A Review on: IoT-enabled Healthcare Monitoring Systems Based on Multi Sensor Unit

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ABSTRACT

The rapid advancements in the Internet of Things (IoT) have significantly impacted healthcare by enabling real-time monitoring and remote patient management. This review paper examines the role of IoT-enabled healthcare monitoring systems, focusing on multi-sensor units that track vital health parameters such as ECG, heart rate, blood pressure, temperature, and respiration. The study explores various architectures and technologies, including cloud computing, federated learning, blockchain security, and low-power sensor networks, that enhance the efficiency, security, and scalability of IoT-based healthcare solutions. A detailed analysis of recent research highlights key developments in IoT-driven healthcare, addressing the benefits and limitations of different approaches. While IoT-based health monitoring systems improve accessibility, accuracy, and real-time data analysis, challenges such as interoperability, data privacy, and energy efficiency persist. This paper provides a comprehensive review of existing literature, identifies research gaps, and discusses potential advancements to further optimize IoT-enabled healthcare solutions.

KEYWORDS

IoT, Health Care Monitoring, Smart Health Care System

1. Introduction

The incorporation of the Internet of Things (IoT) in healthcare has transformed the monitoring and management of patient health. IoT-enabled healthcare monitoring systems employ intelligent sensors, wearable technology, and cloud-based data analytics to monitor essential health metrics, including heart rate, blood pressure, body temperature, respiration rate, and ECG signals [1]. These technologies provide real-time data acquisition and remote patient surveillance, enabling healthcare practitioners to deliver prompt interventions, particularly for persons with chronic conditions, elderly patients, or those necessitating ongoing oversight. The swift progress in wireless sensor networks (WSN), cloud computing, machine learning (ML), and blockchain technology has significantly improved the efficiency, precision, and security of IoT-based healthcare solutions.

IoT healthcare systems generally comprise various interconnected elements, including sensors for physiological data collection, microcontrollers for processing, cloud platforms for data storage, and mobile applications for real-time health monitoring. The rising incidence of chronic diseases and the escalating demand for telemedicine have rendered IoT-based healthcare solutions [2] indispensable in contemporary medical practices. These systems promote healthcare accessibility, decrease hospital visits, lower healthcare expenses, and improve patient outcomes by enabling continuous health monitoring and early disease identification.

Recent studies have examined multiple facets of IoT in healthcare, encompassing the application of federated learning for the privacy-preserving analysis of medical data, blockchain technology for the security of health records, and energy-efficient network protocols for enhancing power consumption in wearable devices [3]. Nonetheless, despite these developments, other issues persist, including data security, interoperability, scalability, and the integration of diverse IoT devices into current healthcare infrastructures. Confronting these obstacles is essential for guaranteeing the smooth integration and extensive implementation of IoT-enabled healthcare monitoring systems.

This review paper offers an extensive examination of IoT-based healthcare monitoring technologies, emphasising multi-sensor systems and its applications in patient care. The article analyses current progress in the domain, emphasising significant advancements, obstacles, and prospective trajectories. This study seeks to enhance IoT-driven healthcare solutions for better medical diagnostics, patient safety, and healthcare accessibility by assessing current research and pinpointing deficiencies.

IoT-enabled healthcare monitoring systems provide several benefits that increase patient care, refine medical diagnoses, and streamline healthcare delivery. A key advantage is real-time health monitoring, enabling the continuous tracking of vital signs like heart rate, blood pressure, temperature, and respiration. This real-time data acquisition facilitates the early identification of anomalies, enabling healthcare practitioners to intervene swiftly and avert medical crises. Moreover, IoT-based systems greatly enhance remote patient monitoring, especially for elderly folks, chronically ill patients, and those residing in rural regions with restricted access to healthcare services. Patients can obtain prompt medical care without necessitating frequent hospital trips, therefore decreasing healthcare expenses and alleviating the strain on healthcare infrastructure [4].

A significant benefit is the automation of healthcare procedures, enhancing efficiency and minimising the likelihood of human error. IoT technologies effortlessly converge with cloud computing and artificial intelligence (AI) to analyse patient data, produce health insights, and aid physicians in making educated medical decisions. Moreover, IoT healthcare solutions improve personalised medicine by gathering and analysing patient-specific health data longitudinally, facilitating customised treatment plans based on an individual's medical history and physiological reactions.

Blockchain integration enhances security and data integrity, guaranteeing that patient records are immutable and available just to authorised personnel. This is especially vital for preserving patient confidentiality and adhering to healthcare rules [5]. The deployment of low-power sensor networks and energy-efficient devices enhances battery longevity in wearable health monitoring systems, rendering them more sustainable and user-friendly.

IoT-enabled healthcare solutions enhance patient outcomes, increase healthcare accessible, reduce costs, and improve medical accuracy. As these technologies advance, they possess significant potential to convert conventional healthcare systems into intelligent, data-driven, and highly efficient medical infrastructures.

Internet of Things

The Internet of Things (IoT) is utilised in the healthcare sector to enhance the quality of human life by facilitating essential tasks that individuals must undertake via applications. Sensors may be installed on health monitoring devices utilised by patients. The data gathered by these sensors is accessible online to physicians, family members, and other stakeholders to enhance treatment and responsiveness. Furthermore, IoT devices can monitor a patient's present prescriptions and assess the danger of new drugs concerning allergic responses and unfavourable interactions. Utilising sensors and the aforementioned technology, we can monitor an individual's body temperature, heart rate, blood pressure, and other vital signs [6]. In the event of an emergency, the individual and their physician will be informed with all data gathered by the sensors. This device will be highly beneficial for elderly individuals and disabled persons residing independently.

