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Real-Time Health Monitoring Smart System for Cardiac Patients using Internet of Things (IoT)

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***Abstract*— Cardiac patients often face challenges in accessing timely and accurate monitoring, particularly in remote or underserved areas. This research presents a remote real-time cardiac monitoring system that harnesses the power of Internet of Things (IoT) technology to address these limitations. By integrating wireless connectivity and IoT infrastructure, the system enables uninterrupted transmission of crucial Electrocardiographic (ECG) signals, ensuring timely monitoring and intervention. The system incorporates a smartphone-based application, enhancing accessibility for healthcare professionals to remotely monitor and analyze patient data conveniently. Precise electrode placement guarantees accurate and reliable ECG measurements, providing clinicians with valuable insights into the patient's cardiac activity. Moreover, the system's advanced data storage capabilities securely store and organize patient records, enabling longitudinal analysis for comprehensive insights and facilitating personalized treatment plans. Through its innovative features, this remote real-time cardiac monitoring system revolutionizes the way cardiac patients are monitored and cared for, combining convenience, accuracy, and comprehensive data management to enhance healthcare outcomes.**

***Index Terms*— Cardiac Monitoring, Real-time, IoT, Blynk Application, Mobile Application.**

I. INTRODUCTION

DEATH rates due to heart diseases have been steadily increasing in Pakistan, comprising a significant proportion of annual mortality. Cardiac diseases remain a leading cause of sudden death worldwide, necessitating continuous monitoring and timely interventions for cardiac patients. While various approaches have been proposed to monitor and manage cardiac conditions, the current literature lacks comprehensive coverage and leaves significant gaps to be addressed. The existing monitoring systems often suffer from limitations such as limited accessibility, lack of real-time data availability, and inadequate remote monitoring capabilities. Furthermore, there is a need to explore novel solutions that leverage the potential of emerging technologies, such as the Internet of Things (IoT), to revolutionize cardiac patient monitoring. By clearly identifying and addressing these research gaps, we aim to contribute to the advancement of remote real-time cardiac monitoring systems and enhance the quality of care provided to cardiac patients. The increasing death rate from heart diseases in Pakistan, comprising 16.49% of annual deaths, underscores the urgency of addressing cardiac diseases as leading causes of sudden death worldwide. Chronic cardiac patients often face lifestyle restrictions to minimize risk factors, including limitations on physical exertion and stress [1]. However, a significant number of individuals experience sudden collapses without reaching a healthcare facility [2]. Consequently, there is a pressing need for healthcare professionals to continuously monitor cardiac patients in order to mitigate the risk of sudden death resulting from acute attacks [3]. Imagine a world where continuous real-time monitoring of cardiac patients is seamlessly achieved, eliminating the demanding and challenging nature of human personnel-based monitoring, whether in hospitals or homes. This is precisely why dedicated researchers are tirelessly working on developing cutting-edge solutions for non-stop health monitoring of critical patients [4]. Through an IoT-based system, we now have the capability to remotely monitor human heart conditions in real-time. The electrocardiogram (ECG), a powerful physiological wave signal that vividly represents the heart's physical activity [5], is generated by the remarkable pumping and compressing of blood within the heart's atria and chambers [6]. By meticulously measuring the duration of electrical signals traveling through the heart, skilled doctors can expertly assess the organ's condition using the invaluable information provided by the ECG [7]. To capture and evaluate this vital data on the heart's electrical activity, Wilson placement technique comes into play, involving the strategic placement of multiple electrodes over the patient's body [8]. In [9] researchers have ingeniously employed the boundless potential of IoT within this system, allowing us to effectively track and monitor the patient's physical well-being. Back in 1999, visionary Kevin Ashton coined the term "Internet of Things" (IoT), which precisely captures the sensor-based linkage between internet-connected devices and computers [10]. Since then, the IoT has revolutionized