various communication protocols, and with this data exchange, huge amount of data can be gathered that can help in improving the patient's outcome and quality of care [1]. In healthcare, IoT devices are either wearable or embedded in the human body, and are used in acquiring patient's vital signs such as pulse rate, blood pressure, body temperature, and patient activity levels, such as medication adherence, sleep pattern, and exercise (.Peng et al., 2017). Other data gathered by these devices include environmental data such as time, date, and environmental temperature [6].

To fully utilize the data collected by IoT devices, an effective information-processing system must be implemented. Information processing in healthcare IoT involves data gathering, storage, analysis, and dissemination [7]. Data collection, the first step of healthcare information processing, is carried out with the use of IoT devices like sensors and other wearable technology. The data is then sent to a database, or cloud storage. The database must be built to handle massive amounts of data and be easily accessible to healthcare providers from anywhere and whenever. Once the data are gathered and stored, the data analysis follows. This involves using advanced algorithms, mostly machine learning and deep learning algorithms, to identify patterns and trends in the data. These patterns and trends can be alterations in vital signs, change in patient behavior, and prediction of future health issues and potential health risks. The dissemination of data is the last stage of information processing, and it needs to be done in a clear and accessible manner. This could be graphs, charts, and highlight of key trends and patterns [6], [7], [8].

Security challenges in the medical IoT are bound to increase owing to the rapid development and deployment of IoMT systems. The response to coronavirus disease (COVID-19) pandemic that effectively shuts down traditional ways of health service delivery led to the lowering of implementation hurdles to technology-assisted healthcare, which ultimately resulted in the quick development and deployment of these systems [9].

The Internet of Things in Healthcare or the Internet of Medical Things is a rapidly developing sector, with new trends emphasizing remote health monitoring, intelligent hospital/healthcare, and predictive analysis. The incorporation of AI in the IoMT is projected to result in a more accurate diagnosis, increased patient involvement, better healthcare outcomes, and reduction in the workload of healthcare providers [10]. Other future possibilities of IoMT systems include the development of customized treatment plans and utilization of data for well-informed health planning.

2. IOT APPLICATIONS IN HEALTHCARE
Technology and Healthcare have come together in remarkable ways, giving rise to great advancements in the Internet of Things (IoT), which has led to the revolutionisation of patient care and medical processes. IoT has transformed healthcare by

using miniature devices (IoT devices), advanced communication protocols, and data analytics [11]. These devices (IoT devices) use the human body as a reservoir of fitness and medical data. Biometric, physiological, and behavioral data are gathered via an IoT device network, sent via IoT systems, processed by the backend infrastructure, and then provided to users—typically through mobile apps [11], [12]. These Internet of Things (IoT) devices include pill dispensers, implants, prostheses, wearable smart fitness trackers, biometric authentication, and other wearable, implantable, and ingestible technologies. IoT enables continuous health monitoring, precise diagnosis, support for chronic conditions, and real-time analysis, which was previously impossible for clinicians [13]. Communication between doctors and patients, accurate diagnosis, and disease prediction have become easier and more reliable with the convergence of IoT and healthcare, application of big data, machine learning, and cloud computing. This has led to increased patient involvement in the treatment process with a decreased financial burden. Furthermore, it has improved people's quality of life and offered a variety of healthcare applications. (Rayan, Tsagkaris, & Iryna, 2021; "The Role of the Internet of Things in Healthcare: Future Trends and Challenges - PubMed," 2022). Some of the most prominent applications of the IoT in Healthcare are discussed below.

2.1 Chronic Disease Management

Diabetes and hypertension are two examples of chronic diseases that can be managed using IoT devices [16]. These devices are utilized in monitoring various health parameters such as blood pressure and blood glucose levels. In the diagnosis and management of hypertension, measurement of blood pressure is the key, and the traditional way of measuring it requires a healthcare worker to perform the recording [17]. However, with the application of the IoT in healthcare, blood pressure measurement has been transformed. For example, [18] presented a wearable cuffless device that can record both systolic and diastolic blood pressure, and in [19], a deep learning-based Convolutional Neural Network model with time-domain properties was employed for diastolic and systolic blood pressure evaluation.