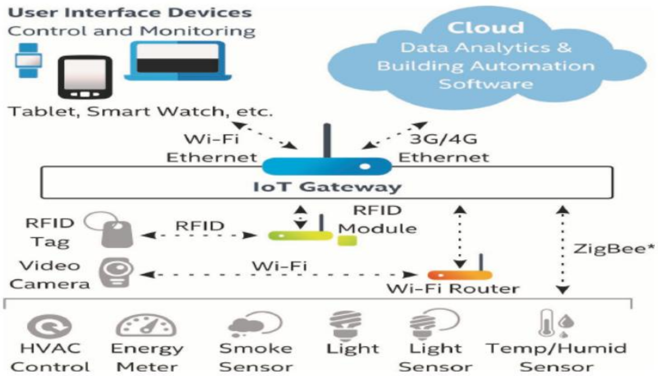

Figure 1: Architecture of IOT [7]

2. Literature Review

Christos L et. al. (2024) Despite significant advancements in medical technology, people around the world are still falling victim to infectious diseases caused by new viruses that harm the respiratory system. For those who suffer from chronic respiratory illnesses like asthma, pneumonia, or bronchitis, this virus poses a significant threat. Therefore, a novel secure machine learning monitoring system for a virus detection model is showcased in this research. The authors' proposed model employs four fundamental emerging technologies—the Internet of Things (IoT), Wireless Sensor Networks (WSN), Cloud Computing (CC), and Machine Learning (ML)—to identify harmful viruses that infect humans or animals, launching a global panic and disrupting people's daily lives. The suggested system is a strong one that could be set up in many different types of facilities (e.g., universities, entertainment venues, hospitals) and will guarantee privacy, speed, and accuracy for data acquired for virus detection. [8]

Madhu Kumar Vanteru et. al. (2023) Interest in IPv6 over 6LoWPAN has just been rekindled because to the development of the Internet of Things (IoT). There has been little progress toward 6LoWPAN mobile compatibility for the massive IP-based detection systems that will power the Internet of Things (IoT) of the future. The hospital's wireless technology, which makes extensive use of

6LoWPAN, tracks patients' vital signs all the time, no matter how active they are. Maintaining connection between patient nodes and the hospital network is crucial for accurate patient position tracking using sensor networks. Device power consumption needs to be improved, and automatic switching is an additional requirement. This study proposed a 6LoWPAN hospital architecture that uses a Media Access Control (MAC) design to protect patient information. The mobile router is often a bottleneck in these types of networks, but the authors' early numerical results show that the costs associated with transfers have decreased. The low pan is used to route biological ECG signals before they are transmitted to the gateway network through routing algorithms. [9]

Ramin Firouzi et. al. (2023) The privacy-preserving characteristics and decentralized model training process of edge-based distributed intelligence approaches like federated learning (FL) have attracted a lot of attention from several academic fields recently. On the other hand, for the most recent public mobile network generations (e.g., 5G and 6G), very few FL apps have been developed due to the lack of efficient RAN deployment models. Disaggregation, hierarchies, and distributed network function processing are some of the new RAN paradigms that are being considered. Claiming to satisfy the high quality standards of 5G services, Open RAN (O-RAN) is a state-of-the-art RAN technology. The ability for RAN to make intelligent judgments is provided by its embedded intelligent controllers. To facilitate the delivery of dispersed intelligence for 5G applications, this study presents a framework for deploying and optimizing FL jobs in O-RAN. To train the model in each iteration, we introduce RAN intelligence controllers (RIC) and reinforcement learning (RL) to allocate resources and pick clients for each FL task. Afterwards, a portion is designated for training based on the clients selected for the assignment. In terms of convergence and amount of communication rounds, our simulation findings demonstrate that the suggested method surpasses state-of-the-art FL methods like FedAvg. [10]

Mrs. X. Ignatius Selvarani et. al. (2024) Overall, the device has great potential in identifying falls and requesting help when needed. Additional customization and improvement is necessary to meet specific needs, though. To make the gadget more accurate and resilient, threshold algorithms can be used. The design of the device should also take into account the user's medical history. The sensors discussed in this work provide a basic technique that can be enhanced for better system performance; further research is being conducted to find the best approaches for fall detection and prevention. [11]

K. Mohanraj et. al. (2017) Internet of Things (IoT) technology allows for continuous monitoring of vital patients and their biological parameters, which is delivered to the doctor's console and domain address in person. As part of the plan, sensors will be incorporated to measure all vital patient data. The dht11, MQ, pulse, and pulse oximeter sensors assess vital signs like temperature, respiration rate, pulse rate, and oxygen saturation level in addition to humidity. After connecting the input sensors to an Arduino board, the signals are sent to the Raspberry Pi controller. From there, the important parameters are sent to the main monitor, where the front end is created using Lab VIEW software. When a patient's condition suddenly changes, doctors are alerted through the Internet of Things. Through the use of Lab VIEW, the doctor's console displays a graphical representation of the patient's data. Critical readings are transmitted to the doctor's domain address via the Internet of Things. Therefore, clinicians can keep tabs on their critically ill patients no matter where they are, allowing them to devote more time and energy to their care. [12]

Ashikur Rahaman et. al. (2019) This article provides a synopsis of the Internet of Things' application to health monitoring systems. There is still need for additional research and enhancement despite the widespread use of IoT in the medical field. If a patient's health issues are detected early enough, they can take the required emergency steps, which may even save their lives. When it comes to this, the

Internet of Things can be useful. Health monitoring systems built on the internet of things can keep tabs on patients in real time and alert them if anything out of the ordinary happens. But, in order to guarantee the correct protection of sensitive data, the IoT architecture needs certain facilities. Additionally, the sensors that are utilized should have a compact size to facilitate their integration into other systems. Finally, further deep learning and machine learning methods might improve the systems' accuracy and resilience. An innovative step forward in healthcare, the concept of an IoT-based smart health monitoring system has the potential to lessen the prevalence of preventable diseases and premature mortality. [13]