the way signals are transmitted and controlled over the internet [11]. While the concept of machine-to-machine communication has been in existence for years, it was the IoT that brought this incredible technology into the spotlight, also known by other names such as ubiquitous computing and the internet of everything [12]. In essence, the IoT represents a flexible and interconnected network architecture that enables calculations and interactions between various devices, sensors, and everyday objects that conventional computers often struggle with [13]. Remarkably, the beauty of IoT lies in its ability to minimize human involvement in the creation, usage, and exchange of data, unlocking a vast array of possibilities across various domains [14]. In the realm of healthcare, the transformative impact of IoT is felt profoundly, empowering us to better manage and observe patients' behaviors, leading to enhanced healthcare outcomes. From home automation to energy management technology, networked cars to intelligent traffic systems, and now to groundbreaking health monitoring gadgets, IoT continues to reshape the landscape of innovation [15]. Hospitals and care centers now have new potential to increase access to and connectivity of healthcare equipment. It helps like from a review on cloud computing [16] and the Internet's medical monitoring and management platform. [17]suggested that their method is divided into two components. the data broadcast component and the data control component. The data possession component of the monitoring plan was created using expert interviews, which is a crucial component. An innovative real-time cardiac monitoring system that considers cost, convenience of use, accuracy, and data security was proposed by Mukati et al. [18]. Due to the low doctor-to-patient ratio, it may not be possible for remote cardiac patients to receive the most recent healthcare services without the help of this system. Because of its high speed, the performance of the proposed system demonstrates that it is dependable and useful. The analysis demonstrates that the proposed system is appropriate and reliable, and that it provides data security at a low cost. Torres and colleagues [19] Based on IoT, a system that detects heart doses by monitoring heart rate was proposed. Failure of the heart can reduce its competence. The amount of blood driven through the body can result in chest pain and faintness. Al-Sheikh et al. [20] Proposed a system that sends ECG signals to a smartphone and personal computer that assists the Doctor with the patient’s condition. This system does not require patient requirements in hospitals. This system covers live ECG signal, heart rate, SPO2, and last body temperature. Ali et al. [21] Proposed a system consisting of both hardware and software components at both patient-doctor ends. This paper provides image-based techniques to analyse the continuous result of ECG signals through MATLAB tools and a data-sending system through an internet network. This system catches energetic signs and limits from the ICU monitoring system and transmits images through the internet. The original image will send to Doctor on an Android cell phone. Rejeb et al. [22] Proposed a system that measured heartbeat using a pulse sensor and temperature sensor interlinked with a microcontroller. The sensor will install in the clothing device. When the heartbeat exceeds a specific limit or value, an alarm will generate to the patient’s family and the medical establishments like the Doctor and Physician of the patient. The microcontroller receives the signals and assesses the pulse. Shihab et al. [23] Proposed a system that is IoT based, which screens heartbeat by hardware system containing Node MCU and beat sensor. Furthermore, an alarm is added to a system that executes when the heartbeat level goes above or lower than the given algorithm. The alert system will receive by the Doctor, and the nurse and duty doctor can go and check the patient. In [24], [25] authors proposed systems that will remotely work for the doctors to check patients every time using IOT Business Process Model and Notation language. They took sessions and interviews, so a general requirement is needed in this process. They also used model of Bizagi Model tool. In [26] authors Current Advances, Challenges, and Future Directions" provides a comprehensive overview of the current state, challenges, and future prospects of using IoT in the context of in-home health monitoring. The authors have done a commendable job in summarizing the key components and functionalities of IoT-based health monitoring systems, as well as highlighting the associated challenges and potential future directions. This kind of systems also being implemented in many other areas, [27], [32].

