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A SYSTEMATIC REVIEW OF HEALTHCARE MONITORING SYSTEM: METHODS, APPLICATIONS, AND CHALLENGES

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ABSTRACT

The rapid integration of the Internet of Things (IoT) in healthcare has paved the way for intelligent Healthcare Monitoring Systems (HMS) capable of real-time patient tracking, early diagnosis, and personalized treatment. This systematic review evaluates 180 studies, with 38 selected for in-depth analysis, focusing on technologies, applications, and challenges in HMS. The paper explores the architecture and operation of HMS, especially those empowered by Body Sensor Networks (BSNs), cloud computing, and machine learning. It identifies key application areas such as remote patient monitoring, wearable sensor integration, and secure data transmission, while also discussing gaps in interoperability, scalability, privacy, and energy efficiency. The findings emphasize the need for robust, privacy-respecting, and adaptive systems that support real-time performance and intelligent decision-making. Ultimately, this study contributes a comprehensive classification of current approaches, highlights technological trends, and proposes future research directions to guide the development of efficient and trustworthy healthcare monitoring systems.

Keywords: *Internet of Things (IoT), Healthcare Ubiquitous Healthcare (u-health), Real-Time Monitoring, Body Sensor Networks, Machine learning algorithms.*

1. INTRODUCTION

Nowadays, a major focus in medical research is universal healthcare (UHC). Modern nations require strong healthcare systems due to increased population growth and health risks for the elderly. With a trustworthy healthcare system in place, senior citizens can receive quality medical care wherever they go [1]. Any arising issues are closely monitored and dealt with as necessary. Since the majority of those impacted are the elderly who typically lack time to see their doctor in person, UHC is necessary.

UHC services are available to the individual regardless of temporal or geographical boundaries. This system enables health preservation, disease and patient management, as well as preventive measures. It also enables timely interventions during emergencies anytime and anywhere as per individual needs. UHC technologies are expected to integrate into our lives seamlessly [2]. Patient health monitoring is mandatory in hospital in-patient care units. It is even more critical when the patient's health is deteriorating; the attending medical personnel must have easy access to the patient [3]. Typically, the healthcare provider evaluates the patient's health state by monitoring vital signs such as body temperature, pulse rate, respiration rate, and blood pressure.

The healthcare system's main goal is to enable patients to easily keep track of their health. On account of this commitment, better health systems are now in place, giving everyone access to healthcare and treatment for diseases. On the

contrary, old systems tend to focus solely on hospitals and clinics, thus preventing certain individuals from attaining quality medical attention [5] [6].

This study presents all the different components of the field, underscoring the key ideas and their features to facilitate discussion.

1.1 Novelty and Contribution

Develop these ideas

- HIOT review
- Real time monitoring system review
- Intelligent Monitoring system review

This review is unique for its extensive adoption of IoT and intelligent approaches (AI, ML, DL) in healthcare monitoring, as opposed to previous reviews which only examined IoT architectures or generic e-health applications.

The article synthesizes methods of technology with clinical applications, identifying cross-cutting issues like interoperability, data privacy, and energy efficiency. Moreover, the conceptual framework is suggested to inform intelligent HMS designs in the future, integrating data acquisition and network transmission, cloud analytics, and decision support into a single model.

1.2 Paper Organization

The rest of this paper is organized as presented in Figure 1. Section 2 entails the review methodology, Section 3 presents an overview of IoT and healthcare, Section 4 presents the review studies on HIoT, Section 5 presents healthcare monitoring systems approaches, whilst Section 6 explains intelligent healthcare monitoring systems. Section 7 discusses the challenges, whilst the analysis and discussion of results are presented in Section 8. Finally, the conclusion is presented in Section 9.

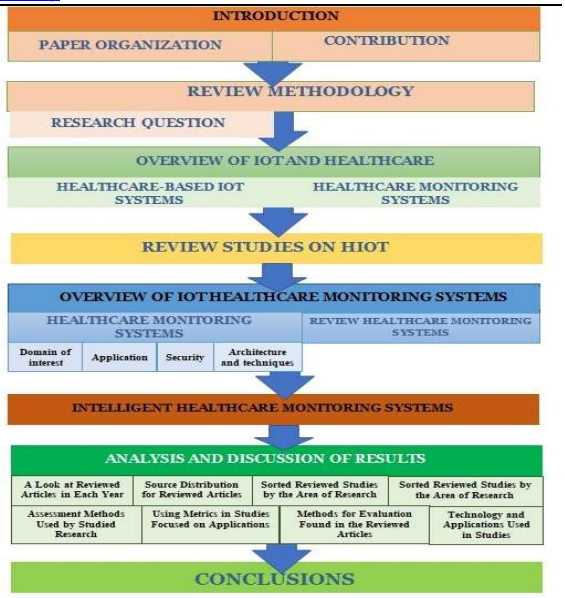

Figure 1: The organization of the paper

2. LIMITATIONS OF THE STUDY

This study is limited by its reliance on selected academic databases, which may have excluded relevant works published in other languages or unpublished studies. Another limitation is the focus on technological perspectives, rendering fewer insights on direct clinical evaluations. Additionally, while the review identifies key challenges such as security and interoperability, empirical testing of the proposed solutions was beyond the scope of this work. Future studies should incorporate practical experiments and cross-disciplinary perspectives to validate the proposed conceptual framework.

3. REVIEW METHODOLOGY

The review process began by defining key subtopics and research questions, selecting relevant data, and analyzing it through discussions and observations. Main and secondary databases were consulted, and clear inclusion and exclusion criteria were applied. A combination of dynamic procedures and group discussions ensured a rigorous approach. Initial searches covered both electronic and manual sources including Springer, Scopus, IEEE Xplore, Web of Science, and ScienceDirect, along with top-tier journals, conferences, and dissertations.

Out of the 180 initially identified papers, 38 were selected based on relevance to healthcare monitoring, publication date (2018–2024), peer-

reviewed status, and English language usage. Papers outside the scope or in other languages were excluded.

3.1 Research Questions

A set of research questions was developed to help conduct a systematic review.