Omar Cheikhrouhoua et. al. (2023) Smart remote healthcare applications have grown rapidly thanks to the Internet of Things. Patients at risk or with chronic conditions can receive rapid and preventive medical services through these IoT-based remote healthcare solutions. A major issue with remote healthcare applications is the confidentiality and privacy of patient data during data exchange among medical IoT devices. Misdiagnosis and serious health problems for patients could result from tampered or damaged medical records. The effectiveness and responsiveness of existing remote medical apps also require improvement. This paper presents a lightweight remote patient monitoring system that is built on the Blockchain and supported by Fogen. It offers a high level of security and has an efficient response time, both of which are important in patient care. The security study and simulation findings demonstrate that the suggested lightweight blockchain architecture is both suitable for the resource-constrained IoT devices and resistant to assaults. The addition of fog computing also increased the responsiveness of the RPM system by 40%. [14]

Bikash Pradhan et. al. (2023) This study looked at the HIoT system from several angles. All the necessary information on the structure, parts, and interconnections of an HIoT system has been covered in this article. This study also details the existing healthcare services that have investigated the use of IoT-based technology. With these ideas in mind, the Internet of Things (IoT) has allowed medical practitioners to track and identify a wide range of health problems, as well as assess a plethora of health factors and offer diagnostic services to patients in far-flung places. The healthcare business has undergone a remarkable transformation, shifting its focus from hospitals to patients. The writers have also covered the latest advancements in HIoT applications and their diverse range of uses. In addition, we have detailed the problems that have arisen throughout the HIoT system's development, production, and implementation. These problems will lay the groundwork for developments and areas of study in the years to come. In addition, readers who are eager to start their own study and contribute to the field of HIoT devices have access to extensive, current information on the subject. [15]

Pallavi Joshi et. al. (2021) Created with the multi-objective paradigm of optimization in mind, it efficiently resolves clustering and routing problems. One solution to the clustering problem is the multi-objective rider optimization method, which involves picking a leader rider, or node, from among all the possible options and designating them as the cluster head. The other nodes in the network that were left out go through the same procedure. Data packets are received by several leader riders, who are also known as cluster chiefs, from their respective clusters. By deciding on the best course, the leader riders are able to communicate with each other and get back to the base station. A sailfish optimizer algorithm that is very good at convergent search runs this job. When an energy drain happens on a leader node, the optimizer handles it. To achieve this goal, it employs a multi-objective strategy that takes into account three primary objectives in order to determine the optimal alternative course of action. At last, the data packets are received by the base station, and the quality-of-service parameters are established. Impressive results in terms of energy usage, throughput, end-to-end delay, and network longevity are demonstrated by the proposed method. [16]

Rajeev Marada et. al. (2022) Most studies in IoMT agree that there needs to be more tailored solutions that benefit both patients and medical staff by making things easier for everyone involved. Despite using identical communication protocols, the IoMT area has seen a surge of proprietary solutions, creating a market of systems and services that are not compatible. By examining several system designs and networking protocols that facilitate the interchange of medical data, this review examines the emerging area of affordable IoMT solutions and the potential use cases for them. In order to provide healthcare services with limitless potential thanks to the advent of the Internet of Things (IoT), this paper offers an insight into the ongoing research in the healthcare industry. The field consists of various systems and technologies, and the goal is to provide affordable and proficient IoMT devices. [17]

Dr. R.Senthamilselvan et. al. (2023) To better detect and monitor Health, a novel approach was proposed in this research. In contrast to earlier iterations, the sensors used to track the patient's vitals are both highly accurate and well-suited to intelligent, continuous monitoring. With the help of ThingSpeak, a newly-named android app, and an open-source cloud, the doctor may keep tabs on the patient's condition around the clock and be alerted to any sudden changes. Through the use of the ThingSpeak server, it is possible to remotely monitor the patient's condition from any location on Earth. Authors may do more than just view a patient's medical history; they can use it to help experts cure the patient's health problems. [18]

Aitizaz Ali et. al. (2022) As a result of the interest generated by its many digital currencies, blockchain technology has emerged as one of the most talked-about innovations of the last five years. Bitcoin, Ethereum, and other blockchain technologies have been put into action in a variety of use cases. Critical infrastructure, which relies on confidential systems and data, was not addressed in any of these use cases. This article examined and highlighted significant privacy and security concerns associated with the usage of blockchains in mission-critical settings, including IIoT environments, despite the fact that blockchains like Ethereum provide users essential advantages like anonymity, integrity, and auditability. Other blockchains also have these privacy problems because ledger distribution is one of their fundamental design assumptions. The paper's discussion of privacy concerns is based on the present roadmap of Ethereum 2.0, which includes enhancements that do just that. With all the extra privacy and security aspects, it's crucial to test and evaluate how well a blockchain framework works before using it in places where latency is a concern. [19]

K. Haripriya et. al. (2016) According to this model, patients can be continuously monitored by collecting physiological data from a variety of sensors, processing it with a PIC microcontroller, sending it through a GSM and IoT module, and finally storing the results online. This way, you can access the data from any location, and it won't be a problem if you forget to bring a report with you when you see your doctor. By inputting the unique patient ID, he gains access to the details. The long-term goal of this research is to expand the patient's mobility by integrating all the sensors into a single chip through nanoscale fabrication. This chip will then be made into a bio patch that can be applied to the skin and send data wirelessly. [20]

Maja Anachkova et. al. (2021) This study introduces an inexpensive smart sensor unit that measures environmental noise levels, drawing inspiration from the idea of the Internet of Things (IoT). A microphone, an Arduino Uno microcontroller, a Lo-Ra click module, and an antenna are all parts of the device that allow it to connect to the worldwide TTN platform and save data in the cloud. Overall, the system has performed admirably in terms of acquiring, transmitting, and representing the measured data for the noise level, and it has also showed good sustainability. When compared to other sensors that have been produced and detailed in the studied state-of-the-art literature, the sensor's relative affordability stands out. Other sensors that are deemed "low-cost" can cost up to 1000 €. Because it is simple to build, the sensor node is straightforward to replicate, and the sensor network can be expanded in many ways. The Things Network (TTN) is an open-access, worldwide, crowd-sourced Internet of Things (IoT) network with public-use potential; connecting to the LoRAWAN network is simple if a LoRAWAN station is nearby, and the interface is user-friendly and easy to manipulate even for non-technicians. The system's small, weather-resistant 3D-printed housing allows it to function independently for at least two weeks on the recommended batteries. Not only is the sensor inexpensive, but it also demonstrates excellent performance in terms of measuring accuracy and precision, with a maximum error of 5 dB, as demonstrated in the study. [21]

