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Article

A Health Monitoring System Using IoT-Based Android Mobile Application

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Abstract: Numerous types of research on healthcare monitoring systems have been conducted for calculating heart rate, ECG, nasal/oral airflow, temperature, light sensor, and fall detection sensor. Different researchers have done different work in the field of health monitoring with sensor networks. Different researchers used built-in apps, such as some used a small number of parameters, while some other studies used more than one microcontroller and used senders and receivers among the microcontrollers to communicate, and outdated tools for study development. While no efficient, cheap, and updated work is proposed in the field of sensor-based health monitoring systems. Therefore, this study developed an android-based mobile system that can remotely monitor electrocardiograms (ECGs), pulse oximetry, heart rate, and body temperature. The microcontroller's Wi-Fi device is used to manage wireless data transport. The findings of the patient are saved on the Firebase server for further usage in the mobile app. The performance of the proposed device is tested on ten numbers of different patients age-wise in terms of beats per minute (BPM), ECG, Temperature, and SpO_2. This system uses temperature, pulse, ECG, blood pressure, and eye blink sensors. This device makes the usage of a tiny pulse sensor that has been designed to provide an accurate and optimal readout of the pulse rate and a temperature sensor is also included. With the help of an MCU, our system measures the pulse rate in beats per minute (bpm), blood oxygen level temperature measurements, and ECG readings and communicates this information to the Firebase server. To check the performance of the proposed system first, the BPM parameter was checked on the cardiac monitor. Then, the proposed model is tested on different patients age-wise. The simulation result shows that the BPM reading is not much different than the BPM of the cardiac monitor. According to the simulation findings, the proposed model achieved the best performance as compared to commercially available devices.

Keywords: ICUs; DS18B20 sensors; SpO_2; AD8232 sensors; ECGs; Internet of Things

1 Introduction

Cardiovascular disease is the leading cause of death in many nations, accounting for more than fifteen million losses of life worldwide. Cardiovascular disorder rhythm affects a large number of people [1]. The interval between the beginning of any cardiac symptom and the decision to seek medical help has a large variation among exceptional people and can have serious effects. Because many people suffer from coronary heart disease and it is critical to monitor the patient's health daily and requires higher level checkups. Many methods for observing a patient have been developed, but each application differs from the others in terms of producing accurate findings. Numerous types of research on healthcare monitoring systems have been conducted such as [2] developed a health-monitoring system for calculating heart rate and respiration. The authors in [3] developed a technique for remotely monitoring a patient's health. Likewise, in [4], the authors used heart rate, electrocardiogram, nasal/oral airflow, temperature, light sensor, and fall detection sensor. A dynamic and compact IoT system was developed by [4] that includes a pulse oximeter, ECG, nasal/oral airflow, temperature, light sensor, and fall detection sensor. They can only see the records for indoor location, fall detection, and light sensor data. The results of the other sensing devices were also investigated inside the experiments. They use the Raspberry Pi 2 single-board microcontroller on front-end modules, which is powered by 3.7 V Li-Ion batteries.

Similarly, an ICU-based real-time IoT surveillance system has been suggested by [5,6] have developed a monitoring system for electrocardiography (ECG), blood pressure, heartbeat, and body temperature. They broadcasted the corresponding information to the health organizations through Global System for Mobiles (GSM), Global Positioning System (GPS), and online mediums in case of unexpected behaviors, allowing for quick intervention to rescue patients. A method was designed by [7] that uses the IoT to track patients that were based on two sensors like a temperature sensor (LM35) and a cardiac rate sensor (KY039), which are connected to the Arduino board's microcontrollers. Also, in [7] a robust system was proposed in which the temperature and heart rate sensors were utilized, as well as an Arduino Uno with an ethernet shield and indications like a buzzer and LEDs. Similarly, in [8], the authors have presented a method that uses the IoT to monitor patients' health. It is necessary to visit hospitals frequently for routine checkups. This has become a cost-effective and time-consuming strategy, particularly for elderly people. Most of the previous studies have used different parameters for IoT-based monitoring systems such as [4] using ECG and BPM checking parameters. Another study [6] used GPS and GSM technology for IoT healthcare monitoring and tracking system which check three parameters such as temperature, ECG, and BPM. Similarly, in [9] the author developed a mobile application which only used for heart rate monitoring. Further, the author in [10] developed a patient monitoring system based on IoT which monitors the temperature, ECG, and BPM. Furthermore, [11] developed a patient monitoring system that only monitors temperature and BPM. Similarly, [12] developed a smart alert device for health monitoring which uses BPM and Server Database. Another study in [13] developed IoT applications to prevent COVID-19 which use SpO_2, temperature, BPM, and mobile applications. While in [14] the author developed a patient healthcare prediction monitoring system which uses SpO_2, temperature, and BPM.