Our proposed heart patient monitoring system aims to revolutionize the monitoring process for heart failure patients, enhancing efficiency and reducing time and costs. The system's objectives include facilitating real-time monitoring of patients' status, minimizing diagnostic errors, transitioning from traditional systems to computer-based digital systems, and integrating various disciplines to improve healthcare services. By leveraging embedded technologies, this system enables remote monitoring and continuous transmission of accurate health data, delivering essential healthcare services to individuals in distant locations. The IoT Blynk application is utilized in this cost-effective, readily accessible, remotely operated, and real-time monitoring system, which utilizes an Arduino Uno to monitor the ECG of heart patients. This system offers unique solutions for heart patients residing in low-income regions, providing structural patient health monitoring without the need for a doctor's physical presence. Prior to its implementation, patient data was not stored, making it difficult, unreliable, and expensive to deploy such a system without wireless communication. Without continuous monitoring, the patient's condition may worsen without the knowledge of healthcare professionals or family members, and crucial data records may not be available for doctors to assess the patient's situation. This is particularly critical for patients residing far from medical facilities, as their transportation to the hospital in case of deteriorating health becomes challenging for their relatives.

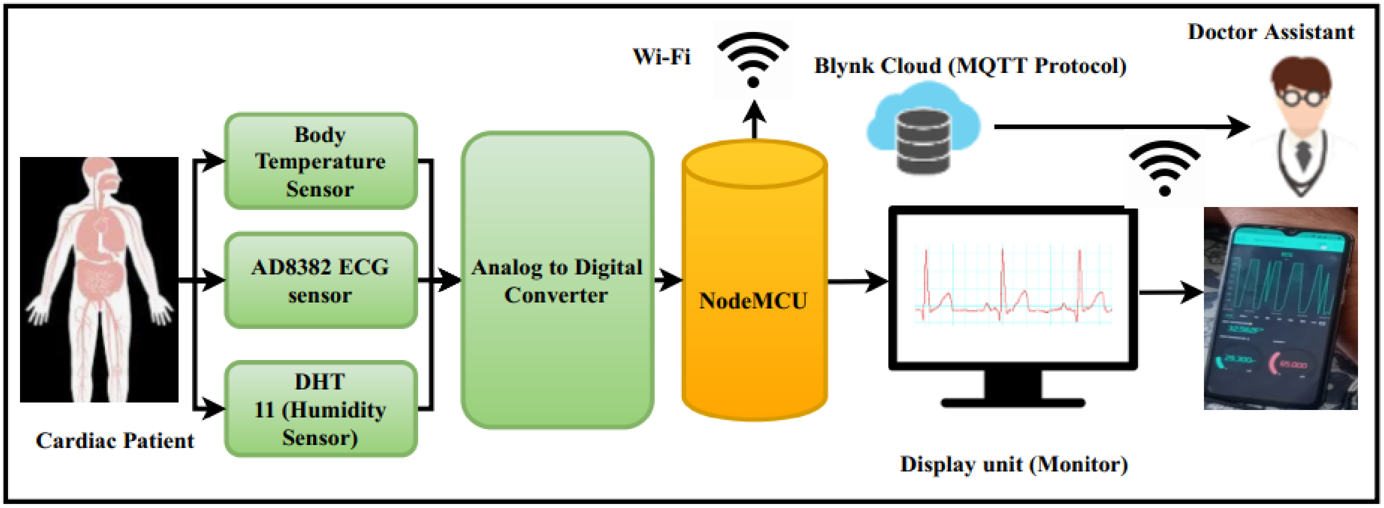

Figure 1: Proposed health monitoring system.

Figure 1 illustrates the monitoring system's objective of enabling remote caregivers to stay informed about patients' health status and make accurate diagnoses or predictions regarding potential risks. It fulfills the crucial role of conducting medical analysis of heart diseases and providing guidelines for parameter selection and sampling in medical practice. The ultimate goal of this heart patient monitoring system is to deliver a comprehensive solution that enhances and streamlines the monitoring process for heart failure patients, resulting in reduced time and cost burdens. The system aims to provide a facility for monitoring the patients' conditions, working cost governments, reducing diagnostic errors, and converting standard systems into computer-based digital systems, as well as supporting professional practice of healthcare services involving multiple disciplines,

The contribution of this research is that we take ECGs done at home without going to the hospital and check patients' conditions on the website and application we introduced. The data storage facility of ECG that tests from websites and applications can be checked thoroughly from anywhere at any time. There is no need to keep records of pages safe and take them whenever someone goes to the hospital.

