DEVELOPMENT OF AN IOT-BASED REAL-TIME PATIENT HEALTH MONITORING SYSTEM

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ABSTRACT: Accurate and timely monitoring of cardiac patients can be difficult, especially in remote or marginalised communities. This study proposes a remote real-time cardiac monitoring system that leverages Internet of Things (IoT) technologies to overcome these challenges. It combines wireless communication and IoT technologies to allow seamless transfer of vital Electrocardiographic (ECG) data, facilitating timely monitoring and intervention. The system also features a smartphone app, making it easier for clinicians to access and monitor patients' data remotely. Accurate placement of electrodes ensures precise ECG data, offering insights into the patient's heart activity. Additionally, the system's robust data storage features securely maintain and manage patient data, allowing for long-term monitoring and analysis for a holistic view of the patient's condition and informed treatment strategies. With its cutting-edge features, this remote real-time cardiac monitoring system transforms the monitoring and management of cardiac patients, offering a convenient, accurate and holistic approach to patient data management for improved healthcare.

Keywords: IoT, Smart device, Health Monitoring, Mobile Software, Cloud Computing

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INTRODUCTION

Cardiac diseases are a leading cause of death in Pakistan, contributing to a large list of the total deaths each year [1]. Cardiac diseases remain the most common cause of sudden death globally, and it's important to be able to monitor and care for patients with cardiac issues [2]. There are many approaches that have been proposed to monitor and provide care to cardiac patients, but the literature does not cover all the aspects of this domain, and can be improved. The existing monitoring systems could have limitations in terms of access, real-time information, and remote monitoring. There is also a need to explore new ways to monitor patients with heart disease by taking advantage of new technologies such as the Internet of Things (IoT). Through a systematic research gap analysis and identification of potential solutions, we hope to leverage these opportunities to improve remote real-time cardiac monitoring systems and improve the quality of care in cardiac patients [3]. The rising mortality rate of heart diseases in Pakistan, which makes up 16.49% of total annual deaths, highlights the need to focus on cardiac diseases as the major causes of sudden death globally. Cardiac patients are often advised to avoid certain lifestyle factors that increase the risk of heart diseases, such as excessive physical activity and stress [4]. But many people suffer sudden death without drawing near to a medical center [5]. As a result, there is an urgent need for continuous health monitoring of cardiac patients by health personnel, to reduce the threat of unexpected death due to acute cardiac attacks [6]. What if continuous real-time monitoring of cardiac patients is achieved effortlessly and eliminates the tedious and difficult task of human personnel monitoring in hospitals and homes? That's why passionate researchers are continuously engaged in the development of innovative technologies for continuous patient monitoring [7]. Using an IoT-based system we are now able to remotely track the health of human hearts. The electrocardiogram (ECG), a powerful physiological wave signal that vividly represents the heart's physical activity [8], is produced by the amazing pumping and squeezing of blood in the heart's atria and chambers [9]. With an acute attention to detail in measuring the time taken for electrical signals to transmit across the heart, experienced physicians can expertly diagnose the heart's condition using the precious data acquired from the ECG [3]. In order to interpret and analyse this critical information regarding the heart's electrical functioning, the Wilson placement technique is applied, which entails the placement of multiple electrodes on the patient's body [10]. In [11], researchers have creatively made use of the limitless possibilities of IoT in the system, enabling us to effectively monitor the patient's health status. The term machine-to-machine (M2M) communication is not new; yet it is the Internet of Things (IoT) that has given rise to this innovative technology. IoT is also known as pervasive

computing, the Internet of Everything [12]. At its core, IoT is an open and dynamic network architecture enabling communication and computing among a wide range of devices, sensors and physical objects, which are often challenging for conventional computing systems to achieve [13]. A key benefit of IoT is that it minimises human intervention in data generation, communication and data processing and therefore can be used in many applications in different areas [14]. IoT has already shown a game-changing impact in the healthcare industry, where it has enabled better monitoring and management of medical conditions, leading to better health outcomes. IoT is revolutionizing smart homes and smart grids, smart cars, smart transportation, smart health monitoring and numerous other technologies [15]. In [16], [17], authors have done systems will be able to work remotely for the doctors to monitor patient regularly using IOT Business Process Model and Notation language.

This proposed system is designed to automatically monitor heart patients, especially those with heart problems, in a simple and efficient way. Instead of relying only on hospital visits, it continuously checks the patient's condition in real time, which helps doctors detect problems early and reduces mistakes. The system uses small electronic devices and the internet to send health data remotely, so patients can be monitored even if they are far from the hospital. It uses an IoT Kit NodeMCU to read heart signals (ECG) and a mobile app called Blynk to display the data, making it easy, low-cost, and accessible. This is especially useful for people in low-income or remote areas, where medical facilities are limited. It allows patients to be monitored without needing a doctor physically present all the time. Existing monitoring systems were expensive, difficult to install, and did not store patient data properly. Without continuous monitoring, a patient's condition could worsen without anyone noticing. This system solves that problem by keeping records and allowing doctors to check patient health anytime, which is very helpful for patients living far from hospitals.