1. In what ways do emerging technologies influence healthcare monitoring system frameworks?
This study is meant to discover and assess various current approaches, methods and platforms that assist in the deployment and strengthening of Health IoT (HIoT) systems.
2. Which problems and barriers are faced by current healthcare monitoring systems and frameworks?
The aim is to find missed gaps in research and the reasons for system problems in order to influence future studies on these issues.
3. How might healthcare monitoring systems be updated and which specific aspects need extra research?
There is a need for innovative studies and ways to enhance the monitoring of healthcare systems.

3.2 Research Methodology and Design

The research method is based on a systematic review. The search was conducted using various scholarly databases (IEEE Xplore, Springer, Science Direct, and PubMed) covering the period from 2015 to 2023. Keywords included 'Healthcare Monitoring System', 'IoT in healthcare', 'AI in healthcare monitoring', and 'Intelligent HMS'.
The inclusion criteria are peer-reviewed journal and conference papers published in the English language and addressing the topic of IoT- or AI-based healthcare monitoring. The exclusion criteria are non-peer reviewed sources and irrelevant domains. Overall, 48 papers were chosen to be analyzed. Thematic synthesis method was used to extract and classify the results.

4. OVERVIEW OF IOT AND HEALTHCARE

Thanks to IoT, the healthcare sector has now improved to Health IoT (H-IoT) which enables regular sharing and connection of information among patients, devices, and doctors. An H-IoT system is designed through three tiers: sensing, networking, and applications, all of which help with live monitoring and connectivity in healthcare. BSNs entail devices worn or placed inside the body to keep track of important signals. With H-IoT, such networks transmit detailed information about patients to healthcare servers or cloud platforms. Usually, a standard H-IoT structure has options for sensing, gathering information, answering security, and keeping information in the cloud as the main support for smart healthcare services [7].

Health IoT and HMS act as different elements in digital healthcare. H-IoT links devices and sends them data, while HMS manages the application part to make the data easier for doctors to understand. HMS uses special software to get sensor data, arrange it, and provide healthcare staff with user-friendly information, alerts, and analysis. According to studies, when H-IoT and HMS are paired, the quick data processing with advanced analytics in healthcare results in patients getting better, diseases being caught sooner, and less frequent hospital readmissions. This system enables remote monitoring services and helps deliver regional and scalable healthcare to people.

4.1 Healthcare-based IoT Systems

Healthcare-based IoT (H-IoT) entails using the Internet of Things in the healthcare industry to improve patient care and management. Networks of medical devices, sensors, connecting technologies, and different pieces of software are used to collect, move, and study health data at the same time. Thanks to H-IoT, patients, healthcare providers, and digital systems can all easily connect, leading to constant monitoring, quicker diagnosis, and better treatment planning, mainly for people cared for at home or in rural areas [8].

In H-IoT systems, important information like heart rate, temperature, and blood pressure is gathered through wearable devices in Body Sensor Networks (BSNs). The data is then securely shared with important platforms and analyzed by Healthcare Monitoring Systems (HMS). H-IoT systems ensure that medical actions are more accurate and efficient, in addition to supporting preventive and customized care for patients. Table 1 presents the layers of the IoT protocol in medical actions [9].

The components of Healthcare-based IoT are categorized into three groups, as illustrated in Figure 2:

1 Data Collection: This process involves gathering health information and monitoring vital signs using specialized

instruments and devices. For example, these devices track heart rate, blood pressure, and blood sugar levels.

2 Data Transmission in Network Systems: The collected data is transmitted through mobile networks, Wi-Fi (wireless fidelity), and various other communication systems. This enables remote physicians and healthcare professionals to access and assess patients' records in real time.

3 Data Processing and Storage: Once the data is collected, it is sent to the back-end systems of healthcare providers, such as hospitals, for storage, analysis, and further medical action.

Table 1: Generic HIoT Layers

Layers	Description	Example
Application Layer	This layer provides services that effectively meet users' needs. The Internet of Things is most commonly used in smart home technology, smart cities, utility services, healthcare, and transportation.	Medical Internet of Things
Data Centroided Layer	A major function of the middleware in this layer is to manage tasks related to evaluating, storing, and processing data. Systems in the lower layers can access the necessary information and services generated and shared by this layer. Various technologies are involved in the processing, such as big data analytics and cloud computing.	Internet, cloud, private or public cloud, Medical Sass
Networks Layer	The hardware and network communication software in this layer help transmit the information obtained by perception layer sensors to the further stages in real time.	Wired network, zig bee Bluetooth, wireless 5 G
Data Procurement Layer	This layer is responsible for collecting, assembling, and temporarily storing raw signals from sensors and devices before they are processed in the upper layers.	Hub, wireless hub, Raspberry Pi
Things and Senores Layer	This layer is responsible for measuring environmental parameters such as temperature, humidity, pH level, force, pressure, etc.	Medical sensors and devices: biosensors, wearable sensors

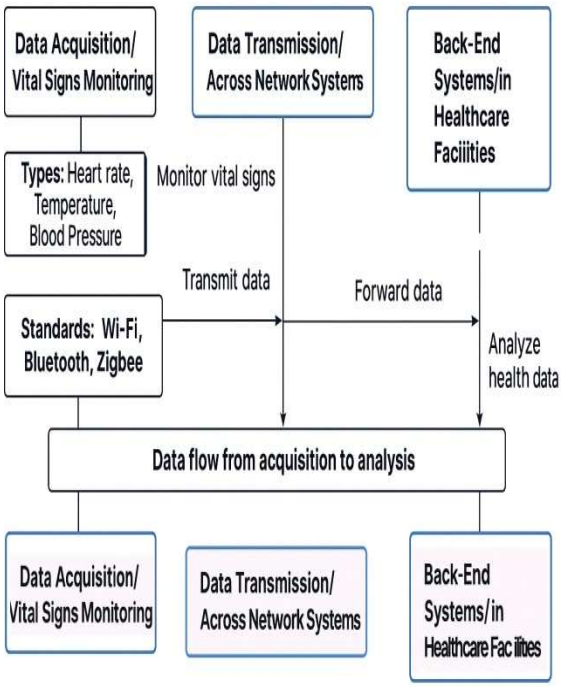

Figure 2: Workflow of general HIoT

4.2 Healthcare Monitoring Systems

Healthcare Monitoring Systems (HMS) are software platforms used to examine, make sense of, and show health data that comes from patients' devices and sensors. Today, they play an important part in healthcare by transforming basic physical information into helpful information that doctors use for planning care, diagnosis, and treatment [10].