Aarti Rao Jaladi et. al. (2017) This system has a low power consumption, is easy to maintain, and is inexpensive as compared to the typical base station (gateway) that collects and forwards information or data. In this paper, we lay out the architectural blueprints for a wireless sensor network system that makes use of Raspberry Pi as the base station, XBee as the networking protocol, and sensor nodes as a hybrid of sensors, controllers, and zigbee. Therefore, developers can build apps that collect data from sensors, apps that follow your location, and a social network of things that can update its state. This way, your location parameters can govern themselves depending on where you are. The system's main selling point is that all the necessary components—a wireless sensor network gateway node, a database server, and a web server—can be housed on a single tiny, low-power Raspberry Pi—a computer about the size of a credit card—that can be set up to operate independently of a monitor, keyboard, and mouse. There are a lot of environmental monitoring and data collecting applications for this kind of device. [22]

Shabarish Krishnan et. al. (2020) As a result, horticultural IoT applications are enabling farmers and ranchers to collect substantial data. In order to increase the intensity and maintainability of their inventions, both large landowners and small ranchers need to understand the potential of the IoT market for agriculture through the introduction of smart technologies. Due to inaccurate weather predictions and poor water management practices, ranchers suffer substantial financial losses. Local management of parameters, such as temperature, precipitation, and humidity, is now within reach, because to developments in miniature sensors and remote technologies. Building a smart remote sensor network (WSN) for a farming domain is the major objective of this record. There are a lot of moving parts when it comes to monitoring the state of rural areas using various sensors, such as temperature and humidity. [23]

M. Alper Akkaş et. al. (2020) The Internet of Things (IoT) and its potential uses in healthcare are the subject of this introductory article. It goes over the current state of the Internet of Things (IoT) and its potential future growth in the healthcare industry. In addition, a prototype system for medical data gathering that is based on the Internet of Things (IoT) is described as an example. Part one of the article delves at the various ways in which healthcare organizations are putting Internet of Things (IoT) technologies to use, from gathering and tracking patient records to managing hospital staff and resources and conducting assessments of vital equipment. Additionally, the article delves into the new ideas of Bio-IoT and Nano-IoT (IoNT) and the key components of these growing concepts. Part 2 details the proposed system's architecture and prototype for ZigBee node-based medical data collection. Due to its license-free operation frequency in the ISM band and low power consumption, ZigBee is chosen as the wireless communication standard. In addition, Crossbow's MicaZ wireless modules are common, inexpensive, readily available parts for WSNs. Assembled into a wireless

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sensor network using the nesC programming language, the prototype has these modules linked to pulse oximeter sensors. Each patient has their own unique record file that includes data from their heart rate monitor, plethysmogram, and blood oxygen levels. This data is transmitted wirelessly to a central database. [24]

Dr. B.Nancharaiah et. al. (2023) This research looks at health monitoring systems that rely on the internet of things. An Arduino UNO was utilized to update the patient's database with their heart rate and temperature, as measured by a sensor. Thanks to the internet of things, medical professionals may now access data. The gadget uses specialized sensors to keep tabs on the patients' vitals, including their blood pressure, heart rate, oxygen saturation, and heart rate. Doctors can prevent serious harm to their patients by acting promptly with the help of our solutions. [25]

Arun Pandi T et. al. (2018) This study presents the design and implementation of an IoT ecosystem for real-time monitoring of water quality indicators. An Internet of Things (IoT) module, an Arduino mega 2560 core controller, and various sensors measuring water quality parameters make up the suggested system. These devices are energy efficient, inexpensive, and can process, analyze, transmit, and view data in the cloud as well as on the mobile device via Wi-Fi. This can be used to monitor ecosystems, environments, and more, and the data can be accessed from any location. The authors intend to incorporate biological parameters of the water and place the system in various ponds and water distribution networks to gather data on water quality for submission to the water board in the future. [26]

Shwetank Dattatraya Mamdiwar et. al. (2021) This document compiles information on the Internet of Things (IoT) in healthcare in great depth. It delves at the ways in which the Internet of Things (IoT) has revolutionized and interconnected numerous sectors in the last several decades, including healthcare, making it more accessible to a wider audience. First, it provides a high-level overview of a healthcare monitoring wearable sensor system that relies on the Internet of Things. Additionally, the report delves into a comparison of approximately 133 studies concerning the use of IoT in healthcare, with the aim of enhancing healthcare even further. The sensors that were employed, the main points of the research articles, and their contributions to the field are all summarized. To assist more individuals get the healthcare they need, we hope this compilation can serve as a footnote for future studies. The authors were able to derive certain conclusions on the fundamental design of the wearable sensor system that is helped by the Internet of Things (IoT) after reviewing all of these articles. [27]

Table: 1 Summary of Review Papers

Author(s) & Year	**Research Focus**	**Key Findings**	**Limitations/Areas for Future Research**
Christos L et al. (2024)	Development of a secure machine learning monitoring system for virus detection using IoT, WSN, CC, and ML.	Proposed a strong system for virus detection in facilities like universities, hospitals, and entertainment venues, ensuring privacy, speed, and accuracy.	None explicitly stated. Future work can focus on improving scalability and adapting the system for varied viruses and settings.

