Cost-Effective Wireless Health Monitoring with ARDUINO for Physiological Parameters

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Abstract. The growing demand within the healthcare sector underscores the need for a sophisticated and efficient monitoring system for healthcare facilities, capturing substantial attention from experts. Many hospitals currently rely on manual assessments to compile patient records, leading to drawbacks such as prolonged measuring times, reduced monitoring accuracy, and heightened labor requirements. This paper presents an innovative solution: a wireless health monitoring system leveraging ARDUINO technology, specifically designed for continuous tracking of patients' temperature and heart rate. The system has a transmitter, receiver, and a microcontroller. The transmitter consistently broad-casts the physiological parameters namely cardiac rate and thermic metric using few dedicated sensors. These sensors collect data, the microcontroller processes information from the sensors, and the developed data is conveyed to the recipient. This monitoring system not only addresses the drawbacks of manual as–assessments but also provides the capability to seamlessly measure, analyze, and store patients' physiological parameters. By offering real-time insights, this ARDUINO-based solution contributes to the advancement of healthcare monitoring, promoting efficiency and accuracy in healthcare centers amid the increasing demands of the sector.

Keywords: ARDUINO · Patient Monitoring · Physiological parameters · Receiver · Sensors · Transmitter

1 Introduction

The landscape of our social interactions, lifestyles, and workplaces is undergoing a profound transformation through information and communication technologies. Among the myriad applications of these technologies, healthcare and wellness management stand out as particularly promising. The integration of advanced technology into healthcare monitoring systems has emerged as a pivotal field, promising substantial enhancements in the quality of everyday life. A notable trend in contemporary healthcare revolves around the vigilant observation of health conditions and the proactive management of wellness, recognized as pivotal elements in individual healthcare. This emphasis gains

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heightened significance in developed nations characterized by a substantial aging population, where leveraging technology for healthcare monitoring becomes increasingly crucial.

Importantly, the advancement of cardiovascular disease diagnosis and treatment depends critically on the constant or sporadic monitoring of many biological data. To address this need, the concept of a continuous health monitoring system has emerged. The healthcare industry is currently experiencing a paradigm change from an outdated model to a more contemporary, patient-centered approach. The conventional paradigm places a strong emphasis on the role of healthcare professionals, who must physically visit patients in order to provide critical diagnosis and guidance. However, this approach presents two fundamental challenges: the need for healthcare professionals to be on-site continuously and patients remaining confined to a hospital, tethered to bedside biomedical instruments for extended periods. The proposed system proves highly beneficial to doctors, enhancing health observability, and doctor-to-patient efficiency, and facilitating early disease detection. By leveraging continuous health monitoring, this innovative approach not only overcomes logistical challenges but also contributes to the proactive and timely management of patient health.

2 Human Anatomy

2.1 Human Heart

The heart, a highly specialized muscle, operates with regular and continuous contractions, facilitating the flow of blood via the lungs and throughout the body. The frequency of these contractions per minute is known as the heart rate, a metric influenced by the body's physiological demands, including the requirements for oxygen absorption and carbon dioxide elimination. Heart rate variations can be brought on by a variety of activities, including physical activity, sleep, worry, stress, disease, and drug use.

In a normal, resting state, the heart rate for an adult human typically falls within the range of 60–100 beats per minute (bpm). A fast heart rate, or tachycardia, is defined as more than 100 beats per minute when at rest. On the other hand, a heart rate that is slower than 60 beats per minute while at rest is known as bradycardia. It's important to note that the specific ranges for tachycardia and bradycardia can vary based on factors such as age and overall physical condition. Understanding these variations is crucial for accurate assessment and interpretation of heart rate data in different individuals. As seen in Fig. 1, the vascular organ is made up of four chambers: two lower ventricles (left ventricle, LV, and right ventricle, RV) and two higher atria (right atrium, RA, and left atrium, LA). Through the coronary sinus, inferior vena cava, and superior vena cava, blood from both the upper and lower bodies is delivered to the right atrium. Via the tricuspid valve, the larger, thinner right atrium and right ventricle are connected, enabling unidirectional blood flow. Blood is pumped from the right ventricle to the lungs to replenish oxygen.