MATERIALS AND METHODOLOGY

The IoT-based heart patient monitoring system aims to facilitate real-time monitoring of heart patients, such as those with heart diseases, without them having to be physically present in hospital. As shown in the figure, the system comprises several physiological and environmental sensors, a microcontroller unit, and a cloud communication platform for effective data collection, processing, transmission and display. The system starts with data acquisition from the patient, which includes three main sensors: the AD8232 ECG sensor, body temperature sensor (DS18B20), and the DHT11 temperature and humidity sensor. The AD8232 ECG sensor monitors the electrical signals of the heart via electrodes (RA, LA, RL) attached to the patient and produces analog signals that correspond to various cardiac components, such as P waves, QRS complex, and T waves. At the same time, the body temperature sensor detects the patient's temperature, and the DHT11 sensor monitors the environmental conditions (room temperature and humidity) that may affect the patient's health. The ECG sensor generates small analog signals, which are fed into an Analog-to-Digital Converter (ADC) to digitise them. The NodeMCU microcontroller serves as the system's brain, receiving digital signals from the ADC and interacting with other digital sensors. It processes, filters and formats the data before sending it to the Blynk cloud platform wirelessly via its Wi-Fi module. Data is transmitted via the MQTT protocol, ensuring efficient and secure real-time communication with the Blynk cloud. The Blynk app is used as an interface to view the data in the form of ECG graph in real-time, and the values of body temperature and humidity. The system also supports remote monitoring of patients by health-care personnel, allowing doctors and relatives to access the patient data on their mobile phones and web interfaces at any time and from any location. This eliminates the need for data logging and frequent visits to the hospital. Finally, it stores data in the cloud, enabling the doctor to view historical data, track trends, detect abnormalities and determine patient care. In this study, the data were collected from patients under medical care, both normal and abnormal ECGs, to test the system. Thus, the proposed methodology is automated, real-time, with reduced diagnostic error and accessible which is the best fit for patients in remote areas and with low resources. The proposed system's methodology is depicted in Figure 1, its components in Table 1 and its testing in Figure 2.

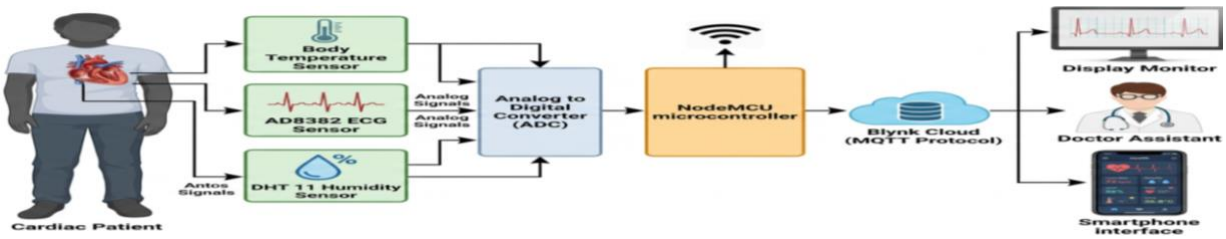

Figure 1: Proposed framework.

Table 1: Summary of components used in the proposed monitoring system

Component	Function	Key Features
AD8232 ECG Sensor	Measures heart electrical activity	Single-lead ECG, low power, analog output
DS18B20 Body Temperature Sensor	Measures body temperature	High accuracy, digital output, no ADC required
DHT11 Sensor	Measures room temperature and humidity	Low cost, digital signal, 2-second update rate
Analog-to-Digital Converter (ADC)	Converts analog ECG signals to digital	Enables microcontroller processing
NodeMCU (ESP8266)	Processes data and transmits via Wi-Fi	Built-in Wi-Fi, low power, IoT compatible
Blynk Cloud Platform	Stores and manages patient data	Real-time data visualization, remote access
Smartphone (Blynk App)	Displays patient health data	Live ECG graph, user-friendly interface
Display Monitor	Visualizes ECG waveform	Real-time signal monitoring
Power Supply	Provides energy to system	Supports continuous operation