Therefore, this study proposed an IoT-based Android mobile application for health monitoring systems for smart ICUs. The goal of this research is to determine which method is best. In healthcare, critical patients are treated in ICUs. Because of the critical nature of the problem, physicians must keep a close eye on the patients. The IoT has recently grown in popularity, allowing all devices to be connected and recognized as a technical revolution. However, this research used IoT-based Android mobile technology to remotely examine the patient's medical information and provide treatment recommendations to the hospital personnel. This proposed system includes a monitoring gadget that takes readings from the patient's various health markers. A heartbeat sensor and a temperature sensor are included in this system. As the Firebase server receives the data from the microcontroller, then the data will be updated accordingly and saved the data along with the doctor's remarks in the Firebase database. This system also includes a blueprint for fabricating the patient's health monitoring system that uses sensors to measure health indicators. This study also tries to construct a smart system that integrates IC and internet platforms to observe and do research in the field of biotelemetry devices, (known as PPG Photo plethysmography). Different standards are linked with coronary heart monitor structures. Fig. 1 shows the use of the proposed system in health care. This architecture shows how the IoT works.

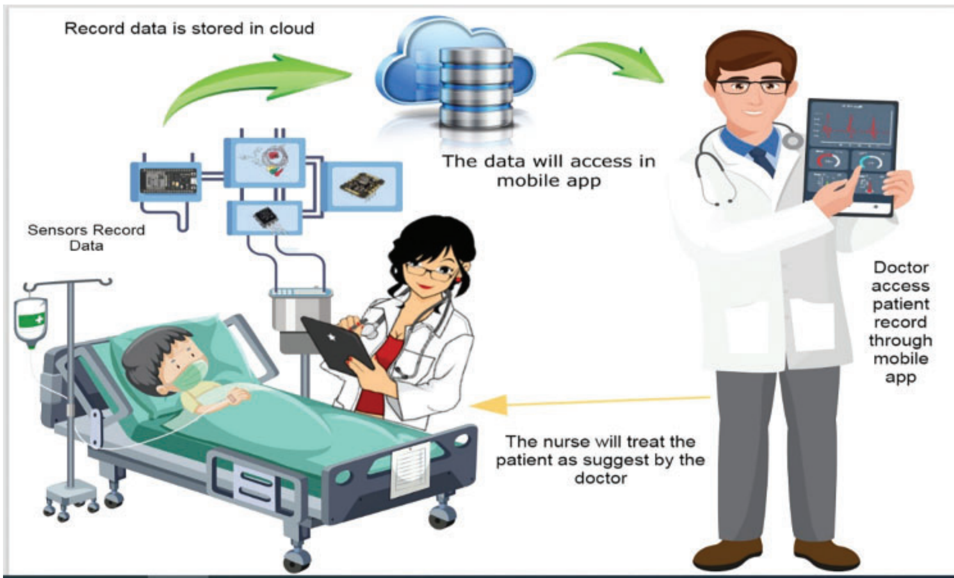

Figure 1: IoT in healthcare

First, the sensors get the patient data and then sent it to the IoT cloud server. From the cloud, the data is sent to the doctor. Then the doctor sends instructions on any emergencies to the nurse, and the nurse treats the patient accordingly. The suggested framework can be accessed at any time and from any location. Our study has the following significant contributions.

- Creation of IoT-based cardiac monitoring framework.
- Development of an Android-based mobile application for the smart ICU mentoring system.
- Usage of various open-source technologies for the designing of the framework.
- Intelligent analysis of cardiac parameters.

The rest of the paper is organized as given. Section 2 gives the Literature Review of this study. While Section 3 explains the methods and material used in this paper. Section 4 discusses the methodology of this paper. Similarly, Section 5 elaborates on the result and discussion of the paper and finally, Section 6 gives the conclusion of this research with some future directions.