Through four pulmonary veins, the left atrium—smaller than the right but with thicker walls—receives oxygenated blood from the lungs. One-way blood flow is made possible by the left atrioventricular valve (bicuspid), which joins the left atrium and left ventricle. The largest artery in the body, the Aorta, is connected to the left ventricle, which is in charge of pumping blood throughout the body.

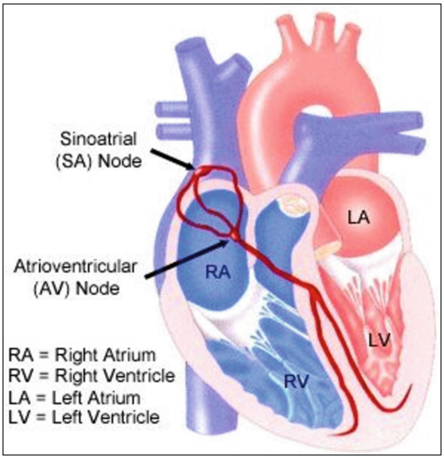

Fig. 1. Anatomical Insight: Cross-Sectional View Revealing the Heart's Chambers

Cardiac Nodes: A cardiac node is a type of specialized tissue that has the ability to behave as both nerve and muscle tissue. Nodal tissue, like muscle tissue, contracts to produce nerve impulses, which are analogous to nervous tissue and travel along the wall of the heart. As seen in Fig. 1, the cardiac conduction system, which drives the cardiac cycle, depends on two essential nodes: the atrioventricular (AV) node and the sinoatrial (SA) node.

Sinoatrial (SA)Node: The heart's pacemaker, also known as the sinoatrial node, is responsible for coordinating the timing of heart contractions. Located in the right atrium's upper wall, this specialized node produces nerve impulses that pass through the heart wall and cause contractions in the right and left atria. Also known as the sinus node, the SA node is the originator of electrical impulses in the heart. These impulses then progress through the heart's cells until they reach the cell cluster known as the atrioventricular node (AV node), which is situated in the middle of the ventricles and atria.

AV Node: Located close to the base of the right atrium, on the right side of the atrial partition, is the location of the atrioventricular node. The impulses from the SA node are delayed by about a tenth of a second before they reach the AV node. This deliberate pause guarantees that the atria contract sequentially, which facilitates the effective emptying of blood into the ventricles. The impulses are then transmitted to the left and right ventricles as well as the central areas of the heart via the AV node via the atrioventricular bundle, a bifurcating fiber bundle.

Heart Rate: In the contemporary global landscape, a significant rise in recorded fatalities is observed, predominantly associated with cardiovascular diseases, sudden cardiac death, hypertension, hemorrhagic shock, and septic shock. Understanding the intricacies of heart malfunctions is crucial, and the heart rate parameter serves as a pivotal metric in this pursuit. Variations in heart rate not only signify potential issues like fatal myocardial infarction and liver cancer but also offer valuable insights into the overall health of an individual. The heart rate, denoting the number of contractions/time unit, expressed as bpm, is among the most critical physiological signals monitored in the human body. Its close correlation with an individual's medical condition stems from its direct proportionality to the body's oxygen absorption requirements. Consequently, healthcare professionals routinely assess heart rate as an integral aspect of medical examinations. Beyond its diagnostic significance, heart rate holds particular relevance as an indicator of an individual's fitness level. This has spurred the interest of numerous athletes who diligently monitor their heart rate to optimize training efficiency. Recognizing the multifaceted role of heart rate, from a vital health parameter to a tool for enhancing athletic performance, underscores its paramount importance in contemporary healthcare and fitness practices.

2.2 Body Temperature

The term normothermia or euthermia refers to the normal body temperature of a human. is influenced by factors such as the measurement location, time of day, and individual activity levels. Although variations exist, commonly cited typical values hover around 36.8 ± 0.4 °C (98.2 ± 0.72°F).

A healthy individual's Body temperature varies during the day by about 0.5 °C (32.9°F), with lower temperatures in the morning and higher temperatures in the late afternoon and evening in response to changing bodily needs and activities. Additional factors, such as the sleep cycle, hunger, sleepiness, illness, or exposure to cold, also impact body temperature. The standard range for normal human body temperature spans from approximately 36.5 °C to 37.5 °C. Any deviation from this range indicates an abnormal condition. Refer to Table 1 for specific temperature ranges correspond-ing to these abnormal conditions is summarized.