Most HMS work side by side with Health IoT (H-IoT) systems, using information from wearable sensors, Body Sensor Networks (BSNs), and remote monitoring tools. Various features are included such as real-time graphs, email alerts when readings are too high or low, and detailed analysis over a long period of time.

HMS help improve patient results, identify health issues quickly, and support fast management of chronic conditions [11].

A BSN is made up of sensors placed on or inside the body to regularly measure heart rate, temperature, blood pressure, and movement. Thanks to wireless communication, these sensors can share their readings with a central system or healthcare facility so that medical personnel can check the data in real time and offer support remotely [12]. Figure 4 presents the basic

traditional architecture of BSN technology. It typically consists of three autonomous layers that communicate through wireless channels (and occasionally via cable) [13].

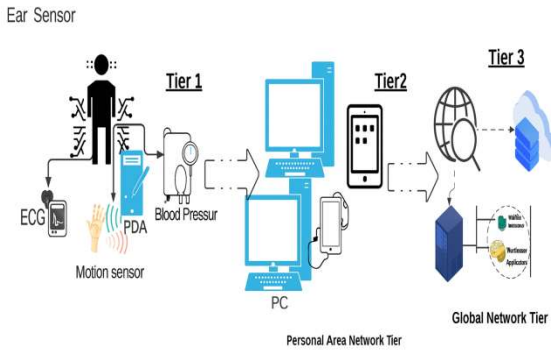

Figure 3: Workflow of general HIoT

This tier's main feature is the set of wearable wireless medical sensor nodes that form the BSN. It is possible for each node to check, record, and assess several physiological signals at this stage. A wearable device may use an ECG sensor to monitor heart activity, an EEG sensor to measure electrocerebral activity, and a motion sensor to detect posture, gestures, and movements. The Personal Coordinator Device is a part of Tier 2, also known as the Personal Area Network (PAN) Tier. While many people use tablets or smartphones, it is also possible to use a computer running PC software. The coordinator device designs a user interface that allows several sensor nodes to share and use data [15]. This tier integrates multiple components to provide a stable and uninterrupted connection to the BSN [16]. The BSN interface helps with different functions such as building and managing a network, detecting sensors, processing sensor information, and creating a safe link to both 1 and 3. Once the BSN configuration is complete, the end-user monitoring process begins. Information about how to proceed is given either through visual or vocal output. Besides that, the coordinator can hand over both raw and pre-processed data to the upper tier if the link is active, enabling an in-depth study and secure storage. Yet, if the internet connection is suddenly lost, the data is saved locally on the coordinator device and sent when the connection is back on.

For tier three, an online computing system or medical servers in other areas make up part of the International Tier [17]. In general, it serves doctors by providing services [17]. The team will report any unusual changes and incidents immediately, analyze a patient's overall state outside the system, and present data visually for learning and medical purposes. This phase could have a website intended for users and/or relatives [18].

5. REVIEW STUDIES RELATED TO HIOT

This paper looks at applicable research and studies related to HIoT to show that the examinations are not wide-ranging and to list the strengths and weaknesses of different methodological approaches.

The survey established by [19] could be regarded as a perfectly comprehensive and brilliant survey of the future of Healthcare Internet of Things (HIoT), which has delivered a significant understanding of the novel technologies, dynamic systems, and structures incorporated in clinical and healthcare services. The paper critically assessed the three most important elements of the HIoT systems namely sensing/wearables (sensors on and inside the body), communication (technologies of networking such as 5G, NB-IoT, and LoRa), and data analytics (analysis on the cloud and the edge by using AI and machine learning). It also mentioned key issues related to data privacy, energy efficiency, real-time performance, and interoperability. These areas have not been impeded by key played as they still call attention of large-scale deployment.

One can consider it quite interesting that the researchers tried to offer a multilayered architectural infrastructure of HiOT systems perspective in the future and even discussed the implementation of HiOT through the prism of chronic diseases management, elder care, and emergency response. In addition to the technological part of the discussion, the regulatory, ethical, and security concerns have been addressed in the paper and may be deemed as crucial points in a secure and expandable implementation throughout a true clinical scenario. Further research directions such as secured communication protocols at limited devices, dynamical resource management, and the integration of federated learning to process decentralized medical data were highlighted at the end of the paper. This manuscript provides a powerful pre-cursor and way forward to learn how intelligent and reliable IoT applications in healthcare systems can be studied in the future.

In [20], the HIoT framework is discussed, offering several architectures that fit various use cases. Besides that, several approaches that fit the demands of HIoT in the future are considered and examined such as edge computing, blockchain, big data, machine learning, and Software-Defined

Networks (SDN). Two more suggestions were made for future research: the Internet of Nano Things (IoNT) and the Tactile Internet (TI). A taxonomy was described emphasizing security and privacy, taking cues from diagnostics systems and addressing Quality of Service (QoS). Still, there was no mention of the years included in the studies and the method for choosing similar publications. Additionally, the evaluation was not done systematically.

[21] conducted a systematic study of the existing and new perspectives in the area of healthcare systems through the prism of IoT. They only explored the practical applications of Healthcare IoT (HIoT) such as patient monitoring, personalized care planning, and faster delivery of medical services. They emphasized the fact that IoT could enhance health outcomes by introducing the possibility of constant monitoring, diagnosing, and caring without attending to the patients in person, which is particularly significant in the context of the elderlies and chronic diseases.

