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IOT-BASED HEALTH MONITORING SYSTEMS: A REVIEW

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ABSTRACT

The emerging technological trend in the healthcare sector is geared towards changing the usual healthcare services and routine medical check-ups from hospital centric to home centric. This offers a reduction in the total expenses incurred and the workload on the clinical personnel. As such, remote health monitoring systems based on Internet of Things (IoT) are developed to aid in monitoring some physiological parameters (such as: heart rate, body temperature, blood pressure, and glucose level.) of patients at home. The devices often use internet connectivity to effectively monitor the health condition of patients. In this paper, a review of IoT based health monitoring systems is presented. Diverse measuring parameters and different approaches were used. Suggestions on possible remediation to the challenges of data privacy and security in such systems were proffered. The significance of developing remote health monitoring systems, factors necessitating the need for such systems, the objectives for designing the systems, potential for product commercialization, application area in the health sector, and system requirements are discussed.

Keywords: Body temperature; Health monitoring; Heart rate; IoT; Security

1. INTRODUCTION

The Internet of Things (IoT) is the concept of connecting devices to the Internet and to other connected devices, to exchange data. Health monitoring system is one of the most notable applications of IoT (Rahaman *et al.,* 2019). The IoT based system uses internet to effectively monitor the health condition of their patients while they are away. Remote health monitoring is very important because it is a cheap and effective solution to tackle the ever-growing demand for health care services (Pramanik *et al.*, 2019). It is vital in terms of prevention, in cases where early detection of a disease can reduce suffering and medical costs. Early diagnosis and prompt treatment of some diseases can help prevent major treatments (Gonzalez *et al.,* 2018).

Health monitoring is vital because it gives early warning thereby reducing the risk of sudden health deterioration. However, there are some factors that can prevent regular monitoring of patient's health, therefore necessitating the need for a remote smart health monitoring process. They include: -

i. Inability to access prompt medical facilities for rural dwellers.

ii. High cost of medical care services when health condition deteriorates.

iii. Busy schedules and daily demanding activities that make it difficult for people to keep track of their patient's health status through regular check-up.

iv. Inadequate health care services from medical personnel's due to large number of patients and their tight schedules, more especially for those patients that require continuous monitoring.

The IoT based health systems monitor the health condition of patients, with a view to reduce health care cost, save time, and offer an automated check-up processes for optimal health diagnosis and control.

The objectives for designing such systems are as follows:

i. To design an automated system that will monitor physiological parameters (such as heart rate, body temperature, pressure, glucose level, etc.) of patients.

ii. To minimize healthcare costs by reducing the need for regular doctors visit or frequent check-up.

iii. To develop a system that stores patient's physiological data in the cloud. Thereby enabling good record keeping and real-time access.

iv. To perform analysis and visualization on the collected data using IoT platforms. Thus, enabling decision making and recommendations.

2. LITERATURE REVIEW

Modern healthcare system has introduced new technologies such as wearable, remote, and mobile devices (Chavan *et al*., 2018). Considerable work has been done by many researchers to design automated means of monitoring the health of patients. The significant works, which are related to these research purpose, are reviewed as follows:

Yang et al. (2012) proposed a contactless IoT-based health monitoring system that monitors the health status of patients. Bhoomika and Muralidhan (2015) designed a continuous patient monitoring system. Ugrevonic and Gardasevic (2015) analyzed and simulated an IoT healthcare system that monitors patients' health condition. Kumar and Rajasekaran (2018) developed an IoT based patient monitoring system using Raspberry Pi. Krishnan et al. (2018) proposed an IoT based patient health monitoring system that tracked data in real-time with timestamps. Patil and Pardeshi (2018) designed a health monitoring system using IoT. Singh et al. (2019) developed an IoT based blood pressure monitoring system. Ruman et al. (2020) proposed a wearable IoT-based patient health monitoring system. Sam et al. (2020) developed an IoT based remote health monitoring system with transmitter and receiver sections. Savaridass et al. (2020) developed an IoT-based smart health monitoring system. Srikanth et al. (2020) designed an IoT-based patient health monitoring system using Arduino microcontroller. Tamilselvi et al. (2020) proposed an IoT-based healthcare monitoring system for the Coma patients.Valsalan et al. (2020) designed and implemented a smart patient health tracking system. Vedaei et al. (2020) developed an IoT framework that monitored participants health conditions and notified them to maintain physical distance. Abuelkhail et al. (2021) proposed a novel IoT-based health monitoring technique using RFID clustering scheme. Ahammed et al. (2021) developed an IoT-based remote health monitoring system. Anan et al. (2021) developed an IoT-based remote health monitoring system for asthmatic patients. Bora et al, (2021) developed a smart real-time health monitoring system using Arduino and Raspberry Pi. Khan et al. (2021) developed a real-time IoT-based health monitoring system for Covid-19 patients. Lakshmi et al. (2021) proposed a cloud based IoT remote health monitoring system. Praba et al. (2021) developed a diagnostic IoT-based smart health monitoring system for Covid-19. Priyanka and Mahalakshmi, (2021) developed an IoT based health monitoring system for covid-19 patients. Sahu et al. (2021) proposed an IoT-based cloud centric remote ECG monitoring system. Wu et al. (2021) presented a deep learning based IoT real-time health monitoring system. Bhardwaj et al. (2022) developed a smart health monitoring system for Covid-19 using IoT technology. Umer et al. (2022) proposed a smart healthcare framework using IoT and cloud technology. Alandjani (2023) proposed a novel deep learning – based approach to disease prediction.

A summary of the reviewed work is given in Table 1. It can be observed that fewer physiological parameters were considered in some of the works. Also, data security mechanisms were not considered in most of the literatures. Multiple diverse sensors can be added to develop a robust and multipurpose health monitoring system. The use of cryptographic techniques and emerging technologies such as blockchain, machine learning, and deep learning can be employed to enhance security and data privacy. Based on the research conducted, the use of IoT for healthcare application in the medical field was mainly in the last decade between 2012-2022.

Table 1: Summary of reviewed literatures

Authors	Title	Measured parameters	Major Hardware/software used	Some system features/ capabilities
Yang et al.	A non-contact health	Facial expression,	MATLAB, database, cam-	- The system was simula-

(2012)	monitoring model based on the internet of things	posture and sound	eras, digital cameras, microphones and other equipment	tion based. - The monitoring system consists of two parts: the client (for data collection using user's facial expressions) and server (for data analysis, management and processing).
Bhoomika and Muralidhan (2015)	Secured smart healthcare monitoring system based on IoT	Body temperature and heart rate	PIC 18F46K22 microcontroller, temperature sensor, pulse oximeter sensor, Wi-Fi module ESP8266, LCD display, GSM modem, piezo electric buzzer, regulated power supply, embedded c programming, MPLAB IDE v 8.92, Proteus 7.0 ISIS professional, Hi-Tech C compiler, DIPTRACE, HTML language	- The data was encrypted to address security issues using standard AES 128. - The data was accessed using a unique IP address via html webpage. - In extreme cases, alert message was sent via GSM to the doctor
Ugrenovic and Gardasevic (2015)	CoAP protocol for web-based monitoring in IoT healthcare applications	Body temperature, ECG, oxygen saturation, respiration rate, glucose level and blood pressure	Contiki OS with 6LoWPAN protocol stack, Cooja simulator, Mozilla Firefox web browser.	- The system was simulation based. - The approach enabled real-time access to the data.
Kumar and Rajasekaran (2016)	An IoT based patient monitoring system using Raspberry Pi	Body temperature, respiratory rate, heartbeat and body movement	Raspberry Pi, sensors, amplifier circuit	- The sensor signals were sent to the Raspberry Pi via amplifier circuit and signal conditioning unit.
Krishnan et al. (2018)	An IoT based patient health monitoring system	Body temperature and heart rate	Arduino uno microcontroller, temperature sensor, ECG sensor, LCD display, Wi-Fi, web server, buzzer.	- The data was tracked in real-time with timestamps over the internetwork. - A buzzer gave alarm in case of emergency.
Patil and Pardeshi (2018)	Health monitoring system using IoT	Body temperature and heart rate	Arduino uno microcontroller, temperature sensor, Pulse sensor, cloud server, Wi-fi module ESP8266, ThingSpeak IoT platform	- The simulation was done on Arduino IDE software. - Data processing was performed at the cloud server.
Singh et al.	Blood pressure monitoring	Blood pressure	Arduino uno microcontrol-	- They developed a simple