Table 1. Clinical Insights: Understanding Body Temperature Ranges and Associated Conditions.

Condition	Temperature Range (°C)	Temperature Range (°F)
Normal	36.1–37.5	97.0–99.5
Fever	>37.5	>99.5
Hypothermia	<35.0	<95.0
Hyperthermia	>37.5 to 38.3	>99.5 to 100.9
Hyperpyrexia	>40.0 to 41.5	>104.0 to 106.7

3 Comprehensive Review of Literature

In earlier times, healthcare professionals faced the challenge of manually recording patient parameters, restricting patient mobility as wireless technologies and sensors were not yet prevalent. The dependence on wired technologies not only constrained patients but also resulted in elevated power consumption, contributing to the costliness of equipment. This manual and wired approach proved to be cumbersome and laborious.

In critical medical scenarios, patients admitted to hospitals underwent treatments employing sensors designed to measure ECG and PPG responses. Traditionally, these sensing systems were wired, creating a connected cardiogram system, as depicted in Fig. 2. Unfortunately, this conventional ECG system posed constraints on patient mobility during monitoring. Fortunately, technological advancements have ushered in wireless solutions, mitigating these limitations and offering enhanced flexibility in patient care.

In the last 10 years, both industry and the scientific community have shown a great deal of interest in the Wireless Health Monitoring System (WHMS). One notable accomplishment was [1]'s development of the Health Tracker 2000, a wireless sensor device. When a user's life is in danger, this cutting-edge technology may quickly notify medical professionals of their location and monitor the user's vital signs showcasing significant advancements in health monitoring technology.

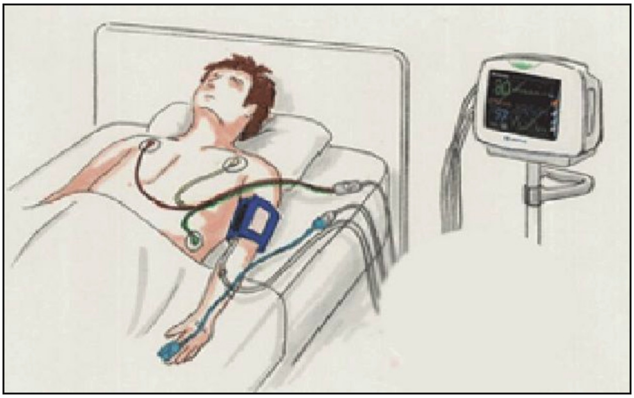

Fig. 2. Conventional ECG System

A mobile healthcare system designed primarily to monitor elderly patients in real-time in various environments, is elaborated upon in [2]. A Smartphone and a biosignal sensor constitute the core components of the system. The Smartphone gathers data from the bio-signal sensor and transmits it to an intelligent server using a GPRS network. This integrated technology makes it easier to remotely monitor the location, mobility, and vital signs of senior patients, underscoring its potential to elevate healthcare services for the aging population.

A system designed for monitoring body parameters on the Windows Mobile platform, as outlined in [3], integrates a body sensor network for measuring and collecting physiological data. As confirmed by the authors, the system effectively transfers data from the sensor network to a mobile device by utilizing Bluetooth technology, demonstrating resilience and dependability. Experimental results substantiate the system's effectiveness in monitoring physiological data even under conditions of mobility.

An alternate method introduces a complete Wireless Body Area Network (WBAN) system, as described in [4]. This system collects physiological data from sensor nodes using specific medical bands chosen carefully to reduce interference with other network equipment. To connect sensor nodes to the Internet or a local area network, a medical gateway wireless board is included, and multi-hopping is used to increase the operational range. This gateway enables the ability for medical personnel to easily access patients' physiological data at anytime and from any location leveraging the Internet for continuous connectivity.

Numerous systems for measuring health rely on portable sensors that continuously produce data and may lead to numerous false alerts, rendering them unsuitable for clinical use. To address this issue, there have been various proposed machine learning techniques in [5]. These methods involve integrating clinical observations with wearable sensor data to provide patients with early alerts for major physiological changes. These methods' effectiveness has been evaluated at Oxford University Hospital, that demonstrates the system's success in integrating data from wearable sensors. This integrated information, when combined with manual observations, assists clinical staff in making crucial decisions about patient care.