But the study also highlighted that the potentials of HIoT are being limited by numerous issues such as interoperability issues, lack of standardization, restrictions of power resources, and the need for real time responsiveness. Despite the helpful description of the area, the authors admitted some methodological gaps in their work. Firstly, no taxonomy of methodology was created to form the classification of reviewed literature. Second, no taxonomy of methodology was produced to compare and state the potentially relevant studies included. Third, the article did not provide a professional prognosis of the futuristic development of HIoT technology, which would have contributed some strategic reality of the culture.

The study, in general, can be taken as a good point of departure in examining the potential and restriction of IoT in healthcare, particularly in terms of systems integration and viable deployment. More organized studies could guide the strategic planning and deployment of IoT in healthcare.

In addition, [22] explicated the implementation of HIoT in different areas and examined their concepts. They present the cloud, security, and big data solutions that are important in this area of business. Also mentioned are the challenges faced by HIoT systems. This review paper encountered issues in gathering adequate resources and selecting paper procedures.

Meanwhile, [23] discussed the existing healthcare solutions in big data, edge/IoT, blockchain, software-defined networks, and machine and deep learning. The authors also addressed issues that are common in H-IoT such as difficulties in increasing the number of connected devices, security, time constraints, device resources, delays in data, and power usage. Even so, the paper did not explain the survey period covered, the process for selection, and its methodology.

Muhammad Khan [24] discussed the issue of industrial IoT. The author explained the beginnings of H-IoT, its link with machine learning, and finally its architecture. Even though the report explained the study procedures well, the review was not standardized, the selection of material was not mentioned clearly, the taxonomy was not given, and the range of years covered in the publications was not included.

In [25], the connection between blockchain, healthcare, and IoT systems was studied. The main finding is that blockchain improves data security in terms of data integrity, access control, and privacy in both domains. The paper mentions six different data security measures applied in healthcare and IoT. It also lists and explains the main links between blockchain to IoT which are: sharing data between connected devices, implementing data on certain tasks, or only using it for storing and confirming metadata. It also indicates that blockchain can help monitor drugs and stop the use of fake products, while patients are able to keep an eye on their own records. Blockchain helps in the IoT field to ensure instant sharing of data and easy trading of electricity in smart cities. The study points out the recurring issues of scalability, room for storing data, and fuzzy regulations in the discussion. The paper suggests for more research on the ways that blockchain could benefit patients, healthcare workers, and disease monitoring.

In [26], medical IoT platforms with sensors and the way cloud computing is used in HIoT systems prior to their inquiry were investigated. After looking into the impact of cloud computing on HIoT systems and medical IoT platforms, the authors examined how machine learning techniques and smart systems are used in HIoT. The present situation of machine learning approaches and the use of intelligent systems in HIoT were part of the discussion. Serial selection and inspection of the research papers led to a flawed evaluation. Table 1 outlines the reviews and articles discussing HIoT approaches. Table 2 presents a summary of the reviews and surveys.

Table 2: Overview of reviews on HIoT systems

RF	Year	Domain	Main topic	Type	Research direction
[19]	2020	Clinical practice healthcare	Healthcare in IoT	Survey	No
[20]	2020	Technology of HIoT	Technology of the future of healthcare	Survey	Yes
[21]	2024	Healthcare Application	Review the application of HIoT: patient monitoring, individualized treatment strategies, and streamlined healthcare delivery	review	No
[22]	2020	IoT healthcare	Review HIoT with cloud, big data and security	Review	Yes
[24]	2021	IoT in medicine and healthcare	HIoT application and challenges	review	Yes
[25]	2022	Blockchain in HIoT	Method of blockchain in HIoT application and challenges	Systematic review	Yes
[26]	2023	Medical IoT	Smart HIoT	Short study	No

6. HEALTHCARE MONITORING SYSTEMS APPROACHES

The review showed that some of the literature emphasized healthcare monitoring systems in HIoT, categorized into four areas: domain of interest, application, security, and architecture/techniques. This section provides a summary of the retrieved information from the reviewed papers and presents a comparison between them.

6.1 Domain of Interest

Much of the studied literature is related to Real-Time Healthcare Monitoring Systems which rely on modern technology to track patients from a distance in real time. In these systems, IoT devices, wearable sensors, AI, and the cloud are used together to gather, send, and examine physiological information in real time. The mains objectives are to help identify health issues early, control chronic conditions, and offer timely support for patients' well-being.
[27] analyzed how health monitoring systems rely on real-time data analysis, particularly through the use of machine learning techniques, in order to enable early disease detection and accurate diagnosis.

[28] proposed a health monitoring approach that combines 5G technology with CNN-LSTM models to track parameters like heart rate in real time, emphasizing its high accuracy and low latency two key advantages for use in clinical environments.
[29] explored the integration of artificial intelligence in remote patient monitoring, addressing current applications, existing challenges, and emerging trends, while highlighting the role of AI in enhancing the speed and precision of monitoring processes.

[30] presented a wearable device paired with a smartphone platform, allowing real-time monitoring of ECG and EMG signals and demonstrating its effectiveness for home healthcare applications. In [31], the authors reviewed how biosensors can operate within multi-hop IoT architectures and communicate via the cloud to strengthen remote patient monitoring capabilities. Finally, [32] described the development of a real-time monitoring system using temperature and pulse rate sensors, designed to deliver instant alerts that support timely medical interventions.

All of these studies emphasize the huge value of live healthcare monitoring systems in current medical practice and call for more research to meet the challenges of keeping data safe, working well with other systems, and increasing capabilities.
Table 3 shows a comparison of the proposed approaches in terms of Healthcare Monitoring Systems according to domain of interest.