In diabetes, one of the most accepted methods of diagnosis is measurement of blood glucose level [20]. Recent advancements in IoT technologies have given rise to various wearable devices for glucose monitoring, which are non-invasive and safe [21]. In [22], [23], a non-invasive mIoT-based glucometer has been proposed for real-time blood glucose monitoring. An Internet Protocol version 6 (IPv6) connection was used as a communication protocol to connect wearable sensors to healthcare professionals.

The data gathered by these devices in real time are processed at higher level and used for future treatment and dose adjustments as well as for predicting the progression of illnesses. Furthermore, the centralized collection of data can help in researching the epidemiological patterns of diseases within a population [11].

2.2 Medication Management

Adherence to the medication schedule is an issue in healthcare, and non-adherence may result in unfavorable health outcomes. Non-adherence to drug prescription is most commonly seen in the elderly because of the conditions that develop as age progresses, for example, dementia and cognitive decline. As a result, strictly following doctors' prescriptions is difficult. IoT technology has helped to tackle this problem, as can be seen in [24], where a smart medical box was created to remind people to take their medications. The box is equipped with three compartments, each containing the medication for three distinct periods of the day (morning, afternoon, and evening). The cloud server receives all the recorded data. Communication between the two end users occurs through a mobile app. Doctors and patients can use a mobile app to access recorded information.

2.3 Health Monitoring

Health Monitoring is the process of tracking the aspects of human health by measuring physiological and other medical data. A Health Monitoring System (HMS) is a technology that uses wearable wireless devices, such as a bracelet with sensors, linked with software/application to collect medical data [25]. IoT devices in healthcare have greatly helped in monitoring the health and management of patients. Monitoring is possible in real time after integrating IoT systems with communication technologies [26]. Health monitoring involves monitoring of vital signs e.g. pulse rate, mood, oxygen saturation, ECG, etc. for early detection of disease or a change in the condition of patient [27], [28]. Health monitoring can be for specific diseases or a combination of many [29], below are some of the health monitoring systems in use.

The electrical activity of the heart is represented by electrocardiography (ECG). This electrocardiogram (ECG) offers insights into the fundamental patterns of cardiac muscle activity and acts as an indicator for a range of cardiac conditions [30], such as arrhythmia and myocardial ischemia. ECG monitoring through IoT technology can lead to the early detection of cardiac conditions. Several studies have employed IoT for ECG monitoring (Acharya, 2017; J.B. Bathilde, 2018; Serhani, El Kassabi, Ismail, & Navaz, 2020; T. Tekeste, 2018). [31] suggested an IoT-based ECG monitoring system with a wireless data collection system and receiving processor. It detects heart abnormalities in real time using a search automation mechanism.

The human body temperature indicates the maintenance of homeostasis and plays a vital role in many diagnostic processes. A change in human body temperature could mean an indication that something is wrong or presence of an illness such as malaria, sepsis, trauma, etc., [35]. The conventional method of taking body temperature involves using a thermometer fastened inside either the mouth, ear, or rectum, which is uncomfortable and carries the risk of introducing infection into a patient (H.Ota, M. Chao, & Y. Gao et al., 2017; Švantner et al., 2022). IoT-based technologies have found ways for monitoring body temperature without the risks mentioned earlier [38]. [39] proposed a wearable device, designed to be worn on the ear. This device utilizes an infrared sensor to accurately detect body temperature from the tympanic membrane. The measured temperature remains unaffected by the surrounding environment or any physical activities.

The World Health Organization described health as not just the absence of illnesses but also as a state of good mental health [40]. Mood monitoring/tracking plays a crucial role in gathering data on an individual's emotional condition, enabling the maintenance of a healthy state. Additionally, it serves as a valuable tool for healthcare professionals in addressing diverse mental illnesses e.g., depression and bipolar disorder. [41] evaluated and classified a person's mood into six categories using a Convolutional Neural Network (CNN) in a mood mining strategy, the classifications include: happy, thrilled (excited), sad, calm, distressed, and angry. IoT technology can be used to design a system that prevents car accidents, as seen in [42]. A wearable device was created that is capable of

estimating four negative moods/emotions (anger, stress, terror, and sadness) experienced by a driver. Through the analysis of these emotions, the intelligent IoT system assesses the driver's level of consciousness. Once it determines that the driver is in a subconscious state, the system halts the operation of the vehicle.