2 Literature Review

This section summarizes the findings of many researchers in the fields of healthcare and IoT-based applications. The majority of the researchers employed lower-frequency devices, and the healthcare trials used one or two health indicators. Certain publications rely just on GSM, which gives a basic information response that only communicates the facts and does not alert the user if the reading is acceptable or unexpected, nor does it have any storage facilities to preserve the data for later use.

In [5], the authors developed an IoT-based real-time tracking system for ICU. This research created a system that connected multiple sensors and physical objects over the internet. Humans may attain optimum efficiency by utilizing IoT technology and to achieve this statement, lots of sensors, platforms, databases, personal digital assistants (PDA), and artificial intelligent operators are employed to evaluate and exchange information from monitors or even other wearable technologies. The authors of [15] suggested a sensor-based IoT system that is used to analyze the patients' inputs and save the input parameters in a database. IoT sensors were utilized to determine the pulse rate in this system. The servers were used to keep track of the medical records of both the patients and doctors. The sensor identifies abnormal changes in the patient and may be used to treat them remotely.

On the other hand, the authors of [7] have developed a technique that uses the IoT to track patients. Two sensors, a temperature sensor (LM35) and a cardiac rhythm sensor (KY039), are connected to the Arduino board's microcontrollers. Arduino UNO R3 is utilized as a coding platform. A Wi-Fi module is linked to the web. Internally, there is a micro-SD card socket and signals such as buzzers and LEDs were also available. The dynamic temperature and cardiac rate parameters were adjusted and updated during the 3 s refresh interval. Although, in [6], the authors have developed a monitoring system using different parameters such as ECG, blood pressure, heartbeat, and body temperature which share this information with the health experts through GSM, GPS, and communications platforms in case of unexpected behaviors, allowing for quick intervention to rescue patients. Sensors gather patient records, match them to threshold levels, sound an alert if an irregularity occurs, show an LCD, deliver a warning to the patient's phone detailing the patient's status, and subsequently offer GPS coordinates. For roughly 15–30 min, maintain the modem in the viewpoint of the sky to activate GPS and a SIM (Subscriber's Identity Module) must be inserted into a GSM phone for communication. Likewise, in [15], the authors have presented a cardiac monitoring system, which comprises a heart rate sensor, Arduino board, and Wi-Fi devices respectively. The heartbeats sensor detects heart rhythm findings and displays the individual's pulse on the digital display. They also used the Wi-Fi device for data communication over the internet. The gadget emitted an alarm if the cardiovascular readings fall above or below the set parameters, indicating a high or low beating.

Moreover, the authors of [9] have developed a method that uses the IoT to monitor patients. This program includes temperature, pulse, ECG, hypertension, and eye blink sensors. Measurement results were controlled by a microcontroller and displayed on a display screen. The findings will be saved on the cloud. Any changes in health problems can be noticed instantly and sent to a specific individual using GSM technology or the internet. In [10], the authors have designed a method on two Arduino devices. The temperature and heart rate sensors, as well as a rechargeable battery and an nRF (transmitter) which delivers data to another terminal, make up 1st Sender. The second device, which includes a display and an nRF receiver receives the corresponding data from the first device and displays it on the screen. A warning system for intelligent patient monitoring has been developed [11]. This gadget was also linked with thing speak Cloud for data analysis through a Wi-Fi-based microcontroller. The output from the pulse oximetry sensor is sent to the cloud/database by the microcontroller. If an irregularity is identified, the process utilizes the Global System for Mobile (GSM) and buzzer to notify a family or professionals.

Recently, [12,15,16] discussed IoT-based smart health monitoring systems, particularly for COVID-19 patients. The IoT-based system described in this paper uses the patients' measured body temperature, pulse rate, and oxygen saturation to provide real-time health monitoring. This device contains a liquid crystal display (LCD) that can be readily synchronized with a mobile application to provide rapid access to the observed temperature, pulse rate, and oxygen saturation level. The suggested IoT-based approach makes use of an Arduino Uno-based setup. Furthermore, [13] presents an article that discusses enhancing healthcare through the detection and prevention of COVID-19 using mobile-based IoT. High temperature, a throat infection, and an abnormal heartbeat are the main signs of COVID-19. This paper describes an integrated wearable device that uses NodeMCU ESP8266 and several sensors to assess temperature and heartbeat in real time. The DHT11 sensor is used to measure temperature, while the pulse sensor is used to measure heartbeat. The NodeMCU ESP8266 reads data from sensors and processes it before sending it wirelessly to the Firebase database (Wi-Fi module). The data are shown in an Android application from the database. The user and administrator are informed about the user's present health based on specific circumstances in the data. Besides, [17,18] discussed IoT-based smart healthcare systems for asthma patients. The suggested system is made up of several sensors that gather information on the user's heart rate, body temperature, ambient temperature, humidity, and air quality. The information is then processed by an Arduino microcontroller and is coupled with a mobile application. A Bluetooth module transmits all this information to the mobile application, which updates it every few seconds so that the medical personnel can immediately track patients' status and emergencies.