In [6], cloud computing is integrated into a healthcare system, presenting a proposed Intelligent Healthcare Monitoring System (CIHMS), cloud-based, for providing patients with online bio-signal input. Using cloud computing equipment, the system gathers pertinent data about a patient's condition and sends it to a remote location, Show-casing the potential for efficient data management and remote healthcare delivery.

A full description of a remote healthcare system that monitors temperature and electrocardiogram data may be found in [7]. The three parts of the system—a hardware module for data collection, a Bluetooth module for data transfer, and a display module for data presentation— collect clinical data efficiently. Using Wi-Fi or GPRS, the collected data are sent to a database server. Comprehensive testing on various patients has demonstrated the system's effectiveness, proving to be a valuable tool for physicians.

In [8], A mobile device-based real-time ubiquitous healthcare system is introduced to monitor ECG signals. Users can conveniently monitor their ECG signals through this system, comprising an abnormal heartbeat check map and an algorithm for detecting abnormal heartbeats. Examining the system against a database of normal arrhythmias shows that it obtains an impressive success rate of 97.8% in detecting R-peaks and 78.9% in identifying abnormal heartbeat conditions.

A wireless electrocardiogram (ECG) monitoring system based on Bluetooth Low Energy (BLE) technology is proposed [9]. The system integrates a single-chip ECG signal acquisition module, a Bluetooth module, and a smartphone. An Apple iPhone 4S, equipped with Bluetooth v4.0, Wi-Fi, and iOS, serves as the mobile platform. ECG signals are acquired using a 2-lead sensor, wirelessly transmitted via BLE, and processed and displayed on the smartphone in real-time. The results highlight that BLE technology not only removes the physical limitations of wired connections but also significantly reduces power consumption, making it highly suitable for continuous long-term ECG monitoring.

In [10], the authors present a blood pressure measuring gadget that is wireless and uses Bluetooth to send blood pressure readings to an intelligent mobile device. The device replaces traditional analogue signal processing and filtering circuits with a digital filter on the cuff, achieving an astounding 93.52% accuracy in sick individuals.

and 94.53% accuracy in healthy individuals.

In another work [11], a software-intensive algorithm is developed to eliminate noise resulting from subject movements while simultaneously monitoring the heart rate of a single rat (four rats). The signals are digitized using a Schmitt-trigger circuit and monitored using Commodore CBM microcomputer and IBM CS9000.

Furthermore, [12] introduces a multi-tasking control system for monitoring ECG using real-time algorithms. This system adjusts priority levels of biomedical signals, demonstrating an advanced approach to real-time monitoring. [13] Introduces an innovative approach that evaluates users' comprehensive health status, and also addressing the performance challenges encountered in mobile applications. Using long short-term memory (LSTM) technology, the innovation is known as Intelligent Personal Health Monitoring and Guidance (IPHMG). Several authors have developed hardware based products along with algorithm based monitoring viz., a sensor based Personal health Monitoring System and Guidance with embedded controllers 14, processors and arrhythmia-related heart disease predictor with Support vector machine support [15].

This paper addresses issues and suggests solutions while offering a thorough analysis of the many uses of fog computing in healthcare systems [16]. Here, the writers have combined data analytics and fog computing to improve healthcare delivery by providing higher-quality care. Integration of Augmented Reality (AR) systems as intelligent tools in healthcare for monitoring the daily activities of individuals, allowing early diagnosis of chronic diseases, and boosting overall quality of life has been addressed [17]. The goal of this research is to improve Activity Recognition's accuracy in comparison to current techniques. Researchers have developed prototypes for a range of applications, including activity recognition intelligent systems [18], smart alert systems tailored for coal mine workers, assistive technologies designed for visually challenged individuals, smart dustbins specifically addressing Covid-19 environments, enhancing women health, Telepresence Robotic System and Smart Street Lights leveraging ARDUINO [19–24] as their primary component.