II. DATA SET COLLECTION AND SIMULATION PARAMETERS

Dataset is a collection of data that we gather through different patient tests. This dataset is collected from H.H. Sheikh Zayed Hospital under the supervision of Doctor Muhammad Ali Tariq. This dataset includes ECGs of some regular patients whose heart rate and body temperature are standard and some abnormal people dataset that includes people whose heart rate and body temperature are not standard. A normal ECG means patients with no severe disease like sugar and high blood pressure. The ECG of some people is expected they have no disease; that is why it is called a normal ECG. The other is abnormal ECG of some patients because these patients have serious health issues and diseases like sugar, high blood pressure, and other diseases. That is why their ECG is not normal. The dataset has been collected under the observation of doctors and laboratory assistants. It takes two to three days to get the patient's record. These data are collected and then checked by seniors. After checking the data then, it is recorded on the system. These data are correct and tested different patients of different ages. The data include body temperature, heartbeat, ECG, and room humidity.

III. METHODOLOGY

In the proposed methodology, three health sensors are employed to capture various body activities. The electrocardiogram (ECG) sensor records the heart's electrical signals, while the DHT11 sensor measures environmental temperature and humidity, providing insight into the patient's physical well-being. The AD8382 sensor and body temperature sensors are utilized to calculate the heart's ECG signal and temperature. The collected data is transmitted to the NodeMCU microcontroller, which performs necessary calculations and communicates the information to the Blynk cloud platform using the MQTT protocol. The ECG signal is then displayed on a mobile application, allowing doctors or monitoring personnel to remotely monitor the detected ECG signal in real-time. This approach serves as a remote monitoring and analytical framework for assessing the condition of the human heart. The ECG signal, which represents the heart's physical activity, is generated through the pumping and contraction of blood between the atria and heart chambers. By measuring the time taken for an electrical signal to traverse the heart, doctors can evaluate the heart's medical health. The ECG signal is obtained by placing a series of non-surgical electrodes on the body surface, providing valuable information about the heart's electrical activity.

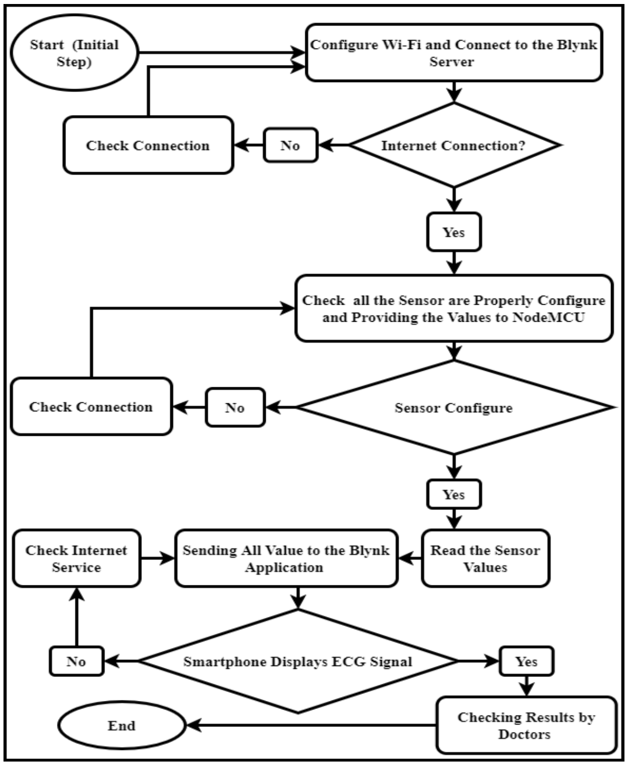

Figure 2: Flowchart showing the working mechanism.