To forecast urinary infectious disorders such as diabetes, cystines, hepatitis, liver disease, etc., Anan et al. deploy an IoT-based home system [19]. This [20] study explores the potential of IoT in monitoring human health using disease management, patient experience, effective treatment, and the function of 5G in communication. In a study by the Kondaka research team, the topic of machine learning's use in analyzing and managing cloud data for precise disease prediction is covered. The shortcomings in IoT smart health systems can be reduced by using deep learning strategies [21]. Kondaka et al. conducted a thorough study on the effectiveness of big data analytics combined with machine learning to address issues such as cloud security, storage allocation, communication delay, data retrieval, etc. [22]. Through machine learning techniques, IoT systems forecast an individual's future behavior by analyzing their actions, gestures, and other health-related indicators [23]. Manocha et al. in [24] presented an IoT/WSN-based cloud system for the diagnosis and treatment of cancer patients, concentrating on key issues like efficiency and security. With the aid of eight distinct learning algorithms that help to differentiate the symptoms of the common cold from those of COVID-19, another IoT system was created for the detection of prospective COVID-19 patients [25].

For ambulances and other emergency help to get to patients' locations, a study discusses the usage of IoT systems for patient monitoring in smart cities [26]. Poongodi et al. created a wearable Internet of Things health monitoring system with its body area network where several sensors continuously record and measure information [27]. All IoT technology was either installed in a hospital, a house, or a wearable, therefore in each of these application areas, the system has some issues. Wan et al. goes over some of the elements that must be taken into account when creating and putting into practice an automated IoT health monitoring system, including network traffic, intelligent computing, big data analytics, and IoT layer architecture [28]. When an IOT-based health monitoring system is developed, certain significant problems arise, most notable incidents of patient information exploitation, cybercrime, data aggregation, etc. [29]. The primary goal of tracking COVID-19 instances is to help the government track the patients and stop the disease from spreading, which would be accomplished with the use of an IOT-based tracking system [30]. With the use of big data on biological signals, real-time monitoring of COVID-19 patients may reduce the number of COVID-19 transmission instances [14]. In [31] the article discusses the use of cryptographic algorithms, such as

Rivest Cipher (RC6) and Elliptic Curve Digital Signature Algorithm (ECDSA), as an efficient access control mechanism for an Internet of Medical Things-based health care system. The algorithms are used to generate key values and encrypt them for enhanced security, data integrity, and availability, as well as confidentiality. Experiments and simulations have shown the proposed system to be more secure against various known attacks. Similarly, in [32] this paper proposes an IoT-based Fog-assisted deep learning network architecture to remotely monitor and analyze healthcare data from patients for sustainable smart cities, with performance measures of 97.6%, 97.9%, and 94.9% accuracy, precision, and sensitivity respectively. Further, in [33], the authors proposed an IoT-based Healthcare Cyber-Physical System that uses Homogeneity Score-based K-means clustering, text mining, and sentiment analysis to provide effective resource utilization and cost-effective task scheduling at the Fog level and cloud level. From the results, it is evident that the proposed work IoT-HCPS outperformed the existing techniques and algorithms. In [34] the author describes an Adaptive Malware Analysis Dynamic Machine Learning (AMDML) algorithm for content-aware heartbeat data in fog cloud computing, which can detect malicious intent in healthcare data and outperform existing machine learning malware analysis models in terms of accuracy, delay, and detection of original heartbeat data. Another study in [35] proposes a blockchain-enabled IMoT system with cost, deadline, and security constraints, named BECSAF, which minimizes latency and execution cost while reducing security risk compared to existing studies in the IoMT system for healthcare applications. Similarly, [36] proposed a cost-efficient blockchain task scheduling (CBTS) cyber-physical system (CPS) for Industrial Internet of Healthcare Things (IIoHT) applications. The proposed CBTS framework sorts, schedules, and stores the tasks in a secure form in the IIoHT network. Simulation results show that the CBTS framework outperforms existing scheduling and blockchain schemes, reducing security execution costs by 50% and blockchain costs for cybersecurity data validation by 33%. The proposed work is a great contribution to the healthcare industry, as it can reduce the cost associated with security and deadline while improving the security of healthcare applications.