In summary, most researchers have focused on developing or modeling monitoring systems capable of measuring a single biological signal as a health parameter, such as electrocardiograph signals, epilepsy monitoring, or body temperature. However, existing systems face two primary challenges. The patient must, first and foremost, always be physically present with healthcare providers. And moreover patients are often confined to hospitals, tethered to bedside biomedical instruments for extended periods. Moreover, the current systems struggle to monitor different parameters simultaneously.

This paper is structured into the following sections. A brief synopsis of the human heart is provided in Sect. 2, and a thorough analysis and summary of pertinent literature are provided in Sect. 3. Technical specifications for the development of the prototype model are outlined in Sect. 4, followed by an overview of the proposed system in Sect. 5. The system's circuit diagram, test approach, and programming details are presented in Sects. 6 and 7, respectively. Section 8 delves into the experimental results, providing analysis and discussion. Conclusions are drawn in Sect. 9, followed by insights into future prospects and a comprehensive list of references.

4 Proposed System Overview

The designed and developed proposed system aims to monitor patients' health remotely, utilizing wireless communication within a range of 10 m. The primary objective of this system is to track the thermic metric and cardiac rate of the patient, with the collected data transmitted to the doctor via Bluetooth technology for timely assessment and intervention.

The block diagram depicted in Fig. 3 comprises sensors (LM35 temperature sensor and IR sensor), Arduino microcontroller, Bluetooth module, and a Smartphone. The patient's thermic measure and cardiac rate are measured using the LM35 temperature sensor and cardiac rate sensor respectively. The sensor data is then relayed to the Arduino microcontroller, where the built-in ADC converts the information into digital values for processing. Afterward, the processed data is then sent over the Bluetooth module.

On the receiving end, a Smartphone functions as the display device. The parameters transmitted through Bluetooth are received by the Smartphone's Bluetooth receiver. The received information is presented on the Smartphone using the Bluetooth Viewer.

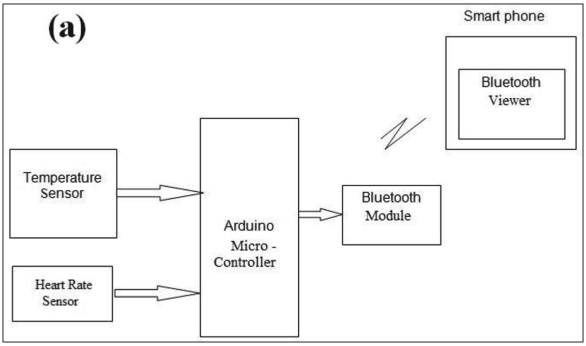

Fig. 3. Block Diagram of Proposed System

Figure 4 illustrates the circuit connections among the sensors, Bluetooth module, and Arduino. The device uses an IR module and an LM35 temperature sensor to measure the cardiac rate and thermic metric of the human body. Upon circuit activation, the user manually selects the person's age using the designated push buttons on the board. Each button corresponds to a specific age group since heart rate varies with age. Following the proper age group selection, the patient holds the sensors, with one fingertip on the IR module and the LM35 firmly held between the fingers.

The sensors capture information, which is then transmitted to the Arduino. The Arduino processes the received data, performs necessary calculations, and displays the results on their respective scales. The HC-05 Bluetooth module is then used to send the processed data to the mobile device, or Smartphone. On the receiving end, the information is displayed using the Android application, namely Bluetooth Viewer LITE. The LEDs on the board visually represent the patient's heart rate condition, with each LED indicating a particular condition as specified.

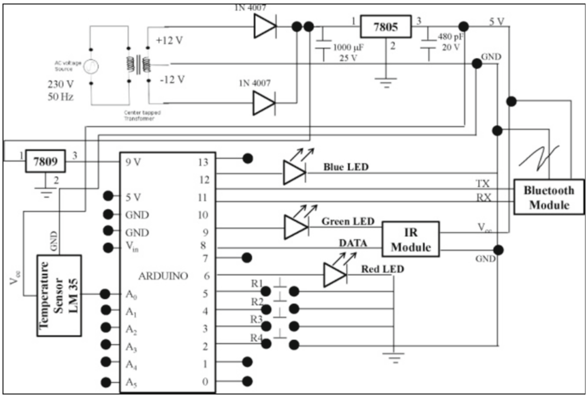

Fig. 4. Proposed System – Circuit Diagram

5 Prototype Test Approach

The suggested system's prototype is shown in Fig. 5, and the section that follows provides specifics on how it works.