The IoT-based health monitoring system flowchart is shown in figure 2 to monitor the physical state of the patients. Wireless technologies enable the establishment of a network of connected devices over the internet. The ECG monitoring system includes an AD8382 ECG sensor for reading patient data, an Arduino Uno, an ESP8266 Wi-Fi module, and the IoT Blynk application. The implementation of the Heart Patient Monitoring System allows the Doctor to notice and check patients remotely by using the Blynk application, which is installed on their android smartphone for dispensation and envisioning the patient's heart ECG signal. This nursing process can be completed anytime and anywhere without needing a hospital. The system invented has heart ECG and heart rate details on mobile phones and Doctor's laptop websites that can be easily checked and managed. The other benefit of that research project is that the previous data stored in an emergency can be checked and monitored by the Doctor so that he can give a prescription for the betterment of the patient.

A. ECG Sensor

The ECG signal is used to check the electrical activity of the heart. The signal is generated by the Sino atrial node (S-A node) and is located at upper atrium. The signal is then transmitted to the atrioventricular node with the power fusion by His bundle. In the cardiac signal, P represents atrial depolarization, QRS complex represents ventricular depolarization and atrial repolarization, and T represents ventricular repolarization.

The ECG largeness is in the microvolt region, with an incidence of 0.01 to 100 hertz. A bandpass filter and an amplifier must be applied to the signal in order to illustrate it. The frequency range of the bandpass sieve is 0.5 to 40 hertz. The intervals between beats and the pattern of each pulse are the most important factors to discern using an ECG signal. The normal intervals are R-R (0.6 - 1.2) seconds, P-R (0.12 - 0.2) seconds, QRS complex (0.08 - 0.12) seconds, and Q-T (0.35 - 0.45) seconds. This research project employs a "Single-Lead ECG sensor AD8232," a Spark fun company analogue sensor with a 3.3V operational voltage. It features three electrodes that can be concealed behind clothing: RA, LA, and RL. Right Arm (RA), Left Arm (LA), and Right Leg (RL) are the three parts. An initial high pass filter with a cut-off frequency of 0.48 Hz serves as the analogue filter for this sensor. In the second step, a low pass filter with a frequency limit of 40Hz is used to create the appropriate bandpass filter. The sensor pins are as follows: 3.3V, GND, Output, LO-, LO+, and SDN. The ECG signal is sent via the output pin. When one of the three wires connects to the patient's chest, the LO- and LO+ pins are linked to the microcontroller and deliver a HIGH signal. As a result, the microcontroller may automatically send a warning message. Finally, the sensor is turned off using the SDN pin to conserve battery life. It is an active low pin that the microcontroller might automate. The primary problem with this sensor is how sensitive it is to motion.

B. Body Temperature Sensor

Maintaining body temperature is critical to good health because enzymes in body cells are responsible for accelerating chemical processes. To do this work, these enzymes must be at an appropriate temperature. If a high body temperature is not maintained, it can cause heat stroke, dehydration, and death. Low body temperature can also cause hypothermia and mortality if not distributed properly. As a result, receiving timely body temperature information aids in avoiding the aforementioned issues. The DS18B20's primary usefulness is its connection to the digital temperature sensor. It is the capacity to function without the use of an external power supply. The DS18B20 boots into a low-power idle mode. The usual body temperature is around 37° C (98.6 ° F). Nonetheless, it may be as cold as 36.1° C (97° F) in the morning and as hot as 37.2° C (99° F) in the afternoon. The benefits of a digital temperature sensor are mostly determined by its precise output. The sensor outputs an accurate temperature in degrees Celsius as a measured digital signal. Inside the electric circuit, no extra processes, such as an analogue to digital converter, are necessary to standardize or enhance the signal.

C. Temperature Sensor (DHT 11)

The DHT11 is an important and low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a current controller to measure the local air. It sends a digital signal to the data pin (no analogue input pins are needed). It is simple to use, but data collecting needs exact timing. The sensor's major severe issue is that it only gives new data every 2 seconds; sensor values can be up to 2 seconds out of date.