Madhu Kumar Vanteru et al. (2023)	6LoWPAN-based architecture for patient monitoring in hospitals.	Developed a MAC design to protect patient information and introduced routing algorithms for efficient ECG signal transmission, reducing transfer costs.	Improvements needed in device power consumption and automatic switching for better mobile compatibility.
Ramin Firouzi et al. (2023)	Framework for deploying and optimizing federated learning (FL) in O-RAN for 5G applications.	Introduced RAN Intelligence Controllers and reinforcement learning for efficient FL task allocation, surpassing FedAvg in convergence and communication rounds.	Limited focus on real-world FL application deployments in 5G/6G networks. Further studies needed to validate scalability and reliability.
Mrs. X. Ignatius Selvarani et al. (2024)	Fall detection system using threshold algorithms and user-specific customization.	Device shows great potential for identifying falls and requesting help. Further development can make it more accurate and resilient.	Additional research needed to enhance accuracy, customization, and system performance.
K. Mohanraj et al. (2017)	IoT-based patient monitoring system using sensors like DHT11 and pulse oximeter.	Enables continuous monitoring of patient vitals, graphical display using LabVIEW, and alerts doctors through IoT.	Limited scalability and adaptation to varied patient conditions. Further improvements needed in integration with advanced IoT platforms.
Ashikur Rahaman et al. (2019)	IoT-based health monitoring systems for real-time patient observation and alerts.	Highlights the potential of IoT in reducing preventable diseases and mortality through early detection.	IoT architecture needs improved data security. Compact sensors and advanced ML techniques are required for better system resilience.

Omar Cheikhrouhoua et al. (2023)	Blockchain and fog computing-based lightweight remote patient monitoring system.	Enhanced security and response time for IoT-based healthcare applications. Improved responsiveness by 40% using fog computing.	Further optimization needed for resource-constrained IoT devices. Additional studies required for real-world implementation.
Bikash Pradhan et al. (2023)	Analysis of HIoT systems, their structure, components, and interconnections.	Covered advancements and applications in IoT-based healthcare, emphasizing the shift from hospital-centric to patient-centric care.	Detailed challenges in HIoT system development and implementation. Future research can explore innovative solutions to these challenges.
Pallavi Joshi et al. (2021)	Multi-objective optimization for clustering and routing in IoT networks.	Proposed a rider optimization method for cluster head selection and data transmission, showing improvements in energy usage, throughput, and network longevity.	Limited application scope. Future work could expand on scalability and performance in diverse IoT scenarios.
Rajeev Marada et al. (2022)	Review of IoMT solutions for patient care, focusing on affordability and compatibility.	Explored affordable IoMT solutions and provided insights into potential use cases and system designs.	Proprietary solutions and lack of compatibility remain significant issues. Future research should focus on standardized protocols and interoperability.
Dr. R. Senthamilselvan et al. (2023)	IoT-based continuous patient monitoring system using ThingSpeak server.	Enabled 24/7 monitoring and remote alerts using an open-source cloud and Android app.	Future research can enhance system usability and extend its application to a wider range of health conditions.

Aitizaz Ali et al. (2022)	Examination of blockchain's privacy and security challenges in critical IIoT environments.	Discussed significant privacy concerns in blockchain systems and highlighted Ethereum 2.0 roadmap enhancements for improved security.	Limited focus on addressing privacy issues in mission-critical systems. Future work should explore robust blockchain designs tailored for IIoT applications.

3. Devices for Data Capturing in Health Care

To deploy the health analysis system, it is essential to determine the requisite health issues for their maintenance. The following discussion pertains to several sensors, including temperature sensors, blood pressure sensors, heart rate sensors, ECG sensors, acceleration sensors, and Raspberry Pi with GSM.

A. ECG Sensor

Electrocardiography (ECG) is employed to document cardiac activity via surface electrodes on the skin. It can detect a variation in an electric cylinder every minute on the surface of the skin. An ECG amplifier is responsible for obtaining certified data. An ECG is a graphical representation of the electrical activity generated by the heart muscle during cardiac cycles. An ECG is utilised to assess the heartbeat with the application of an MCU. The determination of heart rate is primarily facilitated by the electrodes, which are simplified to two connections: one for the right hand and the other for the left [28].

B. Heartbeat Sensor

It is utilised to assess the patient's heart rate. The heart rate sensor operates on a +5V DC supply. This produces the digital outcome, which is positioned on the arterial nerves of the hand. This operates on the idea of light modulation via the blood flow in the arterial nerve with each pulse. The heart rate should range from approximately 60 to 100 beats per minute [29].

C. Blood Pressure Sensor

A hypertension sensor quantifies blood pressure, encompassing systolic and diastolic values, as well as pulse rate. This method yields more precise and dependable outcomes than the sphygmomanometer. The existing approach using airborne gallbladder armour and a stethoscope to assess blood pressure. Blood pressure sensors typically measure pressure from the walls of blood vessels or arteries [30].

D. Temperature Sensor

This sensor quantifies body temperature by voltage measurement. The LM35 sensor has an advantage in converting Kelvin to Celsius and is also appropriate for wireless applications, surpassing the performance of a thermostat [31].

E. Acceleration Sensor

The ADXL335 accelerometer sensor employed here is a compact, low-power, three-axis device with minimal signal outputs. This quantifies the complete spectrum of acceleration (± 3g). This sensor can detect gravitational fixed acceleration in diverse applications. The user sensor employs the X, Y, and Z capacitors at the XOUT, YOUT, and ZOUT terminals. The bandwidths for the X and Y axes span from 0.5 Hz to 1600 Hz, while the Z axis ranges from 0.5 Hz to 550 Hz [32].

F. Respiration

This sensor can detect breaths per minute in people. The normal respiratory rate for people is from 12 to 18 breaths per minute. Children aged 10 years will exhibit a respiratory rate of 30 to 60 breaths per minute. Two sensors utilised for breath measurement are coupled to a resistor bridge network. The bridge network terminals link to the LM741 amplifier via an inverting input terminal [33].