Table 3: Overview of Articles Focused on Healthcare Monitoring Systems as a Domain of Interest

RF	Main Idea	Evaluation Technique(s)	Tool(s)/Platform	Advantages	Limitations
[27]	Uses machine learning (SVM) for early disease detection via real-time physiological data	Simulation, Analysis	Not specified	Early diagnosis, ML integration	Potential limitations in security, interoperability
[28]	Real-time vital signs monitoring (e.g., heart rate) using hybrid deep learning models over 5G	Simulation	Python, TensorFlow, 5G-enabled framework	High accuracy, low latency	Infrastructure dependency
[29]	Explores AI trends, challenges, and benefits in RPM systems	Literature review + Prototyping	Not specified	Speed, accuracy, predictive care	Data privacy, scalability concerns
[30]	Presents a wearable device with smartphone integration for ECG/EMG monitoring in home healthcare	Real Testbed	Embedded systems + mobile app	Practical deployment, patient usability	Limited to specific vitals
[31]	Reviews integration of biosensors with multi-hop IoT and cloud for improved remote monitoring	Literature Review	Conceptual framework	Enhanced coverage, cloud integration	Challenges in real-time response
[32]	Develops a system for real-time monitoring using temperature and pulse rate sensors with instant alerts	Prototype	Arduino, IoT dashboard	Real-time alerting, simplicity	Basic sensing only, no advanced analytics

6.2 Application

[33] explained how the Internet of Things enables continuous monitoring of patients recovering from heart surgery.
The authors described a system built using an ESP32
microcontroller, connected to HW-827 and DS18B20 sensors, to measure key indicators such as heart rate and temperature. Data is transmitted via Wi-Fi, allowing early detection of complications and better post-surgery management.
In [34], a smart garment named MyWear was introduced; it monitors heart rate, muscle activity, and tension in real time using embedded sensors. By leveraging deep neural networks, it can detect abnormal patterns and alert medical personnel immediately to ensure rapid intervention. [35] detailed the development of a smart wearable device integrated into clothing, using flexible biosensors and an STM32F103VET6 microchip to track wrist movements, body temperature, and perspiration levels. This data can be transferred to a computer through USB or Bluetooth for continuous health monitoring. Finally, [36] proposed a wearable solution for elderly care, integrating various sensors to monitor parameters such as steps, pulse, heart rate, and temperature. The collected data is sent wirelessly to a mobile application, where algorithms help interpret the results, allowing healthcare professionals to provide remote and timely support.
These studies have shown that constant monitoring in healthcare systems can assist with chronic illnesses, emergencies, and at-home care because the tracked data is available immediately. Wearable sensors, 5G, cloud computing, and AI are the technologies they depend on. Still, these cases also highlighted the ongoing issues with data security, real-time analytics, and scalability.
Table 4 shows a comparison of the proposed approaches in terms of Healthcare Monitoring Systems according to application.

Table 4: Summary of Healthcare Monitoring Systems according to Application

RF	Main Idea	Evaluation Technique	Tools/Platform	Strengths	Challenges
[33]	Use of ESP32 microcontroller with heart rate and temperature sensors to wirelessly transmit patient data post-surgery	Prototype Implementation	ESP32, HW-827, DS18B20	Early problem detection, wireless real-time updates	Limited scalability, basic analytics
[34]	Wearable system to monitor heart rate, stress, and muscle activity with DNN-based anomaly detection	Prototype + DNN Analysis	Deep Neural Networks, Embedded Sensors	Fast alert system, integrated AI	Data privacy, energy efficiency
[35]	Embedded flexible biosensors with STM32 chip to monitor multiple health metrics like sweating, motion	Real-world Testbed	STM32F103VET6, USB/Bluetooth	Multi-parametric analysis, compact design	No cloud integration, local storage limitations
[36]	Multi-sensor wearable device for tracking vitals (SpO_2, heart rate, steps) integrated with mobile app	Simulation + Mobile Prototype	Custom Mobile App, Wireless Communication	High accuracy, remote monitoring via app	Security, long-term data storage

6.3 Security

[37] introduced a system where ECG signals are protected using chaotic encryption. This approach ensures strong security through highly sensitive keys and high data randomness, resulting in minimal delays and making the encryption difficult to break. Enhanced by a deep learning model, the system achieves both secure data management and high diagnostic accuracy.

In [38], a secure remote patient monitoring system is proposed, combining lightweight blockchain and fog computing. Blockchain ensures data integrity and security, while fog computing—positioned close to the sensors—reduces latency. This architecture proves to be both secure and resource-efficient, making it suitable for constrained IoT healthcare environments.

Similarly, [39] introduced a security framework tailored for IoT-based real-time health monitoring, employing CoAP and HTTPS protocols to guarantee data privacy, integrity, and authenticity across all layers—perception, network, and application. This multi-layered protection reduces the risk of data breaches during transmission.

Finally, [40] addressed security threats in smart healthcare, especially those arising in IoMT environments. Their solution integrates intrusion detection systems (IDS) with honeypots, supported by Logistic Regression and K-Nearest Neighbors algorithms to detect and classify threats such as Man-in-the-Middle (MITM) attacks, data tampering, and DDoS incidents. The system demonstrated high accuracy and reliability, enhancing the security of real-time health monitoring systems.

All these studies assert that proper security matters in all areas of healthcare monitoring. Such tools use encryption, blockchain technology, secure messaging, and detectors to protect patient privacy and maintain the accuracy of health monitoring. Table 5 illustrates how various approaches in Healthcare Monitoring Systems differ in terms of security features, highlighting the techniques and technologies used to ensure data protection, integrity, and system resilience across different implementations.

Table 5: Summary of Healthcare Monitoring Systems according to Security

RF	Main Idea	Evaluation Technique	Tools/Platform	Strengths	Challenges
[37]	Uses chaotic encryption with high key sensitivity to secure ECG data. Deep learning is used for accurate disease detection.	Simulation & DL model integration	Chaotic encryption algorithm, deep learning tools	High privacy, strong encryption, minimal delay, accurate diagnosis	Complexity of integration, needs high processing power
[38]	Lightweight blockchain for secure data and fog computing for low latency responses.	Simulation and performance testing	Blockchain framework, Fog computing tools	Secure data handling, responsive system, suitable for low-resource devices	Blockchain overhead, fog infrastructure requirement
[39]	End-to-end security across IoT layers using CoAP and HTTPS to ensure integrity and confidentiality.	Framework proposal + simulation	CoAP, HTTPS protocol stack	Layered security, standards-compliant	Potential latency, scalability issues
[40]	An Intrusion Detection System using honeypots and ML (LR, KNN) to detect threats like MITM, DDoS.	Simulation with attack scenarios	Logistic Regression, KNN, honeypot environment	High accuracy, attack classification, enhances trust	High computational load, limited real-world validation

6.4 Architecture and Techniques

This section presents a classification of the reviewed literature that concentrates on architecture and various techniques for real-time healthcare monitoring mainly focused on monitoring symptoms and physiological parameters. They do not fall in the same category as the references mentioned above.