An AI-based Deep Convolutional network was proposed in [43] together with fog and edge computing to analyse health-monitoring tasks. This work analysed the motion and architecture of a person for fall detection, and good performance matrices were achieved.

The application of IoT in healthcare is not limited to the ones mentioned above, but the above applications have shown that IoT technology has a great impact in healthcare. The ability of doctors to remotely monitor the health status of their patients is one of the most evident applications of IoT in healthcare. This empowers individuals to seek medical assistance at any time and from any location. Not only does this improve convenience and emergency care, it also promotes increased accessibility to medical assistance. Applications of IoT in healthcare is increasing significantly with the rapid growth in technology. Some of the healthcare aspects where IoT technology was not integrated are now using the technology efficiently e.g. remote surgery, cancer treatment, rehabilitation system, etc. An IoT-based system was developed in [44], [45] to detect lung cancer where various machine learning algorithms were used. In [46] a surgical framework is used in which the device uses virtual reality to create a teaching environment as well as a platform for interacting with other surgeons from around the world. IoT technology can also be applied in rehabilitation and wheelchair management [47], [48].

3. BENEFITS AND CHALLENGES OF IOT IN HEALTHCARE

The healthcare industry has been revolutionized by the implementation of IoT, bringing about significant advancements in patient experiences and enhancing efficiency for healthcare providers and facilities. The utilization of IoT in healthcare, also known as Internet of Medical Things (IoMT), is anticipated to generate large amount of data, ultimately resulting in improved healthcare outcomes for patients. Like any other new and emerging technology, IoT has its benefits and challenges that can serve as a potential area for future research [49]. Below are some benefits and challenges associated with IoT in healthcare:

3.1 Benefits

As with every technology, there are a lot of benefits of IoT to all aspects of human endeavour, healthcare inclusive. The healthcare sector faces many challenges e.g. lack of real time data, and inaccurate standard analytics, this can be overcome and the capabilities of healthcare be enhanced using IoT [50]. IoMT increases human-to-machine interaction thereby enhancing monitoring of human health, data collection, and health record maintenance in real time leading to patient and data driven decision making. Other benefits of IoMT to patients include cost reduction, real-time intervention in emergency situations, and decrease hospital stay [16]. On the part of healthcare service providers, there is optimal utilisation of infrastructure and resources as only the patients that need to be at the facility will be. Some patients will be monitored remotely and some will be guided by the technology on management of their illnesses. In the case of emergency, healthcare facility will be notified by the technology and emergency assistance can be given quickly, this reduces the response time for medical emergency [51].

3.2 Challenges

Some of the challenges of IoMT include:

3.2.1 Security and Privacy

Health Monitoring System captures private health information of individuals. With the current technology that enables the devices responsible for capturing the information to be more connected and accessible, the information is vulnerable to cyberattack. Medical data can be of great value to cybercriminals, who may exploit it for identity theft, fraud, and various other nefarious purposes. [52], [53]. Furthermore, the integration of the IoT devices with the cloud technology has made it more vulnerable to cyberattack [54], [55]. A breach in the security of an IoMT system can result in significant harm to patients as a result of the possible disclosure of sensitive medical data and/or the manipulation of medical devices. To prevent the monitoring systems from malicious attacks, preventive measures must be put in place right from the design of the system. The devices involved in healthcare IoT must employ measures like fault tolerance, identity authentication, authorization management, secure pairing protocol, password encryption, etc. to prevent attack. The network protocols used in the system must also be integrated with message integrity verification technique [7]. Application of deep learning for intrusion detection is also another way of enhancing security of IoMT. Implementation of technologies such as edge computing, fog computing, blockchain, and cryptography will help in increasing security of data in IoMT systems [9], [56].