In [37], the authors presented the mobility-aware security dynamic service composition (MSDSC) algorithmic framework for workflow healthcare, using serverless, and restricted Boltzmann machine mechanisms. It suggests a stochastic deep neural network to train probabilistic models for service composition, task sequencing, security, and scheduling. Experiments reveal that MSDSC outperforms traditional methods by 25% in terms of safety and 35% in application cost. Table 1 gives a comparative study of the state-of-the-art models.

Table 1: Comparative study

Developed systems	System functionality					
	SpO_2	Temperature	ECG	BPM	Server database	Mobile application
[4]	×	×	✓	✓	×	×
[6]	×	✓	✓	✓	×	×
[9]	×	×	×	✓	×	✓
[10]	×	✓	✓	✓	×	×
[11]	×	✓	×	✓	×	×
[12]	×	×	×	✓	✓	×
[13]	✓	✓	×	✓	×	✓

(Continued)

Table 1 (continued)

Developed systems	System functionality					
	SpO_2	Temperature	ECG	BPM	Server database	Mobile application
[14]	✓	✓	×	✓	×	×
Proposed system	✓	✓	✓	✓	✓	✓

3 Materials and Methods

3.1 Microcontroller

A microcontroller is a small computer that is built into a single integrated circuit. It's a component that's built into a system to do a certain task. On a single chip, a microcontroller has a CPU, main memory, and input/output ports. Microcontrollers are commonly utilized in devices that are automatically controlled. Microcontrollers are used in the majority of IoT initiatives. As a microcontroller, this study will utilize Node-MCU in our suggested system. The Node-MCU is a low-cost open-source IoT board. It comes with a built-in Wi-Fi module. This study uses ESP32 as a main Microcontroller, for which the specifications are described below:

The ESP32 features two processors, making it dual-core. Which runs 32-bit applications and has built-in Wi-Fi and Bluetooth.

- The clock frequency can go up to 240 MHz and it has 512 kB RAM.
- Developed by Espressif Systems, in Shanghai china
- It has 30 or 36 pins, 15 in both rows.
- It also has a wide variety of peripherals available, like capacitive touch, ADCs, DACs, UART, SPI, I2C, and much more.

3.2 SpO_2 Sensor (Max 30102)

Max 30102 is developed by sigma electronics in 2015. It's an I2C detector, and the ESP32 has two I2C ports. One is for the screen, and another is for the Oximeter that allows the transfer. These techniques are used to obtain the patient's heartbeat, as well as the ECG. This study not using the internal temperature sensor provided by this device. IR and red LEDs paired with a photodetector make up the optical sensor. The wavelength of pumping blood is measured. The INT pin is added to the I2C interface. A charger with a voltage of 3.3 volts is used. Sensitivity of image noise elimination of artificial light. Fig. 2 shows the front view of the Max30102 sensor. The following parameters are measured:

- Heart rate.
- SpO_2

Figure 2: Heartbeat sensor

3.3 Temperature Sensor (DS18b20)

This is Maxim IC's latest DS18B20 1-Wire advanced temperature sensor, developed by Analog Devices Inc./Maxim Integrated. Which is used to detect body temperature. −55C to 125C (+/− 0.5C) in degrees C with 9 to 12-bit precision. Every sensor has a unique 64-bit serial number carved into it, enabling a large number of sensors to be used on single data transmission. This is a fantastic component that serves as the base for a variety of data logging and temperature control projects. The following are different features of the DS18b20 sensor:

- The special 1-Wireâ® interface requires just a single port pin for correspondence
- Every gadget has an extraordinary 64-bit sequential code stored in a locally accessible ROM, requiring only a single port pin for communication.
- Disentangles applicable temperature sensing applications with multi-drop capability needing no external parts.
- Could be regulated by the materials.
- Counts temps from â€″55°C to +125°C (â€″67°F to +257°F)
- 0.5°C preciseness from â€″10°C to +85°C
- Customer-adjustable thermometer objectives between 9 to 12 bits.
- Customer definable captures (NV) warning parameters.
- Convert temperature to a 12-bit digitalized term in 750 ms (max.)