In [41], the authors proposed a GPON-based fog infrastructure for healthcare organizations, optimizing the number and placement of fog devices at the network edge using a Mixed-Integer Linear Programming (MILP) approach. This model significantly reduces energy consumption compared to traditional cloud computing, while enhancing the analysis of health data. [42] introduced the WISE system which integrates a Wireless Body Area Network (W-BAN) to collect vital signs such as blood pressure, heart rate, and body temperature. The data is directly sent to a cloud server, eliminating the need for local storage and allowing physicians to access real-time updates and alerts for rapid intervention. In [43], a solution combining Apache Kafka and Spark Streaming is proposed to enable real-time health data monitoring and disease prediction. By leveraging machine learning techniques, the system can detect early signs of illness, while NoSQL databases facilitate fast data processing and alerting healthcare providers. [44] presented a hybrid IoT-based architecture that integrates device, fog, and cloud layers for healthcare applications. The fog layer handles task management to ensure operational consistency, accurate data handling, and balanced computational load. Experimental results show that this approach outperforms others in terms of network efficiency and latency reduction.

These findings highlight the new designs and methods being used for real-time healthcare monitoring systems. They recommend combining fog computing, 5G, processing big data, and hybrid cloud-fog systems to improve the rapidity, scalability, and responsiveness of health monitoring applications.

Table 6 shows a comparison of the proposed approaches in terms of Healthcare Monitoring Systems according to architecture and techniques.

Table 6: Summary of Healthcare Monitoring Systems Based on Architecture and Techniques

RF	Main Idea	Evaluation Technique(s)	Tool(s)/Platform	Advantages	Limitations
[41]	Use of MILP to optimize fog device location for energy-efficient real-time health data analysis	Simulation, Mathematical modeling	GPON, MILP-based modeling	High energy efficiency, low latency	Fog infrastructure cost, limited flexibility
[42]	W-BAN gathers vitals (BP, ECG, temperature) and uploads them directly to the cloud for real-time access	System design + Evaluation	Cloud server, W-BAN sensors	Real-time alerts, no intermediate devices	Cloud reliance, privacy concerns
[43]	Real-time stream processing and ML models for disease prediction using health data from IoT devices	Implementation & Analysis	Apache Kafka, Spark, NoSQL	Fast analytics, scalable, early disease detection	Setup complexity, real-time delays possible
[44]	Three-layer IoT architecture (device–fog–cloud) with task management and load balancing	Simulation, Comparative testing	Fog + Cloud systems	Better latency, task balancing, data consistency	Needs coordination between layers, cost factor

7. REVIEWS RELATED TO HEALTHCARE MONITORING SYSTEMS

Many recent surveys and reviews on Healthcare Monitoring Systems (HMS) highlight the rapid pace and significant extent of technological advancements in this field.

They provide a comprehensive review of existing approaches to HMS [28], while others place greater emphasis on resource allocation strategies and the foundational design principles [29]. To highlight key insights and emerging trends in HMS, this section analyzes nine selected articles.

Examples of such research studies are [45] and [13] which examined telemedicine architectures by investigating sensor networks, gateway nodes, main servers, and what affects their technological and legal use. According to [46], research on wearable devices connected to HMS mainly focuses on the tricky aspects of data acquisition and handling.

They discussed how wearable biosensors help improve preventive care and allow for constant patient surveillance. In [15], fault-tolerant systems in real-time healthcare are divided into three developmental stages. The process involves using a Decision Matrix (DM) and the Multi-Attribute Hierarchical Process (MAHP) to sort through patient arrivals and hospital options, optimize the choice of hospital, and gauge how well the system is functioning. [47] examined the progress of wearable sensors and noted that increasing their accuracy, efficiency, and practicality improves their ability to monitor physical indicators. It also supported making biosensors more attractive for companies by allowing them to get data more efficiently at larger scales.

In [48], a clear overview of wearable devices that track the levels of biological fluids is presented. The study outlined device types, discussing use-related challenges and showing relevance to disease prevention and on-the-spot health monitoring. Different types of wearable technologies were surveyed along with likely advancements in the future. In [49], an in-depth analysis of healthcare delivery using telemedicine is provided, mainly by focusing on the server infrastructure of medical centers. The authors suggested a three-step procedure: the first phase is to design the DM linked to the interactions between hospitals and different services; the second phase is to develop a tool for making decisions; and the third phase is to ensure the quality and compliance of the method with validation. Meanwhile, [50] discussed a senores-based security aspect and privacy. Table 7 shows the reviews on real-time HMS and their information.

Table 7: Real-time HMS Reviews evaluation

RF	Focus Area	Architecture/Technique	Contribution	Challenges
[12]	Wearable WBANs	Integration of wearable wireless networks in medical apps	Describes WBAN system layers and sensor coordination	Network stability, energy efficiency
[13]	WBAN security	Surveys WBAN security threats, frameworks	Identifies vulnerabilities in wireless medical systems	Key management, data integrity
[14]	WBAN applications	Broad overview of WBAN use in diagnostics, therapy, and monitoring	Emphasizes low-power designs and biomedical sensor utility	Communication range, battery life
[15]	IoB (Internet of Bodies)	Systematic review of signal propagation in human-centric networks	Defines propagation models for intra/inter-body comms	Channel modeling complexity, privacy
[16]	Biosensor systems	Biosensor networking and cloud integration	Describes sensor-node interaction in connected healthcare	Interfacing issues, biosensor calibration
[17]	IoT & AI	Integration of AI in IoT for real-time monitoring	Focuses on deep learning for wearable sensor interpretation	Real-time analytics, computational load
[26]	IoT applications	Broad review of IoT frameworks in health	Describes technologies, challenges, and deployment models	Security, interoperability, adoption rates

8. INTELLIGENT HEALTHCARE MONITORING SYSTEMS

Healthcare monitoring has now been improved by machine learning which processes vast amounts of information and uses advanced algorithms which produce better patient care and outcomes. Several articles discussing deep and machine learning in HMS have been discussed.