3.2.2 Standardization

Numerous vendors are producing different kinds of healthcare IoT devices with the claim of following standard protocols in the design [24]. However, that claim cannot be validated. Lack of standardization can lead to creation of devices that can easily be compromised. There is a need for a body responsible for making sure the vendors follow a standard protocol in designing their products, this is to give confidence in the usage of the technology by people [11], [57].

3.2.3 Power Consumption

Devices used in Internet of Things for healthcare run on battery and once they are put on, the replacement of the battery becomes very difficult. As such, high-power batteries are used in those systems. Currently, researchers [13] are working to design devices that can generate their own power. This could be achieved by integrating the system with renewable energy system.

3.2.4 Scalability

In this situation, scalability is the ability of healthcare IoT devices to adopt to changes in the environment. It is critical to design a system with higher scalability because a device with higher scalability runs smoothly and efficiently, making the best use of available resources [58]. The absence of uniformity in healthcare IoT devices hinders the scalability of the IoT system.

4. IMPACT IOT ON PATIENT CARE

The Internet of Things (IoT) has a significant impact on the healthcare industry, offering numerous benefits and opportunities for improving patient care, increasing efficiency, and reducing costs [10].

The utilization of IoT technology enables continuous monitoring of patients' vital signs and various health parameters in real-time. This enables healthcare providers to intervene promptly if any abnormalities are detected

particularly in individuals with chronic conditions. This leads to improved patient outcomes and reduced hospital admissions. In order to reduce frequent hospital visits, IoT has enabled the development of smart medical devices such as pacemakers, insulin pumps, and medication dispensers [10], [47]. IoT has impacted healthcare by increasing patient adherence to treatment plans and overall health awareness. This is done by enhancing patient engagement through providing access to their health data, personalized health recommendations, and reminders for medication or appointments [51]. Another area where IoT has impacted healthcare is through the huge amount of data generated by IoT devices which can be analyzed to identify patterns, trends, and insights. Healthcare providers can use this information for predictive analytics to anticipate disease outbreaks, optimize resource allocation, and even predict equipment failures, enabling preventive maintenance [51]. IoT can be used by healthcare facilities to monitor the location and condition of medical equipment ensuring efficient use of resources and reducing the time spent searching for items. This can lead to cost savings and improved workflow within hospitals. IoT plays a great role in the expansion of telemedicine and virtual care. Connected devices facilitate remote consultations, allowing healthcare providers to monitor patients and deliver care without the need for hospital visitation by patients. This is especially valuable for patients in remote or underserved areas [59].

Overall, integration of IoT in healthcare has revolutionized and has the potential to revolutionize the industry even more by improving patient outcomes, increasing efficiency, and transforming the way healthcare is delivered and managed. However, it is essential to address security and privacy challenges to ensure a responsible and ethical use of IoT in healthcare

5. FUTURE TRENDS AND RECOMMENDATIONS

The current trends in Internet of Things (IoT) in healthcare are focused on improving patient safety, staff satisfaction, and operational efficiency [60]. The Internet of Medical Things (IoMT) is redefining healthcare solutions, with a focus on personalized care and improved outcomes [7]. The development of Healthcare Internet of Things (HIoT) is driven by advancements in sensing, communications, and data analytics, enabling the personalization and modernization of care [61]. Future trends in IoT in healthcare include the use of advanced technologies to resolve challenges and improve the quality and productivity of treatments [11].

One of the biggest trends in IoMT is remote patient monitoring which enables patient monitoring in their homes thereby reducing hospital visitations and admissions and also improve overall patient outcome. More investment in secure and scalable remote patient monitoring solution that allows collection and real-time analysis of data from patients is recommended [7], [60]. Growing emphasis on data security and privacy is another trend, this is due to sensitive nature of health information and growing usage of IoMT. Putting in place strong security measures such as encryption, secure authentication, and regular security audits and complying with data protection regulations is a good measure to stem this trend. Because of increase in production of IoT devices and healthcare systems by different vendors, seamless data transmission often becomes problematic due to interoperability issues. Adopting interoperable standards and technologies to ensure that IoT devices and platforms can communicate seamlessly and effectively will help in stemming this trend [7], [11].