G. Raspberry pi

This apparatus functions effectively as a multiprocessor. It possesses a graphics card, volatile memory, RAM, device interfaces, and additional external wireless device interfaces. This Raspberry Pi consumes minimal power while being affordable and powerful. A keyboard, display unit, and power supplies are necessary for operation, similar to a regular PC. The Raspberry Pi utilised the SD card as a storage device. The Raspberry Pi can connect by a LAN/Ethernet, a USB modem, or wirelessly. The Raspberry Pi is designed to facilitate a range of home and business applications. The Raspberry Pi operates on a Linux-based operating system, specifically Raspbian OS. Python is a computer language utilised for implementing the Raspberry Pi. It can communicate with external devices using wireless communication technologies, cellular networks, NFC, ZigBee, Bluetooth, etc. This paper was conducted on a high-speed 4G cellular network. Raspberry has numerous applications, thus presenting various potential for the future [34].

4. Smartphone Based Health Monitoring System

Smartphones are among the most valuable resources globally. A smartphone typically comprises 14 sensor types, with additional sensors anticipated in the future. The voice monitoring system on a smartphone is a notable feature. A multitude of hardware solutions have been created utilising the adaptability of this feature. Smartphones use several sensors, including wireless sensors, Bluetooth modules, accelerometers, fingerprint sensors, gyroscopes, magnetometers, barometers, proximity sensors, GPS trackers, cameras, and NFC (near field communication) sensors, which are extensively utilised in the development of health monitoring systems. A primary benefit of a smartphone is its extensive storage capacity. Contemporary smartphones can efficiently retain patient data in primary storage. Android smartphones facilitate data streaming, device information management, and seamless interaction. [35] created a mobile voice health monitoring system utilising a smartphone equipped with an accelerometer sensor. A small accelerometer serves as a voice sensor, while the smartphone functions as the data collecting platform in the examined system. The system is positioned around the patient's neck. This method employed frame-based voice characteristics; however, raw accelerometer data may also be utilised for monitoring purposes. [36] suggested a multi-lead ECG health monitoring system utilising a smartphone. This system employs a seven-lead real-time ECG for signal acquisition. The sampling frequency is as high as 500 Hz. The vast volume of ECG data complicates the detection of problems by physicians. An automated alert system is employed. The alarm activates upon detection of anomalous ECG data by the system. Nevertheless, an average alert delay of 13.37 seconds exists in this system, which diminishes the accuracy rate. Moser and [37] introduced a personal health monitoring system with a smartphone called WellPhone. The device employs speech synthesis and speech recognition technologies to interact with the user. It maintains a record of the semantics and big data associated with the data acquired from the measurement instrument. The data is additionally saved on the mobile device. Nonetheless, the data from Well phone is non-clinical. [38] developed a mobile phone-based wireless health service system. The system is engineered for familial health care. This system comprises three components: data communication designation, Android mobile client designation, and system server designation. The data transmission technology facilitates the interaction between the server and the Android terminal. The mobile client designation operates on the intelligent terminal of the Android system. The system server functions as the webserver responsible for the control centre and back-end data management system. Nonetheless, due to the substantial volume of data, SQLite fails to deliver satisfactory outcomes. MySQL can be utilised to surmount this constraint. [39] presented a continuous heart rate monitoring device. It is an embedded device that utilises wireless signals to broadcast an individual's heartbeat to a smartphone. The device continuously monitors heart rate, allowing patients to access real-time heart rate information via the display. Nonetheless, it does not monitor heart rate continuously and is incapable of accurately detecting cardiovascular disease. The majority of the examined systems utilised Android-based smartphones. Android is a mobile operating system derived on a modified Linux kernel and other open-source software, specifically built for touchscreen mobile devices, including smartphones and tablets. Android facilitates straightforward access to smartphone sensor data, unlike other proprietary operating systems, which is essential for the efficient creation of smartphone-based health monitoring systems. Currently, there are over 2.5 billion active Android devices. Android devices currently possess 75.85% of the overall mobile operating system market share. The advancement of Android-based healthcare solutions is highly viable.

5. System Architecture of the Health Monitoring Systems

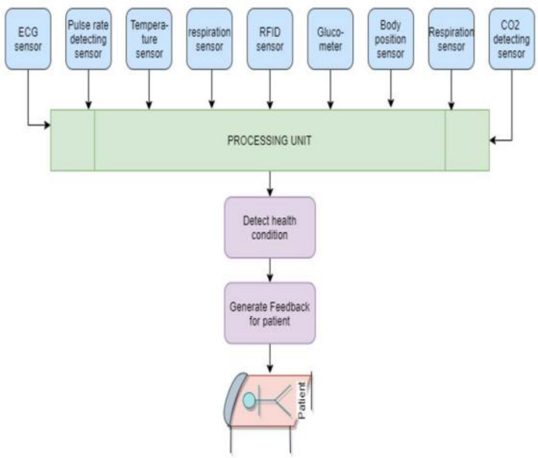

Figure 2: System architecture of the health monitoring systems [40]

Intelligent health monitoring systems assess health parameters such as pulse rate, body temperature, respiration rate, blood glucose levels, body location, ECG, EEG, and more metrics through the use of sensors. The sensors are interfaced and managed using multiple microcontroller-based platforms, including Arduino and Raspberry Pi. The microcontroller acquires data through sensors. Biomedical data is typically stored on servers. The device can determine if the patient's state is normal or abnormal based on the stored data. This technology offers real-time healthcare monitoring for physicians and medical assistants, enabling them to access data at any time. The primary advantage is the device's reduced power consumption, enhanced performance, great sensitivity, and straightforward setup. It is projected that by 2020, there will be around 26 to 50 billion network-connected devices, and 100 billion by 2030 [41]. The Raspberry Pi is the predominant platform for the Internet of Things (IoT). It is an economically priced device based on Linux. The combination of

Raspberry Pi and IoT has initiated a new era in healthcare systems. A Raspberry Pi can be converted into a mini-clinic by the integration of sensors, including a pulse rate sensor, temperature sensor, accelerometer, and respiration sensor. These methods are utilised in numerous regions globally. Microcontroller units (MCUs) serve as the primary controllers of systems; nevertheless, they lack the capability for concurrent data processing. Processing multimodal data concurrently can decrease time expenditure. A field-programmable gate array (FPGA) is a circuit characterised by real-time performance and a distinctive hardware logic control architecture. Consequently, FPGA has surpassed MCU in prominence for multi-sensor data management inside the IoT ecosystem. Consequently, recent breakthroughs have been achieved utilising FPGA instead of MCU. Figure 2 depicts a general design of a smart health monitoring system. Diverse sensor types have been employed in various health monitoring systems. In Figure 2, the sensors gather data from the patient and transmit this information to the processing unit. The processing unit analyses the data against previously-stored cloud information to ascertain patients' health conditions. The technology delivers input subsequent to assessing the patient's status.