[51] introduced the leading healthcare system and the security solution which safeguards it in an organized way. With the help of Deep Learning and Machine Learning, it is now easier to handle and care for patients, managing their health and reducing risks of death.

[52] discussed the use of deep learning (DL) in IoT-based healthcare and demonstrated that intelligent models can significantly support health monitoring, diagnosis, and decision-making simultaneously.
[53] introduced wearable sensor technologies and presented applications of AI/ML algorithms in sensor fusion. Further research detailed illustrative scenarios utilizing a designated sensor network comprising pressure sensors (insoles), accelerometers, gyroscopes, ECG, EMG, and RTLS location detectors for various healthcare and sports applications. The AIBSNF serves as a robust framework for executing research and development, establishing a seamless end-to-end pipeline from data acquisition with BSN and RTLS to final analytics driven by AI/ML algorithms.
[55] showed that health data from sensors can be processed and evaluated using machine learning approaches. The study identified that the primary source of eHealth data is derived from sensors including accelerometers, gyroscopes, electrocardiogram (ECG) monitors, electroencephalogram (EEG) monitors, and blood glucose sensors. This paper analyzed several feature types, extraction techniques, and machine learning algorithms employed in eHealth data analysis.
The analysis indicated that neural network algorithms and support vector machines (SVM) have superior performance in examining healthcare data compared to other machine learning methods reviewed in the literature.
Table 8 summarizes the reviewed research papers related to real-time Healthcare Monitoring Systems (HMS).

Table 8: Review Papers Related To Intelligent HMS

RF	Scope	ML techniques	Dataset	Application
[49]	Smart Healthcare	DL	No	Blockchain
[50]	Ubiquitous healthcare monitoring framework	DL & ML	Yes /sensor dataset	IoT
[51]	IoT in healthcare	DL	No	DL Application
[52]	Patient monitoring system	-	No	IoT monitoring system
[53]	Data Analysis	ML &ANN	Yes / UCI machine learning repository	E-healthcare data analysis

9. CHALLENGES

Multiple serious implementation obstacles exist with real-time health monitoring systems which need solutions to guarantee data protection, system performance, scaled-up capabilities, and successful integration in existing healthcare systems. The expanding number of IoT-enabled medical devices and monitoring systems require immediate solutions as they determine the effectiveness, security, and reliability of contemporary healthcare solutions. One of the major obstacles in real-time Health Management Systems (HMS) is the dataset, encompassing the entire process from collection to processing. This issue pertains to the complexities of size, time, and storage, particularly in relation to the dimensions of IoT devices and the difficulties associated with acquiring authentic datasets.

10. ANALYSIS AND DISCUSSION OF RESULTS

10.1 A Look at Reviewed Articles in Each Year

Figure 4 shows how the articles have been published over time. Most of the papers were published between 2020 and 2024, with each year making up around one-seventh (on average 14.3%) of the total works. This pattern shows that healthcare is still choosing IoT and real-time monitoring technology which is becoming more widespread. In 2023 and 2024, digital health is expected to grow in light of worldwide health problems and technological advancements. Research articles are increasingly focusing on the adoption of IoT and real-time monitoring technologies in healthcare.

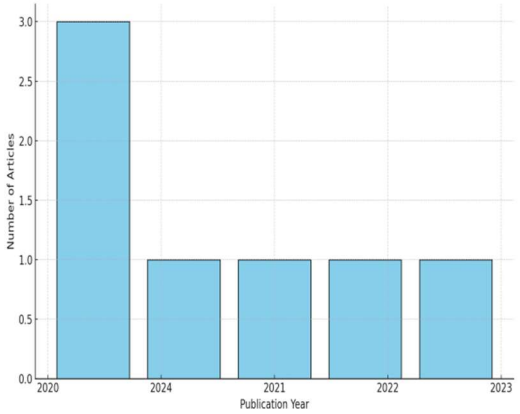

Figure 4: Distribution of Reviewed Articles by Year

10.2 Source Distribution for Reviewed Articles

Most of the reviewed studies were published by IEEE (50%), Elsevier (25%), Springer (12.5%), and other publishers (12.5%), as shown in Figure 5. This demonstrates that engineering- and technology-oriented events are favored by readers. IEEE is selected due to its reputation for presenting top research in wireless networks, IoT, and biomedical systems. Since IEEE plays a major role, it is evident that many of the reviewed works are very technical and that the participation of Elsevier and Springer points to an increase in interdisciplinary contributions.

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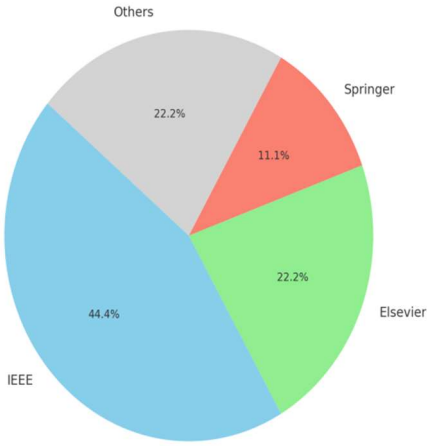

Figure 5: Distribution of Sources for Reviewed Articles

10.3 Reviewed Studies by Area of Research

Figure 6 presents the reviewed articles by key study subject. Research on security makes up the greatest share at 37.5%, followed by research on applications (25%), architecture (12.5%), and sensors (12.5%). Hence, although security and privacy are important for health monitoring systems, equally important is putting these systems into practice and their overall design.