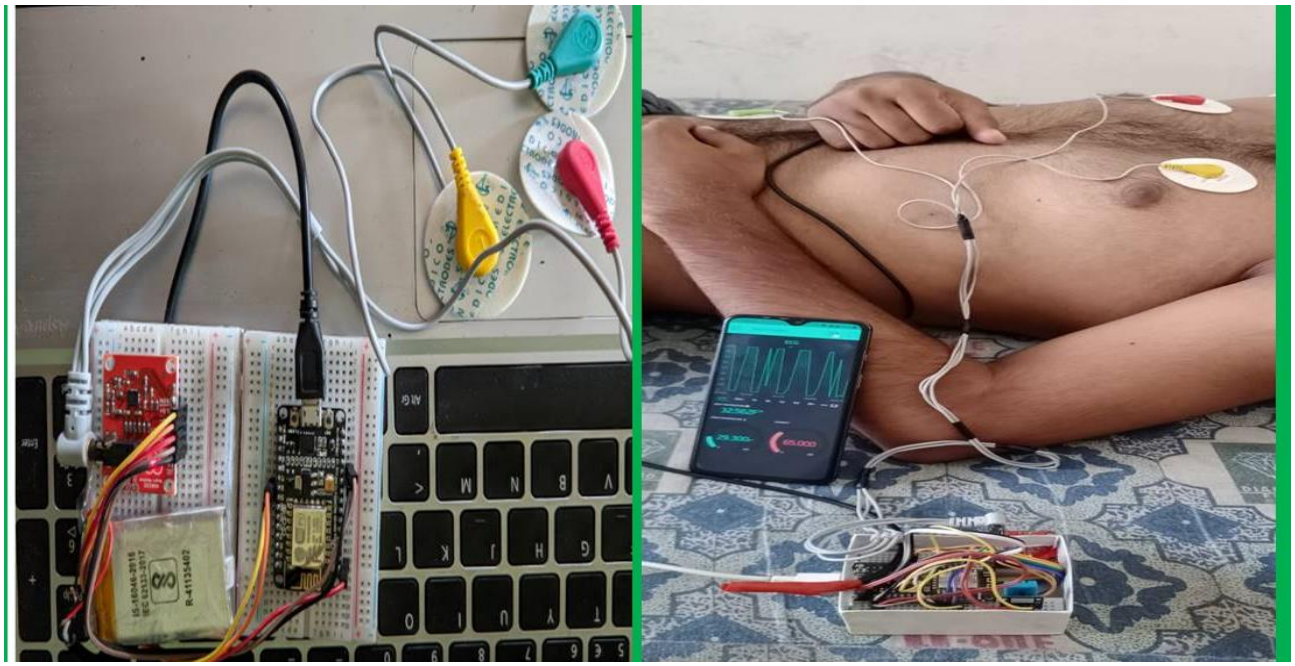

Figure 2: Design and implementation of the proposed monitoring system

RESULTS AND DISCUSSION

The table 2 shows the recorded data for monitoring health of five patients, listing heart rate, room temperature and body temperature. Heart rate values include normal (60-100 BPM) and abnormal readings (low heart rate for some patients, which could be a sign of health problems). Likewise, the body temperature values vary, with the normal human body temperature being around 98.6°F and lower readings may be a cause for concern. We also included the room temperature, which can affect patient comfort and health. This sample data shows how the system can track several parameters and assist doctors in detecting abnormal conditions and make timely decisions.

Table 2: Test results of patients with the proposed system

Sr#	Patient ID	Heart Rate (BPM)	Room Temperature (°F)	Body Temperature (°F)
1	Patient 1	75	84.2	98.6
2	Patient 2	56	98.6	93.2
3	Patient 3	75	87.8	84.2
4	Patient 4	70	82.4	95.0
5	Patient 5	76	84.2	93.2

The material and method, monitoring conditions, proposed technique description and ECG rate parameters are compared against the current work in Table 3.

Table 3: Comparison between current work

ECG rate parameter		Monitoring		Ref.
Normal	Others	Real-Time	Remote	[18]
Yes	No	No	Yes	[19]
Yes	No	Yes	No	[20]
Yes	No	Yes	No	[21]
Yes	No	Yes	No	[22]
Yes	Yes	Yes	No	[9]
Yes	Yes	No	No	[18]
Yes	Yes	Yes	Yes	Current Research Work

Conclusion: This research has successfully demonstrated the design and development of a prototypes of IoT-based health monitoring systems, in particular an ECG system for cardiac patients. The system is designed using the Blynk IoT platform, which allows medical professionals to remotely monitor patients' heart health. The proposed system has several benefits, such as being easy to use, portable, economical, easy to install and accessible remotely. Additionally, the use of a cloud-based database provides secure storage and access to patients' health information. Further enhancements could be the inclusion of more electrodes to improve ECG signal acquisition and the use of other sensors to monitor other vital signs such as blood pressure and heart rate. In summary, this research has provided insights into the design and development of IoT-based health monitoring systems, with a focus on enhancing the monitoring and management of patients with heart diseases.

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