Conclusion

IoT-enabled healthcare monitoring systems have emerged as a revolutionary technology, markedly improving patient care, medical diagnostics, and healthcare efficiency. These systems facilitate real-time health monitoring, remote patient supervision, and data-driven decision-making through the integration of intelligent sensors, cloud computing, machine learning, and blockchain security. The capacity to consistently monitor essential health metrics, including heart rate, blood pressure, ECG, and body temperature, has transformed early disease identification and preventative healthcare, diminishing hospital visits and enhancing patient outcomes. The integration of smartphone applications and low-power sensor networks has enhanced the accessibility and comfort of healthcare services, rendering them more efficient and cost-effective.

Notwithstanding these developments, some obstacles persist, encompassing concerns regarding data security, interoperability, power consumption, and scalability. Facilitating the seamless integration of diverse IoT devices with current healthcare infrastructures is essential for wider adoption. Moreover, subsequent investigations ought to concentrate on improving the security and privacy of patient information, maximising network efficiency, and creating more energy-efficient wearable technology.

This analysis emphasises the substantial benefits of IoT in healthcare and stresses the necessity for ongoing innovation and research to overcome current constraints. The evolution of IoT technology possesses significant potential to revolutionise conventional healthcare systems into intelligent, interconnected, and patient-centered frameworks, hence enhancing the quality of healthcare globally.

References

[1] C. Li, J. Wang, S. Wang, and Y. Zhang, "A review of IoT applications in healthcare," *Neurocomputing*, vol. 565, p. 127017, 2024. [Online]. Available: https://doi.org/10.1016/j.neucom.2023.127017

[2] H. Bhojwani, G. K. Sain, and G. P. Sharma, "A Hybrid Connectivity Oriented Telemedician System For Indian Landscape Using Raspberry Pi SBC & IOT," in *Proc. IEEE TIMES-iCON*, 2018, doi: 10.1109/TIMES-iCON.2018.8621799.

[3] W. B. Qaim *et al.*, "Towards Energy Efficiency in the Internet of Wearable Things: A Systematic Review," *IEEE Access*, vol. 8, pp. 175412–175435, 2020, doi: 10.1109/ACCESS.2020.3025270.

[4] A. I. Paganelli, A. G. Mondéjar, and A. C. da Silva, "Real-time data analysis in health monitoring systems: A comprehensive systematic literature review," *J. Biomed. Inform.*, vol. 127, p. 104009, 2022. [Online]. Available: https://doi.org/10.1016/j.jbi.2022.104009

[5] A. Haleem, M. Javaid, R. P. Singh, and R. Suman, "Blockchain technology applications in healthcare: An overview," *Int. J. Intell. Netw.*, vol. 2, pp. 130–139, 2021. [Online]. Available: https://doi.org/10.1016/j.ijin.2021.09.005

[6] A. Rejeb, K. Rejeb, and H. Treiblmaier, "The Internet of Things (IoT) in healthcare: Taking stock and moving forward," *Internet Things*, vol. 22, p. 100721, 2023. [Online]. Available: https://doi.org/10.1016/j.iot.2023.100721

[7] Advantech. [Online]. Available: https://www.advantech.com

[8] C. L. Stergiou, A. P. Plageras, and V. A. Memos, "Secure Monitoring System for IoT Healthcare Data in the Cloud," *Appl. Sci.*, vol. 14, no. 1, p. 120, 2024. [Online]. Available: https://doi.org/10.3390/app14010120

[9] M. K. Vanteru and K. A. Jayabalaji, "Multi-Sensor Based healthcare monitoring system by LoWPAN-based architecture," *Measurement: Sensors*, vol. 28, p. 100826, 2023. [Online]. Available: https://doi.org/10.1016/j.measen.2023.100826

[10] R. Firouzi and R. Rahmani, "5G-Enabled Distributed Intelligence Based on O-RAN for Distributed IoT Systems," *Sensors*, vol. 23, no. 1, p. 133, 2023. [Online]. Available: https://doi.org/10.3390/s23010133

[11] X. I. Selvarani and M. A. Ajis, "Health Care Monitoring System for Paralysis Patient," *Int. J. Adv. Res. Sci. Technol.*, vol. 13, no. 3, pp. 1282–1287, 2024. [Online]. Available: https://doi.org/10.62226/ijarst20241333

[12] K. Mohanraj, N. Balaji, and R. Chithrakkannan, "IoT BASED PATIENT MONITORING SYSTEM USING RASPBERRY PI 3 and LabVIEW," *Pak. J. Biotechnol.*, vol. 14, no. 3, pp. 337–343, 2017.

[13] A. Rahaman, M. M. Islam, and M. R. Islam, "Developing IoT Based Smart Health Monitoring Systems: A Review," *Rev. Intell. Artif.*, vol. 33, no. 6, pp. 435–440, 2019. [Online]. Available: https://doi.org/10.18280/ria.330605

[14] O. Cheikhrouhou, K. Mershad, and F. Jamil, "A Lightweight Blockchain and Fog-enabled Secure Remote Patient Monitoring System," *Elsevier Preprint*, 2023.