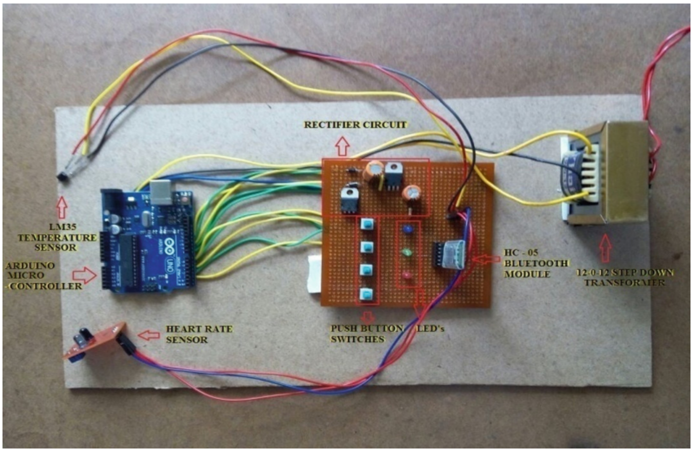

Fig. 5. Prototype model of the proposed system.

- The board is powered by an AC power supply, which is converted to 9 V and 5 V using LM7809 and LM7805 voltage regulators, respectively.
- The Arduino UNO is supplied with 9 V, while the sensors and Bluetooth module are powered by 5V.
- The regulated power supply is where the LM35 temperature sensor and heart sensor get their power and ground connections from.
- To find the patient's body temperature, connect the DATA pin of the temperature sensor to the A0 pin of the Arduino.

- The IR module, four push button switches, and three LEDs (Red, Green, and Blue) make up the cardiac rate sensor.
- The DATA pin of the IR module is linked to pin8 of the Arduino.
- The push button switches enable manual selection of age groups by pressing the switches. The four switches correspond to four different age groups.
- Starting from the lower age group, the first push button is assigned to children aged 6 to 12 years, and it is connected to pin 2 of the Arduino.
- The second push button is designated for teenage individuals aged between 13 and 20 years, connected to pin 3 of the Arduino.
- The third push button is allocated for adults aged between 21 and 34 years, connected to pin4 of the Arduino.
- The fourth push button is assigned for middle-aged adults aged between 35 and 52 years, connected to pin 5 of the Arduino. The person's age can be selected by depressing the appropriate push button at any given time.
- The three LEDs signify the three heart rate conditions: Bradycardia, Normal, and Tachycardia.
- Bradycardia is the condition in which the red LED, is attached to pin 6 of the Arduino, lights.
- When the heart rate is normal, the GREEN LED, which is attached to pin 9 of the Arduino, glows.
- When the heart rate is elevated (tachycardia), the BLUE LED, which is attached to pin 12 of the Arduino, illuminates.
- The Bluetooth module (HC-05) has 6 pins (STATE, RX, TX, GND, +5 V, EN). The STATE and KEY pins are not used.
- The VCC and GND of the regulated power supply output are connected to the + 5 V and GND pins of the Bluetooth module. The TX and RX pins of the Bluetooth module are connected to pins10 and 11 on the Arduino, respectively.
- After completing the proper connections, the Arduino is programmed using the ARDUINO IDE software platform.
- After successful programming, the Bluetooth module HC-05 needs to be paired with the Smartphone using the Bluetooth Viewer application.
- The transmitted parameters are then displayed on the Smartphone screen, as depicted in Fig. 6.

6 Arduino Programming

The body temperature in ° Celsius and the cardiac rate in beats per minute (bpm) are computed by the Arduino code every five seconds. It then displays the person's age group, body temperature, and heart rate on Bluetooth Viewer. The code is divided into three parts:

a. Code for LM35 Temperature Sensor.
b. Code for Heart Rate Sensor.
c. Code for Bluetooth Module.

To facilitate serial communication between the HC-05 module and the Arduino, the inclusion of the SoftwareSerial library is crucial. The HC-05 module serves as an accessible Bluetooth Serial Port Protocol (SPP) designed for serial communication via pins 10 (transmit data) and 11 (receive data) on the module. The "mySerial.println" command is employed to display data on the Bluetooth device, while "Serial.println" is used to print data on the Serial monitor. The primary code is written within the void loop () function to ensure the repetition of the process.