(2019)	system using wireless technologies		ler, MATLAB software, BMP 180 pressure sensor, Node MCU with Wi-fi technologies, Bluetooth technologies with HC-05 Module	solution for blood pressure monitoring using IoT concept. - They incorporated a prediction algorithm via MATLAB software.
Ruman et al. (2020)	IoT based emergency health monitoring system	Body temperature, heart rate and pulse rate	Arduino mega microcontroller, cloud server, Wi-fi module, temperature sensor, ECG sensor, pulse sensor, ThingSpeak IoT platform	- They proposed a user-friendly and cost-effective system that monitored and diagnosed patient's condition.
Sam et al. (2020)	Progressed IoT based remote health monitoring system	Pulse rate, circulatory strain, breath rate, body temperature, body development and saline dimension	Arduino uno microcontroller, heart beat sensor, accelerometer sensor, blood pressure sensor, temperature sensor, IR sensor, respiration sensor, GSM, IoT web server, PC	- The proposed framework sends an email, alarm and SMS when a specified limit was exceeded. - The system was split into transmitter section and receiver section.
Savaridass et al. (2020)	Development of smart health monitoring system using internet of things	Body temperature, Blood pressure, glucose level, pulse rate and oxygen level	Node MCU microcontroller, Wi-fi module, Cloud & Google sheet	- The measured parameters were sent to the cloud and Google sheet via the Wi-fi module.
Srikanth et al. (2020)	Patient health monitoring using Arduino through IoT	Blood pressure, body temperature and heart rate	Arduino ATMEGA 328 microcontroller, LED, buzzer, ThingSpeak IoT platform, web server, pressure sensor, pulse sensor, temperature sensor	- The data was accessed by authorized users. - Data visualization was done on ThingSpeak IoT platform.
Tamilselvi et al. (2020)	IoT based health monitoring system	Body temperature, coronary heart rate, eye movement and oxygen saturation	Arduino uno microcontroller, Wi-fi module, mobile app, ThingSpeak, temperature sensor, heartbeat sensor, eye blink sensor, oxygen saturation	- The data was sent to the IoT cloud via Wi-fi module and to the mobile app via SMS. - Emergency alert message was predefined and sent when a threshold value was exceeded.
Valsalan et al. (2020)	IoT based health monitoring system	Heart rate, body temperature, hu-	IoT server, base station, control unit, temperature	- They proposed a portable physiological checking