D. Blynk

Blynk, an IoT stage, is utilised to display the patient's information. The Blynk cloud provides live disease nursing in a challenging, professional situation. Additionally, a local server may be used to run it. For instance, the cloud service ensures a live feed of information on the patient's state outside the facility, whether it be within or close to a hospital. It does various more tasks, such as displaying sensor data, recording data, visualizing it, and remotely managing computer hardware.

E. Layout of Blynk app Design

As is shown in pic, at the top of the page, a live graph for exemplifying a live ECG signal is inserted. At the same time, below it, there are three devices for live imagining each Body temperature, the second is room temperature, and the last is room humidity.

IV. RESULT AND DISCUSSION

This scheme is verified on different Patients to screen their health. We collect ECG, heartbeat, humidity, body, and room temperature; all of these tests are taken at different ages of patients. Patients and the details are given in the table 1, and values are plotted on the chart.

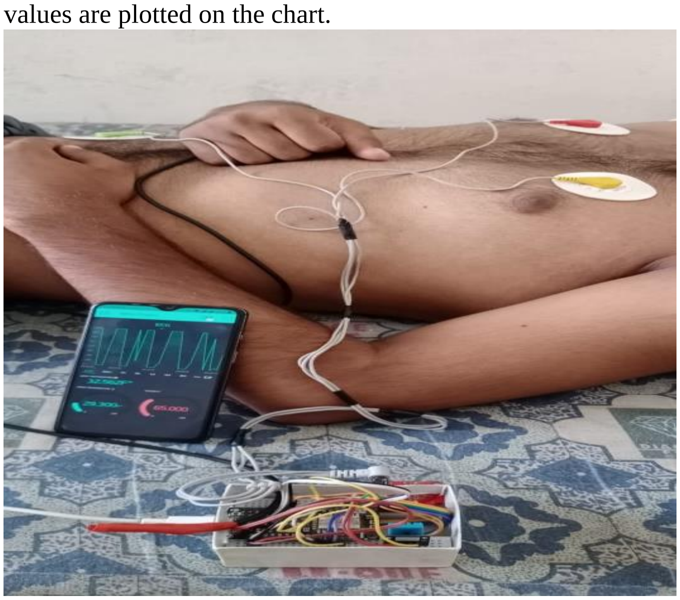

Figure 3: Shows the ECG signal on Blynk mobile app

Table 1: Patient's name details

Sr#	Patients	Heartbeat	Temp (^{0}F)	Body Temp (^{0}F)
1	Patient 1	75	29	20
2	Patient 2	30	37	34
3	Patient 3	75	31	29
4	Patient 4	70	28	35
5	Patient 5	76	29	34
6	Patient 6	65	30	34
7	Patient 7	64	39	34
8	Patient 8	65	30	35
9	Patient 9	75	29	33
10	Patient 10	30	37	34

TABLE 2: Critical Parameters of the ECG monitoring System

Sr	Name	Parameters	Values
1	ECG Sensor	Type Power Voltages Output Voltages	AD8232 3.6 v 0 – 3.3 v
2	WIFI Module	Wireless transmission Protocols Power Voltages Consumption	IEEE 802.11 b/g/n 3.3 v < 71 mA
3	Server	Blynk	Blynk communication
4	Volunteers	Gender Age Height Weight	Male / Female 25 to 55 >150 cm > 60 kg

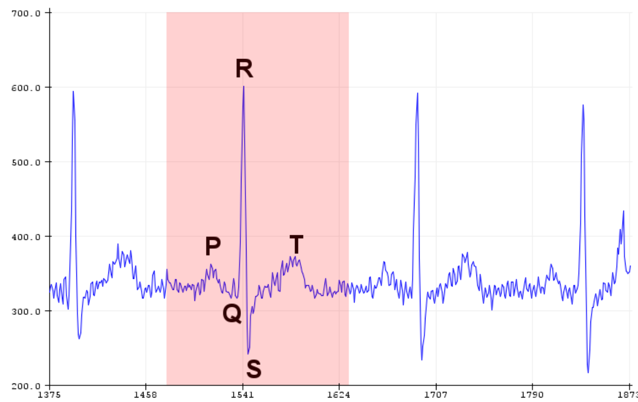

Figure 4: ECG Signals Plot on Arduino IDE.