6.1 Calculation of Heart Rate in bpm

In the code, 'k' represents the count value, incrementing from k = 0 as the sensor detects values. When the count reaches its maximum value (k = 5), it resets, and the rate is calculated for each second, i.e., Rate = rate/5.

Number of beats per minute can be as Rate in bpm = 60000/rate;

To calculate the heart rate for different individuals, considering variations across age groups, push button switches are incorporated. The "digitalRead (_)" function is utilized to capture signals from these buttons:

- "digitalRead (2)" is designated for ages between 6–12 years.
- "digitalRead (3)" is assigned for ages between 13–20 years.
- "digitalRead (4)" is allocated for ages between 21–34 years.
- "digitalRead (5)" is utilized for ages between 35–52 years.

Considering average heart rate ranges, the code then outputs either "Normal," "Tachycardia or "Bradycardia" accordingly.

6.2 Calculation of Body Temperature

The output of the LM35 temperature sensor is measured in 'mV'. Typically, temperature is expressed in degrees Celsius or degrees Fahrenheit. To convert mV to ° Celsius, (1) is employed in the ARDUINO code for the temperature sensor.

$$\left(\frac{supply\_Voltage}{1024}\right)\Big/10 \tag{1}$$

where, Supply_Voltage is 5.0 V (the voltage required to power the LM35 sensor); 1024 is 2^10 (the analog value that the ATmega microcontroller can represent) or 1023 (its highest value). The voltage obtained by Supply_Voltage/1024 is the actual voltage in millivolts (mV). To change the unit from mV to volts (V), the actual voltage is multiplied by 1000; 1010 is a constant, as every 10 mV is directly proportional to 1 °C. For example, if the Supply_Voltage is 5.0 V, the number we get using (1) is 0.48828125. On the other hand, If 4.5 V is used as Supply_Voltage, then using (1) 0.439453125 is got. Moreover, using (2) the temperature can be converted into degree Fahrenheit.

$$^{\circ}\mathrm{C}x\left(\frac{9}{5}\right) + 32 =^{\circ}\mathrm{F} \tag{2}$$

7 Results and Discussion

The output of the body temperature is measured in degrees Celsius, and the IR sensor senses the heart rate in beats per minute (bpm), which is displayed on the Bluetooth viewer as illustrated in Fig. 6(a). Furthermore, the age group of the person and the heart rate condition (Bradycardia/Tachycardia/normal) are also displayed on Blu- etooth Viewer. If the heart rate is too slow, below 60 bpm, it is considered Bradycar-dia. Trained athletes may exhibit Bradycardia with heart rates below 40 beats per minute. The blazing red LED in Fig. 6(b) indicates that the test subject's heart rate is sluggish. Generally, a heart rate between 60–100 bpm is considered normal. An individual's age, body size, cardiac condition, posture (either sitting or moving), use of medications, and even the temperature of the surrounding air all affect their typical heart rate.

The normal heart rate varies across age groups: it ranges between 70–100 bpm for children, 60–100 bpm for teenagers, and 90–150 bpm for adults. For instance, a normal heart rate for an adult may be 147 bpm, which is considered within the normal range. In Fig. 6(c), the green led is shown glowing in the heart rate circuit, indicating that the person being tested, with their index finger on the IR sensor module, has a normal heart rate.

If the heart rate is too fast, typically exceeding 100 bpm, it is classified as tachycardia. The occurrence of a fast heart rate depends on factors such as age and physical condition. For example, during physical exertion or running, a person may experience a fast heart rate (tachycardia). Figure 6(d) displays the blue led glowing in the heart rate circuit, signifying that the person being tested, with their finger on the IR sensor module has a fast heart rate.

The normal heart rate of a healthy individual typically falls between 70–120 bpm. However, various physiological factors contribute to heart rate variations among individuals and across different age groups. Table 2 presents the normal heart rate and the measured heart rate of individuals belonging to various age groups, ranging from lower age group (6–12 years) to upper age group (35–52 years).