Integration of Artificial intelligence and predictive analysis is a very good trend as IoMT takes a center stage in healthcare industry, this is because it leads to more accurate diagnosis, treatment planning, and resource optimization. Artificial Intelligence algorithms that can analyze the large datasets generated by IoT devices like deep learning algorithms are the way to go [61], [62].

Above are some of the current trends and recommendations in IoMT aimed at improving the delivery and quality of healthcare.

6. CONCLUSION

The most important challenge faced by IoMT is the security and privacy of patient's health information. Several innovative methods have been used to overcome such challenge, but they had certain limitations. A review of secure data transmission across IoT devices was conducted and edge computing, blockchain technology, and cryptography, has a great potential in increasing the security and privacy of information in IoMT systems. Ensuring the security and privacy of users is essential to gaining IoT adoption in healthcare systems. The challenges and benefits associated with IoMT systems, along with potential applications were also discussed in this paper. This paper also explores current trends and offers suggestions for the future of IoMT, opening up possibilities for the development of advanced applications and solutions that enhance patient care and optimize healthcare outcomes. The solutions presented in this paper have the potential to address the challenges discussed and facilitate the widespread adoption of reliable IoMT systems. Therefore, the study advocates for the implementation of legislative measures and policies that establish frameworks to foster collaboration between legislative bodies and the research community in the field of IoMT. It can serve as a valuable resource for researchers interested in working with H-IoT.

7. REFERENCES

[1] B. Pradhan, S. Bhattacharyya, and K. Pal, "IoT-Based Applications in Healthcare Devices," 2021, Hindawi Limited. doi: 10.1155/2021/6632599.

[2] Research and Markets, "Internet of Things(IoT) in Healthcare," 2019.

[3] J. T. Kelly, K. L. Campbell, E. Gong, and P. Scuffham, "The Internet of Things: impact and implications for healthcare delivery," 2022, doi: 10.2196/preprints.20135.

[4] A. Rejeb et al., "The Internet of Things (IoT) in healthcare: Taking stock and moving forward," Internet of Things, vol. 22, pp. 2542–6605, 2023, doi: 10.1016/j.iot.2023.100721.

[5] H Peng, Y. Tian, J. Kurths, L. Li, Y. Yang, and D. Wang, "Secure and energy-efficient data transmission system based on chaotic compressive sensing in body-to-body networks," IEEE Trans Biomed Circuits Syst, vol. 11, no. 3, pp. 558–573, 2017.

[6] F. Mirsparsa and A. Mirzaei, "IoT Application in Hospitals," Journal of Medical Education and Development, Sep. 2022, doi: 10.18502/JMED.V17I2.10616.

[7] A. Bajaj, M. Bhatnagar, and A. Chauhan, "Recent Trends in Internet of Medical Things: A Review," pp. 645–656, 2021, doi: 10.1007/978-981-15-5243-4_61.

[8] Z. Ali, M. S. Hossain, G. Muhammad, and A. K. Sangaiah,

"An intelligent healthcare system for detection and classification to discriminate vocal fold disorders," Future Generation Computer Systems, vol. 85, pp. 19–28, Aug. 2018, doi: 10.1016/J.FUTURE.2018.02.021.

[9] Cynerio, "The State of Healthcare IoT Device Security 2022." Accessed: Jan. 12, 2024. [Online]. Available: https://www.cynerio.com/landing-pages/the-state-of-healthcare-iot-device-security-2022

[10] S. Prakash Dash, "The Impact of IoT in Healthcare: Global Technological Change & The Roadmap to a Networked Architecture in India," 2020. doi: 10.1007/s41745-020-00208-y.

[11] Z. N. Aghdam, A. M. Rahmani, and M. Hosseinzadeh, "The Role of the Internet of Things in Healthcare: Future Trends and Challenges," Comput Methods Programs Biomed, vol. 199, p. 105903, Feb. 2021, doi: 10.1016/J.CMPB.2020.105903.