Figure 3 showing the ECG signal on Blynk mobile app. The amplitude of the ECG is in the microvolt range, and the incidence ranges from 0.01 to 100 hertz. Figure 4 showing the ECG signals plot on Arduino IDE. A bandpass filter and an amplifier are required to display the signal. The frequency range of the bandpass filter is 0.5 to 40 hertz. The most important aspects to discern with an ECG signal are the intermissions between the bats and the form of each pulse. The regular intermissions are the R-R interval (0.6 - 1.2) seconds, the P-R interval (0.12 - 0.2) seconds, the QRS complex (0.08 - 0.12) seconds, and the Q-T interval (0.35 - 0.45) seconds. The "Single-Lead ECG sensor AD8232," an analogue sensor manufactured by Spark fun with a 3.3V operating voltage, is used in this research study. It has three electrodes that can be concealed behind clothing: RA, LA, and RL. LA (Left Arm), RL (Right Leg), and RA (Right Arm). An initial high pass filter with a cut-off frequency of 0.48 Hz serves as the analogue puzzle for this sensor. The second is a low pass sieve that can be used to obtain the necessary bandpass filter. It has a cut-off frequency of 40 Hz. Sensor pins include 3.3V, GND, Output, LO-, LO+, and SDN. The ECG signal is sent through the output pin. The LO- and LO+ pins are connected to the microcontroller to tell it that if one of the three electrodes fails, it is linked to the affected role chest. Whenever a standstill occurs, they send a HIGH signal to the microcontroller. As a result, the microcontroller can deliver an automated warning transmission based on it. Finally, the SDN pin shut off the sensor in order to save battery power. It is an active low pin, and the microcontroller has the ability to switch off the sensor on a regular basis. The most problematic aspect of this sensor is that it requires a rest area to read correctly because it is sensitive to motion.

V. COMPARISON AND DISCUSSION

Researchers have made several attempts to propose and make a healthcare monitoring system based on sensor technology to offer sustainable medical treatments based on various parameters such as purity, low cost, low energy consumption, and real-time feedback. Table 3 compares the material and method, monitoring conditions, proposed technique description, and ECG rate parameters with the current work.

Table 3: Comparison between current work

Ref.	**ECG rate parameter**		**Monitoring**	
	Normal	**Others**	**Real-Time**	**Remote**
[28]	✓	x	X	✓
[29]	✓	x	✓	X
[30]	✓	x	✓	X
[21]	✓	x	✓	X
[31]	✓	✓	✓	X
[6]	✓	✓	X	X
This Work	✓	✓	✓	✓

VI. CONCLUSION AND FUTURE WORK

This study focused on the development of essential prototypes for IoT-based health monitoring systems, particularly an ECG healthcare system for patients with cardiac conditions. The proposed system utilized the Blynk IoT application, enabling clinicians to remotely monitor their patients' cardiac activities. Key strengths of the system included its user-friendly interface, portability, remote accessibility, cost-effectiveness, and rapid deployment. Future enhancements may involve expanding the system by adding more electrodes for improved ECG data accuracy and incorporating additional sensors for measuring parameters such as blood pressure and heart rate. The implementation of a cloud database will facilitate secure storage of patients' health information and medical history. By integrating artificial intelligence, machine learning, and deep learning algorithms, the goal is to automate the analysis of continuous ECG signals, reducing the burden on healthcare professionals and enhancing the accuracy of diagnostic reports. Overall, this research contributes to the advancement of IoT-based health monitoring systems, aiming to improve the monitoring and management of cardiac patients in a more efficient and effective manner.

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