8 Conclusion

A wireless health monitoring system has been designed, developed, and thoroughly tested, demonstrating proficiency and user-friendliness in all aspects. The proposed system is cost-effective, making it accessible to the general population. The remote patient health monitoring system employs Bluetooth technology to relay real-time physiological parameters, such as temperature and heart rate, to medical professionals in case of emergent situations when monitored values deviate from normal ranges. The system enables doctors to receive alerts on abnormal heart rates through their Smartphone's, facilitating timely corrective actions. The implemented model for temperature and heart rate monitoring has been successfully deployed and evaluated on patients across different age groups.

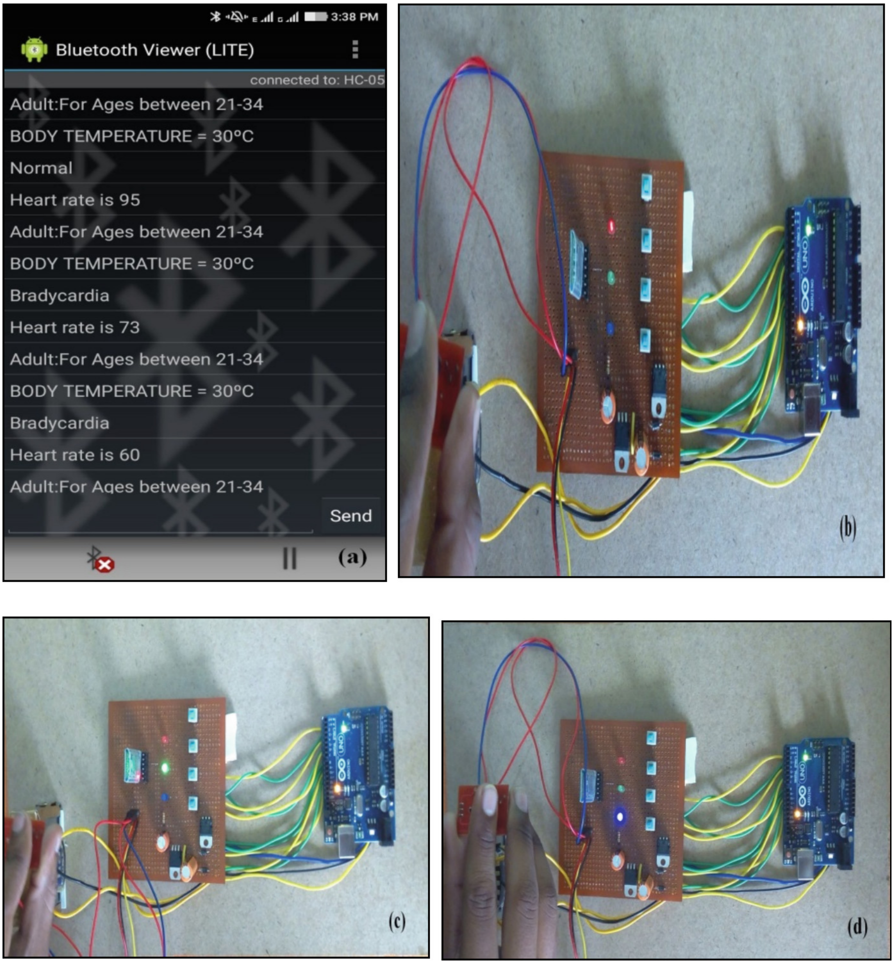

Fig. 6. a) Output displayed on a smart phone (b) LED indication of Bradycardia (c) LED indication of normal heart rate (d) LED indication of Tachycardia.

Table 2. Experimental results for different age groups

Age (Years)	Normal Heart Rate (bpm)	Measured Heart Rate (bpm)
6–12	36.1–37.5	97.0–99.5
13–20	>37.5	>99.5
21–34	<35.0	<95.0
35–52	>37.5 to 38.3	>99.5 to 100.9

9 Expansion Opportunities

Implementing this patient monitoring system not only enhances application performance but also reduces power consumption. The system's capabilities can be extended to enable patient detection over longer distances in the future, leveraging Zigbee Technology. Furthermore, the developed system can be expanded to monitor additional physiological parameters. Consideration may also be given to incorporating a voice alert system to signify when measured parameters exceed predefined limits.

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