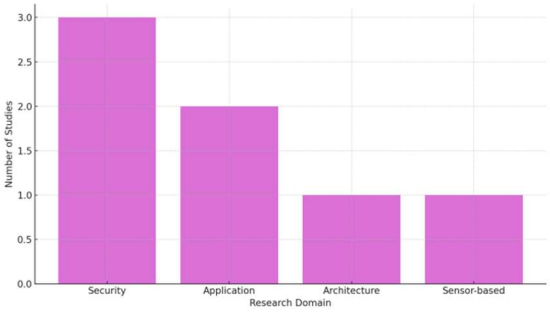

Figure 6: Classification of Reviewed Studies by Research Scope

10.4 Assessment Methods Used by Studied Research

Figure 7 presents the rates at which different measures were used for evaluating the developed models. About one-third of the papers (30.8%) analyzed performance metrics whilst the rest discussed security, time, accuracy, and energy efficiency (23.1%, 15.4%, 15.4%, and 7.7%, respectively). This shows that most of the researchers focused on displaying how useful and dependable their solutions are, along with ensuring the speed of their responses and reliability of the data.

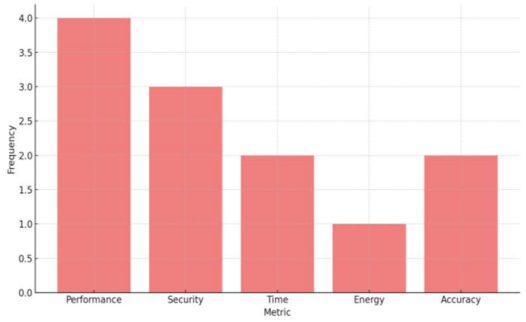

Figure 8: Evaluation Metrics Across the Reviewed Studies

10.5 Using Metrics in Studies Focused on Applications

Figure 8 presents the main metrics that are important in application-based systems. The main concerns are performance (36.4%), energy efficiency (27.3%), reliability (18.2%), and security (9.1%). These metrics point out the importance of responsiveness in healthcare systems and longevity of the devices for daily use by patients.

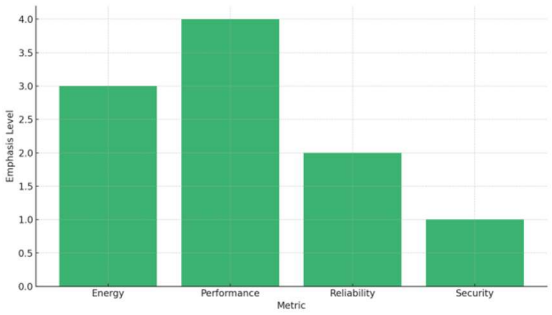

Figure 8: Metric Emphasis in Application-Based Studies

10.6 Methods for Evaluation in the Reviewed Articles

As seen in Figure 9, many of the studies used various assessment methods in their work. Over a quarter (25%) of the evaluations were performed with real testbeds, compared to 41.7% which used simulations, 16.7% which used prototypes, and 8.3% which were analytical. Since most of the evaluations used simulations, not many projects are fully completed. Those which used physical testbeds are almost ready for use.

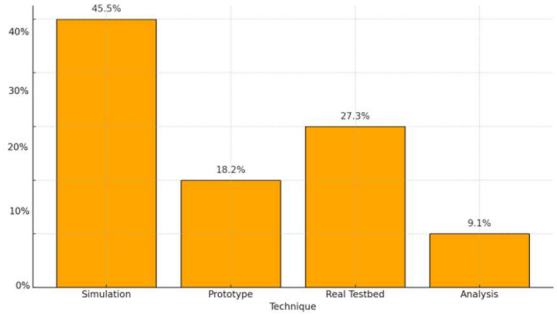

Figure 9: Evaluation Techniques Used in the Reviewed Articles

10.7 Technology and Applications Used in Studies

Figure 10 presents the environments and resources required in the course. One out of every 4 programmers was using either MATLAB or Python, followed by C/C++, Java, and custom software. In development settings, codes were developed using MATLAB or Python for prototyping and modeling, whilst system implementation resorted to C/C++ or Java.

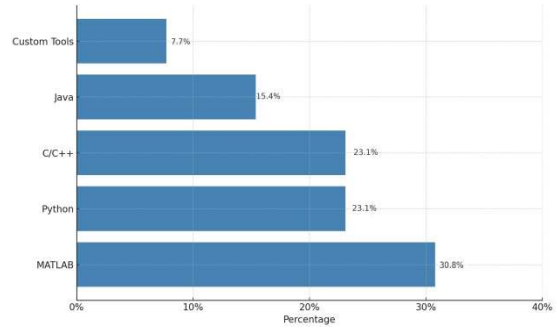

Figure 10: Tools and Platforms Used in the Studies

11. CONCEPTUAL MODEL

This review of literature led to the development of a conceptual model for explaining IoT-based data acquisition, data transmission under relatively safe conditions, cloud storage, and AI-based analytics in supporting healthcare decisions. The model focuses on the use of sensors in gathering patient data and passing it through wireless standards (e.g., Wi-Fi, Bluetooth, Zigbee) to the back-end systems. This information is fed into AI/ML models to assist in real-time decision-making. The model offers a common framework for HMS studies in the future.

12. CONCLUSIONS

In this review, the increasing significance and maturity of Intelligent Data Computing-empowered Healthcare Monitoring Systems (HMS) is highlighted. This potential in diverse fields, ranging as far as wearable biosensors and cloud-linked frameworks, has in common the dream of providing perpetual and individualized healthcare services. Although technological development has produced incredible achievements in real-time control, system design, and security policies, certain issues persist. These include data privacy issues, non-standardization, integrational difficulties, and the lack of deployment datasets in the real world. However, new and promising solutions have emerged including blockchain, fog computing, federated learning, and machine learning-based analytics. Also noted is the importance of hybrid solutions based on cloud and edge resources to create scalable low-latency opportunities. With the changing face of healthcare, this study opens up viable avenues for future studies in identifying the gaps between theoretical innovation and actual system implementation to eventually help create healthy and responsive healthcare systems.

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