[12] R. Indrakumari, T. Poongodi, P. Suresh, and B. Balamurugan, "The growing role of internet of things in healthcare wearables," Emergence of Pharmaceutical Industry Growth with Industrial IoT Approach, pp. 163–194, Jan. 2019, doi: 10.1016/B978-0-12-819593-2.00006-6.

[13] J. Calvillo-Arbizu, I. Román-Martínez, and J. Reina-Tosina, "Internet of things in health: Requirements, issues, and gaps," Comput Methods Programs Biomed, vol. 208, Sep. 2021, doi: 10.1016/j.cmpb.2021.106231.

[14] Z. A. Nasiri, M. R. Amir, and H. Mehdi, "The Role of the Internet of Things in Healthcare: Future Trends and Challenges," 2020, Accessed: Mar. 26, 2022. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/33348073/

[15] R. Rayan, C. Tsagkaris, and R. Iryna, "The Internet of Things for Healthcare: Applications, Selected Cases and Challenges," in Studies in Computational Intelligence, vol. 933, Springer Science and Business Media Deutschland GmbH, 2021, pp. 1–15. doi: 10.1007/978-981-15-9897-5_1.

[16] Y. Shelke, "Technology Intelligence & IP Research INTERNET OF MEDICAL THINGS Thematic Report By," 2020.

[17] A. Heart Association, "What is High Blood Pressure?," 2021.

[18] González, M. Chen, and V. Leung, "Mobility Support for Health Monitoring at Home Using Wearable Sensors.," 2021.

[19] M. Nour and K. Polat, "Automatic Classification of Hypertension Types Based on Personal Features by Machine Learning Algorithms," 2020, doi: 10.1155/2020/2742781.

[20] Kumar and Clark, Clinical Medicine Eighth Edition, 8th ed. Wiley-Blackwell, 2021.

[21] T. Nguyen Gia et al., "Energy efficient fog-assisted IoT system for monitoring diabetic patients with cardiovascular disease," Future Generation Computer Systems, vol. 93, pp. 198–211, Apr. 2019, doi: 10.1016/J.FUTURE.2018.10.029.

[22] F. Soltanian et al., "On-body non-invasive glucose monitoring sensor based on high figure of merit (FoM) surface plasmonic microwave resonator," Scientific Reports |, vol. 13, p. 17527, 2023, doi: 10.1038/s41598-023-44435-6.

[23] R. Istepanian, "The potential of Internet of m-health Things 'm-IoT' for non-invasive glucose level sensing," in The 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Boston, MA, USA., 2020, pp. 5264–5266.

[24] V. S. Naresh, S. S. Pericherla, P. S. R. Murty, and S. Reddi, "Internet of things in healthcare: Architecture, applications, challenges, and solutions," Computer Systems Science and Engineering, vol. 35, no. 6, pp. 411–421, Nov. 2020, doi: 10.32604/CSSE.2020.35.411.

[25] R. Kavitha and C. Niranjana, "Smart Healthcare Monitoring System," 2019.

[26] M. Talal et al., "Smart Home-based IoT for Real-time and Secure Remote Health Monitoring of Triage and Priority System using Body Sensors: Multi-driven Systematic Review," J Med Syst, vol. 43, no. 3, Mar. 2019, doi: 10.1007/s10916-019-1158-z.

[27] G. Gopal, Suter-Crazzolara C., L. Toldo, and W. Eberhardt, "Digital transformation in healthcare—architectures of present and future information technologies," Clin. Chem. Lab. Med, pp. 328–335, 2019.

[28] P. Gope and T. Hwang, "BSN-Care: a secure IoT-based modern healthcare system using body sensor network," IEEE Sens, 2019.

[29] A. I. Paganelli et al., "Real-time data analysis in health monitoring systems: A comprehensive systematic literature review," Mar. 01, 2022, Academic Press Inc. doi: 10.1016/j.jbi.2022.104009.