		midity and room temperature	sensor, pulse sensor, humidity sensor (or hygrometer), Wi-fi module, LCD display	framework. - The measured values were displayed on an LCD screen.
Vedaei et al. (2020)	COVID-SAFE: An IoT – based system for automated health monitoring and surveillance in post-pandemic life	Body temperature, cough rate, respiratory rate and blood oxygen saturation	Raspberry Pi Zero (RPIZ), fog (or cloud) server, wearable sensors, mobile app, Bluetooth/Wi-fi, fuzzy inference system	- The framework consists of a wearable IoT device, a smartphone application, and fog server. - The app notified the user to maintain a physical distance of 2m (or 6 ft).
Abuelkhail et al. (2021)	Internet of things for healthcare monitoring applications based on RFID clustering scheme	Heart rate	Pulse sensor, RFID, wearable smart nodes	They proposed a novel IoT monitoring technique using RFID clustering scheme (with clusters of wearable smart nodes)
Ahammed et al. (2021)	An IoT-based real-time remote health monitoring system	Heart rate, oxygen saturation and body temperature	Pulse oximeter & heart rate sensor, temperature sensor, node MCU, Wi-fi module, mobile app	- The data were presented under normal, fever, and sacred health conditions. - The Wi-Fi module uploads data to the mobile app-based web server.
Anan et al. (2020)	Research and development of an IoT-based remote asthma patient monitoring system	Oxygen saturation, heart rate, body temperature, humidity, volatile gases, room temperature and ECG	Node MCU ESP8266, sensors, android app, website	- The system was tested on both demo patient and real human. - The sensed data showed high level of accuracy.
Bora et al. (2021)	Smart real time monitoring system using Arduino and Raspberry Pi	Heart rate, body temperature, heart rhythm and ECG	Pulse sensor, ECG sensor, temperature sensor, GPS module, Arduino, Raspberry Pi, LCD display, cloud	- Patients location extracted using GPS in case of emergency.
Khan et al. (2021)	IoT-based smart health monitoring system for Covid-19 patients	Body temperature, pulse rate and oxygen saturation	Arduino uno microcontroller, Node MCU ESP8266, LCD screen, Bluetooth module, buzzer, pulse sensor, temperature sensor, Proteus Design Suite Software	- The system was implemented using an IoT-based mobile application. - Alert was triggered during emergency.
Lakshmi et	Cloud based IoT smart	Heart rate and	Arduino Nano microcon-	- The database was pass-

al. (2021)	healthcare system for remote patient monitoring	body temperature	troller, Raspberry pi, cloud server, ThingSpeak platform, wearable sensors, Wi-fi and Bluetooth module	worded to allow only authorized access. - ThingSpeak platform was used to monitor and visualize the sensed data.
Praba et al (2021)	IoT based handheld smart health monitoring system for Covid-19	Heart rate, oxygen saturation and body temperature	Arduino uno microcontroller, Node MCU Wi-fi module, sensors, website module, server module, database module	- The Node MCU uploaded the data to the cloud server. -The uploaded data was accessed via a dedicated Covid19 website.
Priyanka and Mahalakshmi (2021)	IoT-based Covid-19 patient health monitoring system	Heart rate, body temperature, blood pressure and pulse rate	Raspberry pi, heartbeat sensor, temperature sensor, pressure sensor, pulse oximeter, buzzer, voice module, Wi-fi module, LCD display, emergency button	- The proposed framework monitored people's health and notified them to keep physical distancing. - Alarm was triggered during emergency.
Sahu et al. (2021)	IoT-enabled cloud-based real-time remote ECG monitoring system	ECG	ECG sensor, Bluetooth Low Energy (BLE 4.0), Amazon Web Service (AWS) Cloud	- The system performed remote monitoring of cardiovascular diseases. - The system was implemented with filtering algorithms to ignore distractions, environmental noise and motion artefacts.
Wu et al. (2021)	Internet of things -enabled real-time health monitoring system using deep learning	ECG, acceleration and blood oxygen saturation	ECG sensor, acceleration sensor, oxygen saturation sensor, Timing module	- The system analyzed athletes' condition and offered proper medication. - The system performance was evaluated using a cross-validation test (using various statistical-based metrics).
Bhardwaj et al. (2022)	IoT-based smart health monitoring system for Covid-19	Blood pressure, heart rate, oxygen level and body temperature	Raspberry Pi, Raspberry Pi, pulse rate sensor, temperature sensor, oxygen level sensor, ADC, Cloud server, Display Unit (monitor), ThingSpeak platform	- The device ensured real-time monitoring and data storage on the cloud platform. - The data were sent to the ThingSpeak platform.
Umer et al.	IoT based smart monitor-	ECG, heart rate,	Heart rate sensor, tempera-	-The system was designed

(2022)	ing of patients with acute heart failure	body temperature, blood pressure, glucose and cholesterol level	ture sensor, pressure sensor, ECG sensor, blood glucose & cholesterol sensor, web server	to monitor and predict heart failure patients' survival rate. -The sensed data were processed by CNN-based deep learning model to determine the state of the acute heart failure patients.
Alandjani (2023)	IoT enabled healthcare monitoring system using Convolutional Neural Network	Not stated	Wearable IoT-based sensor devices, Cloud database, Java programming implementation platform	- 5G network was utilized in the transmission of data to the cloud. -For security purpose, they proposed a novel Rivest-Shamir-Adleman (RSA)-based encryption and decryption to secure data stored in the cloud.