[15] B. Pradhan, S. Bhattacharyya, and K. Pal, "IoT-Based Applications in Healthcare Devices," *J. Healthc. Eng.*, vol. 2021, Article ID 6632599, pp. 1–18, 2021. [Online]. Available: https://doi.org/10.1155/2021/6632599

[16] P. Joshi and A. S. Raghuvanshi, "A Multi-Objective Metaheuristic Approach Based Adaptive Clustering and Path Selection in IoT Enabled Wireless Sensor Networks," *Int. J. Comput. Netw. Appl.*, vol. 8, no. 5, pp. 566–584, 2021, doi: 10.22247/ijcna/2021/209988.

[17] R. Marada, E. S. Anant, and K. Vadivukkarasi, "A Survey on Affordable Internet of Things (IoT) Enabled Healthcare Systems," *Grenze Int. J. Eng. Technol.*, 2022.

[18] R. Senthamilselvan, M. Keerthi, and M. P. Raju, "IOT BASED HEALTH MONITORING SYSTEM," *Int. J. Eng. Technol. Manag. Sci.*, vol. 7, pp. 157–161, Apr. 2023, doi: 10.46647/ijetms.2023.v07si01.024.

[19] A. Ali and M. A. Almaiah, "An Industrial IoT-Based Blockchain-Enabled Secure Searchable Encryption Approach for Healthcare Systems Using Neural Network," *Sensors*, vol. 22, no. 2, p. 572, 2022. [Online]. Available: https://doi.org/10.3390/s22020572

[20] K. Haripriya *et al.*, "Patient Health Monitoring System Using IoT and Cloud Based Processing," *Indian J. Sci. Technol.*, vol. 9, Dec. 2016, doi: 10.17485/ijst/2016/v9iS1/108434.

[21] M. Anachkova, S. Domazetovska, and Z. Petreski, "Design of low-cost wireless noise monitoring sensor unit based on IoT concept," *J. Vibroeng.*, vol. 23, no. 4, pp. 1056–1064, Jun. 2021, doi: https://doi.org/10.21595/jve.2021.21709.

[22] A. R. Jaladi, K. Khithani, and P. Pawar, "Environmental Monitoring Using Wireless Sensor Networks(WSN) based on IOT," *Int. Res. J. Eng. Technol.*, 2017, pp. 1371–1378.

[23] S. Krishnan, S. S. Kumaran, and R. Preethi, "FIELD MONITORING USING WIRELESS SENSOR NETWORKS BASED ON IOT," *Int. Res. J. Eng. Technol.*, 2020, pp. 3532–3536.

[24] M. A. Akkaş, R. Sokullu, and H. E. Çetin, "Healthcare and Patient Monitoring Using IoT," *Internet Things*, 2020, doi: https://doi.org/10.1016/j.iot.2020.100173.

[25] B. Nancharaiah, G. C. Sekhar, and P. Radhakrishnan, "An Iot Based Healthcare Monitoring System," *J. Pharm. Negat. Results*, vol. 14, no. 3, pp. 127–134, 2023, doi: 10.47750/pnr.2023.14.03.19.

[26] A. P. T, S. V. S. B, and V. S, "Multi-Sensor based Water Quality Monitoring in IoT Environment," *Int. Res. J. Eng. Technol.*, 2018, pp. 3237–3240.

[27] S. D. Mamdiwar, A. R., and Z. Shakruwala, "Recent Advances on IoT-Assisted Wearable Sensor Systems for Healthcare Monitoring," *Biosensors*, vol. 11, no. 10, p. 372, 2021. [Online]. Available: https://doi.org/10.3390/bios11100372

[28] Elprocus, "AD8232 ECG Sensor Working and its Applications." [Online]. Available: https://www.elprocus.com/ad8232-ecg-sensor-working-and-its-applications/

[29] Elprocus, "Heartbeat Sensor Working Application." [Online]. Available: https://www.elprocus.com/heartbeat-sensor-working-application/

[30] R. Ratnadewi, M. F. Ramdhani, N. Kurniasih, and L. D. Putri, "Automatic Blood Pressure Detector Using Arduino," *Int. J. Eng. Technol.*, vol. 7, no. 2.5, pp. 115–118, 2018.

[31] ElectronicWings, "LM35 Temperature Sensor." [Online]. Available: https://www.electronicwings.com/sensors-modules/lm35-temperature-sensor

[32] LastMinuteEngineers, "ADXL335 Accelerometer Arduino Tutorial." [Online]. Available: https://lastminuteengineers.com/adxl335-accelerometer-arduino-tutorial/

[33] T. Dinh *et al.*, "Stretchable respiration sensors: Advanced designs and multifunctional platforms," *Biosens. Bioelectron.*, vol. 166, p. 112460, Oct. 2020. [Online]. Available: https://doi.org/10.1016/j.bios.2020.112460

[34] Wikipedia, "Raspberry Pi." [Online]. Available: https://en.wikipedia.org/wiki/Raspberry_Pi

[35] D. D. Mehta *et al.*, "Mobile voice health monitoring using a wearable accelerometer sensor and a smartphone platform," *IEEE*, 2012.

[36] H. Gao *et al.*, "Design and tests of a smartphones-based multi-lead ECG monitoring system," in *Proc. IEEE EMBC*, 2013, pp. 2267–2270.

[37] L. E. Moser and P. M. Melliar-Smith, "Personal health monitoring using a smartphone," in *IEEE Int. Conf. Mobile Services*, 2015.

[38] X. Kong *et al.*, "Design on mobile health service system based on Android platform," in *IEEE IMCEC*, 2016.

[39] J. Turner *et al.*, "Continuous heart rate monitoring using smartphone," in *IEEE Int. Conf. Electro Inf. Technol. (EIT)*, 2017.

[40] A. Rahaman *et al.*, "Developing IoT Based Smart Health Monitoring Systems: A Review," *Rev. Intell. Artif.*, vol. 33, no. 6, pp. 435–440, 2019. [Online]. Available: https://doi.org/10.18280/ria.330605

[41] E. A. Rogers and E. Junga, "Intelligent efficiency technology and market assessment," *ACEEE*, 2017.