[30] Y. Sattar and L. Chhabra, "Electrocardiogram," StatPearls, Jun. 2023, Accessed: Jan. 09, 2024. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK549803/

[31] M. A. Serhani, H. T. El Kassabi, H. Ismail, and A. N. Navaz, "ECG monitoring systems: Review, architecture, processes, and key challenges," Sensors (Switzerland), vol. 20, no. 6, Mar. 2020, doi: 10.3390/S20061796.

[32] T. Tekeste, "Ultra-low power QRS detection and ECG compression architecture for IoT healthcare devices ," IEEE Transactions on Circuits and Systems I: Regular Papers, pp. 669–679, 2020.

[33] J. Bathilde, "Continuous heart rate monitoring system as an IoT edge device ," in 2018 IEEE Sensors Applications Symposium (SAS), Mar. 2019, pp. 1–6.

[34] U. Acharya, "Application of deep convolutional neural network for automated detection of myocardial infarction using ECG signals," Inf Sci (N Y), pp. 196–198, 2017.

[35] Medscape, "Malaria: Practice Essentials, Background, Etiology." Accessed: Jan. 10, 2024. [Online]. Available: https://emedicine.medscape.com/article/221134-overview

[36] M. Švantner et al., "Statistical Study on Human Temperature Measurement by Infrared Thermography," Sensors 2022, Vol. 22, Page 8395, vol. 22, no. 21, p. 8395, Nov. 2022, doi: 10.3390/S22218395.

[37] H. Ota, M. Chao, and Y. Gao, "3D printed 'wearable' smart devices for real-time detection of core body temperature," ACS Sens, vol. 2, no. 7, pp. 990–997, 2019.

[38] S. Nookhao, V. Thananant, and T. Khunkhao, "Development of IoT Heartbeat and Body Temperature Monitoring System for Community Health Volunteer," 2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering, ECTI DAMT and NCON 2020, pp. 106–109, Mar. 2020, doi: 10.1109/ECTIDAMTNCON48261.2020.9090692.

[39] I. K. A. A. Aryanto, I. P. Wijaya, I. N. R. Hendrawan, and K. Y. E. Aryanto, "A Prototype IoT based Technology for Body Temperature Monitoring," 3rd International Conference on Cybernetics and Intelligent Systems, ICORIS 2021, 2021, doi: 10.1109/ICORIS52787.2021.9649631.

[40] "Constitution of the World Health Organization." Accessed: May 13, 2022. [Online]. Available: https://www.who.int/about/governance/constitution

[41] Zhu, "Smart healthcare in the era of internet-of-things," IEEE Consumer Electronics Magazine, pp. 26–30, 2019.

[42] M. Manchala, H. Bommala, V. R. Raju, and R. Pant, "IoT-Based System for Automated Accident Detection and Rescue," E3S Web of Conferences, vol. 430, Oct. 2023, doi: 10.1051/E3SCONF/202343001159.

[43] S. Vimal, Y. H. Robinson, S. Kadry, H. V. Long, and Y. Nam, "IoT Based Smart Health Monitoring with CNN Using Edge Computing 173," 2021, doi: 10.3966/160792642021012201017.

[44] K. Pradhan and P. Chawla, "Medical Internet of things using machine learning algorithms for lung cancer detection," Journal of Management Analytics, vol. 7, no. 4, pp. 591–623, 2020.

[45] Z. Liu, C. Yao, H. Yu, and T. Wu, "Deep reinforcement learning with its application for lung cancer detection in medical Internet of Things," Future Generation Computer Systems, vol. 97, pp. 1–9, 2019.

[46] M. Laspro, L. Groysman, A. N. Verzella, L. L. Kimberly, and R. L. Flores, "The Use of Virtual Reality in Surgical Training: Implications for Education, Patient Safety, and Global Health Equity," 2023, doi: 10.3390/surgeries4040061.

[47] S. Nazir, Y. Ali, N. Ullah, and I. García-Magariño, "Internet of Things for Healthcare Using Effects of Mobile Computing: A Systematic Literature Review," Wirel Commun Mob Comput, vol. 2019, 2019, doi: 10.1155/2019/5931315.