3. SIGNIFICANCE AND APPLICATIONS

3.1. Internet of Things (IoT)

IoT is an emerging technology where many embedded devices (things) are connected to the internet. The connected devices often communicate with people and other things and provide data to cloud storage. IoT is used in many application areas such as: - environmental monitoring, health monitoring, industrial control and monitoring, vehicle-fleet monitoring, home automation, etc., (MathWorks, 2022).

3.2. Significance of IoT Based Health Monitoring

With the advent of new healthcare technology, IoT is rapidly revolutionizing the healthcare industry. Medical personnel play a very important role, but the process of check-up is quite lengthy because it includes registering, booking appointments, and generating check-up reports. Due to this lengthy process, some people tend to ignore regular check-up or rather postpone it (Patil and Pardeshi, 2018). The modern approach to healthcare services automates the processes, thereby making it time saving and offering easy access to information.

Early diagnosis is very important in providing better health care services, because the appropriate measures can be taken to cure the ailment before it aggravates. Lack of proper treatment because of negligence in performing regular check-up, normally worsen the health condition of patients and may eventually lead to sudden death. This often results in high cost of treatment because the patient's health condition might have become critical. Therefore, there is the need for a smart patient health monitoring system that will monitor and keep records of the health status of patients, most especially the elderly ones. The obtained record can then be viewed by the medical personnel for analysis and decision-making.

These measured physiological parameters (heart rate, body temperature, body pressure, glucose level, etc.) may become early signs for diagnosing certain diseases such as hypertension or cardiovascular diseases.

Congestion control by adopting social distancing due to deadly communicable diseases such as the Covid19, has imposed great fear on people who wish to undertake routine medical check-ups. It is also both time and resource consuming. Hence, these IoT based healthcare monitoring devices have the potential for product commercialization as patients can monitor their health status in the comfort of their homes without being physically present in the health institution.

3.3. Applications

IoT-based remote health monitoring systems are used for monitoring certain parameters and diagnosing ailments (Pradhan *et al*., 2021; Maji, *et al.,* 2020; Rghioui *et al.,* 2020; Tuli *et al.,* 2020; Singh *et al.,* 2019; Hayati and Suryanegara, 2017) in the healthcare sector. They include:

i. Electrocardiogram (ECG) monitoring - for heart diseases.
ii. Blood Pressure (BP) monitoring – for hypertension.
iii. Temperature monitoring – for fever detection.
iv. Glucose level monitoring – for diabetes detection.
v. Mood monitoring – for mental diseases such as depression.
vi. Respiratory rate monitoring – for lung diseases such as asthma.

To effectively monitor some health conditions, IoT based devices are integrated with Machine learning, Deep learning, Cloud computing, or Big Data analytics techniques (Pradhan *et al.,* 2021; Verma *et al.,* 2022). The recorded information is transmitted to the cloud server via Wi-Fi, Bluetooth, or Zigbee Technology. Figure 1 shows some application areas of IoT in healthcare.

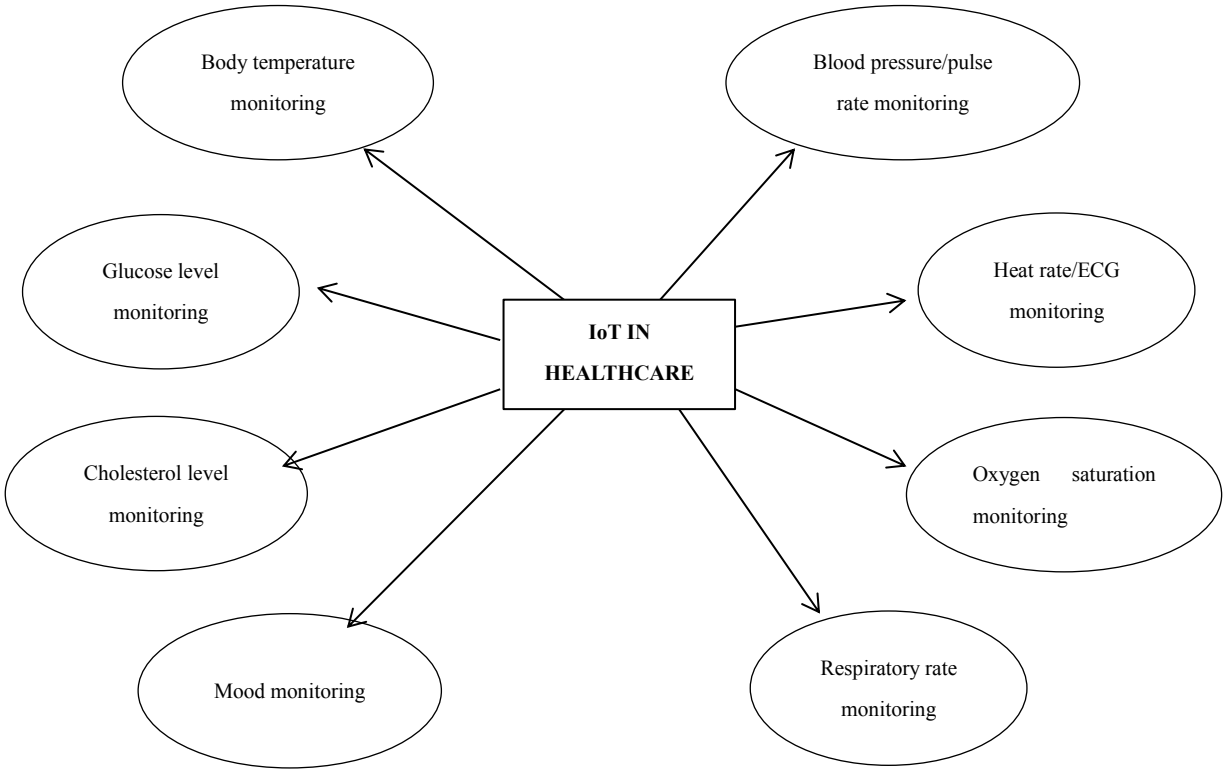

Figure 1: IoT-Based Applications in Healthcare

4. CHALLENGES AND REQUIREMENTS

Data security, privacy and accuracy are the major challenges militating against wide acceptance of the IoT-based healthcare services. Security is a major concern because sensitive information can be hacked. Data confidentiality is also crucial in the healthcare industry and there is possibility of privacy violation. The captured data is expected to be accurate because it will reflect the exact status of the patient. Data accuracy will ensure reliable and accurate diagnosis and prescription. Integrating blockchain technology with end-to-end encryption will enhance the security and privacy of the systems (Mohammed *et al*., 2021). To enhance the robustness and accuracy, machine and deep learning algorithms can be employed.

For optimal monitoring and diagnosis, the following requirements are needed to address some challenges (Ver-

ma *et al*., 2022; Jeong *et al*., 2021) associated with IoT-based health monitoring devices. They include:

i. Standard architecture and protocol to enable uniformity in the design process.

ii. Ensuring adequate data privacy and security to guarantee reliability and accuracy.

iii. Ensuring system scalability for efficient usage.

iv. Provision of high-powered sensor battery or self-generating power sensors, to enable long time usage most especially for wearable devices.

For future research, an architecture/framework aimed towards standardizing the design, development, and deployment of successful IoT healthcare service is recommended.

5. CONCLUSION

In line with the recent technological advancement in the healthcare sector, the use of IoT in health monitoring has come up with an automated and innovative means that can reduce frequent hospital visitation for such simple procedures as monitoring of body temperature, pressure, heartbeat rate or glucose level. The importance of developing such systems cannot be overemphasized. They will offer an easy, timesaving, cheap, and convenient alternative to both patients and clinical personnel. Data security and privacy issues can be tackled by employing encryption techniques and emerging technologies. For a robust and multipurpose health monitoring system, multiple physiological parameters should be considered.

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