[48] H. Ahmadi, G. Arji, L. Shahmoradi, R. Safdari, M. Nilashi, and M. Alizadeh, "The application of internet of things in healthcare: a systematic literature review and classification," Univers Access Inf Soc, vol. 18, no. 4, pp. 837–869, Nov. 2020, doi: 10.1007/S10209-018-0618-4/TABLES/6.

[49] C.-A. Jorge, R.-M. Isabel, and R.-T. Javier, "Internet of things in health: Requirements, issues, and gaps," Comput Methods Programs Biomed, p. 106231, Sep. 2021, doi: 10.1016/J.CMPB.2021.106231.

[50] P. Ratta, A. Kaur, S. Sharma, M. Shabaz, and G. Dhiman, "Application of Blockchain and Internet of Things in Healthcare and Medical Sector: Applications, Challenges, and Future Perspectives," 2021, doi: 10.1155/2021/7608296.

[51] B. Al-Shargabi and S. Abuarqoub, "IoT-enabled healthcare: Benefits, issues and challenges," ACM International Conference Proceeding Series, Nov. 2020, doi: 10.1145/3440749.3442596.

[52] M. Kumar et al., "Healthcare Internet of Things (H-IoT): Current Trends, Future Prospects, Applications, Challenges, and Security Issues," 2023, doi: 10.3390/electronics12092050.

[53] S. P. Amaraweera and M. N. Halgamuge, "Internet of Things in the Healthcare Sector: Overview of Security and Privacy Issues," Security, Privacy and Trust in the IoT Environment, pp. 153–179, 2019, doi: 10.1007/978-3-030-18075-1_8.

[54] P. Panchatcharam and S. Vivekanandan, "Internet of Things (IOT) in Healthcare – Smart Health and Surveillance, Architectures, Security Analysis and Data Transfer: A Review," https://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/IJSI.2019040103, vol. 7, no. 2, pp. 21–40, Jan. 2021, doi: 10.4018/IJSI.2019040103.

[55] R. Somasundaram and M. Thirugnanam, "Review of security challenges in healthcare internet of things," Wireless Networks 2020 27:8, vol. 27, no. 8, pp. 5503–5509, May 2020, doi: 10.1007/S11276-020-02340-0.

[56] D. N. Le, L. Le Tuan, and M. N. Dang Tuan, "Smart-building management system: An Internet-of-Things (IoT) application business model in Vietnam," Technol Forecast Soc Change, vol. 141, pp. 22–35, Apr. 2019, doi: 10.1016/J.TECHFORE.2019.01.002.

[57] S. Mohapatra and P. K. Sahoo, "Internet of Medical Things: Applications and Research Issues in Healthcare Monitoring," pp. 1–31, 2022, doi: 10.1007/978-3-030-91096-9_1.

[58] S. Ketu and P. K. Mishra, "Internet of Healthcare Things: A contemporary survey," Journal of Network and Computer Applications, vol. 192, Oct. 2021, doi: 10.1016/j.jnca.2021.103179.

[59] Adril, "IoT in healthcare: applications, benefits, and challenges." Accessed: Jan. 09, 2024. [Online]. Available: https://stfalcon.com/en/blog/post/iot-in-healthcare-benefits-challenges

[60] L. Minh Dang, M. Jalil Piran, D. Han, K. Min, and H. Moon, "electronics A Survey on Internet of Things and Cloud Computing for Healthcare," 2020, doi: 10.3390/electronics8070768.

[61] H. Habibzadeh, K. Dinesh, O. Rajabi Shishvan, A. Boggio-Dandry, G. Sharma, and T. Soyata, "A Survey of Healthcare Internet-of-Things (HIoT): A Clinical Perspective," IEEE Internet Things J, vol. 7, no. 1, pp. 53–71, Jan. 2020, doi: 10.1109/JIOT.2019.2946359.

[62] M. Javaid, A. Haleem, R. P. Singh, S. Rab, M. I. Ul Haq, and A. Raina, "Internet of Things in the global healthcare sector: Significance, applications, and barriers," International Journal of Intelligent Networks, vol. 3, pp. 165–175, Jan. 2022, doi: 10.1016/J.IJIN.2022.10.002.