3.4 ECG Sensor (AD 8232)

The Spark Fun AD8232 single lead heart rate monitor is a low-cost board that monitors the electrical activity of the heart. These electrical impulses can be shown as an ECG and viewed as an analog readout. The AD8232 single lead heart rate monitor serves as an op-amp to make it simpler to receive a clear signal from the PR and QT intervals since ECGs can be noisy. The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It's designed to gather, amplify, and filter small biopotential signals in noisy situations, such as those created by mobility or remote electrode insertion. Fig. 3 shows the AD8232 sensor with a chip.

Figure 3: ECG sensor

3.5 Cloud Sensor

All the measured results by each sensor are stored in the online database. In our proposed work, the Firebase server is used for cloud services. Data is stored in the Firebase server for further use in the mobile application.

3.6 Mobile Application

This system uses temperature, pulse, ECG, blood pressure, and eye blink sensors. This device makes the usage of a tiny pulse sensor that has been designed to provide an accurate and optimal readout of the pulse rates and a temperature sensor is also included. With the help of an MCU, our system measures the pulse rate in beats per minute (bpm), blood oxygen level temperature measurements, and ECG readings and communicates this information to the Firebase server. The Firebase server is linked to the mobile app, and when the readings surpass their typical values, the doctor is notified of the proposal of appropriate action. Another intriguing feature of this exact design is the product's reprogrammable and open supply nature, which makes it easier to re-specify the specific heart price to keep an eye out for, as well as tinker with the system parameters to better fit the customers' needs. This is required due to a variety of environmental and patient circumstances. This study presents various contributions in the field of smart health monitoring systems which is IoT based on Android health monitoring systems. The open-source Arduino board created in this project is extremely specialized, which allows for more investigation and optimization of its exceptional flexibility features and the quantity that can be applied for a variety of purposes. This approach is appropriate for hospital ICUs if the doctor is not available 24 h a day. The mobile application is made in the Flutter framework so it can be configured for iPhone in the future. It will have two options on the sign-up page. Either user can be a doctor or nurse or both of them can see the results of the patients. The main page is used to display the selected patient's measured data from the Firebase databases, such as temperature, heartbeat, SpO_2, and an ECG diagram. In the chat activity, the nurse and doctor can chat according to the situation of the patient if he/she needs any tablets or precautions. In the setting activity, they can upload records to a Google sheet and can see patient history records. They can select patients and can log out.

4 Proposed Model

The open-source Arduino board created in this project is extremely specialized for more investigation and optimization of its flexible features and the quantity that can be applied for many purposes. This approach is appropriate for hospital ICUs if the doctor is not available 24 h a day. However, he may use this technology to remotely examine the patient's medical information and provide treatment recommendations. This system includes a monitoring gadget that takes readings from the patient's various health markers. A heartbeat sensor and a temperature sensor are included in this system. The data from these sensors has been sent to the Firebase server. Because the mobile app is associated with the Firebase server that accordingly updates the readings after receiving the data from the microcontroller, and saves them together with the doctor's remarks in the Firebase database. This system also includes a blueprint for fabricating a patient's health monitoring system that uses sensors to measure health indicators. This study also attempts to construct a smart system that integrates IC and internet platforms to observe and research in the field of biotelemetry devices such as PPG photo plethysmography. Different types of standards are linked with the coronary heart monitor structures. The detectors in this suggested system would analyze the patients' medical indicators. They gather the patient's data in the first stage that is further relayed to the microprocessor, which is linked to all of the detectors.

After that, the Wi-Fi module creates the communication and sends these results to the Firebase server through Firebase hosting using JavaScript API. The modules first establish connections with a network that has previously been specified in the script that was submitted to the Microcontroller. The findings are then transferred to the cloud after a secure connection. The concerned expert may obtain these results on the web from anywhere in the globe because the mobile app is synced with Firebase when the connection is available to the mobile device. The smartphone app is tailored to the needs of doctors and nurses. If the results go outside of the usual range, the application will send a notification to the doctor about the patient's health. The doctor advises the available personnel in the facility on the best course of action. This approach is for hospitalized patients who are on bed rest. The doctor cannot see all of the patients at the same time, and the patients cannot come to the hospital daily. Our device allows physicians to monitor the patients remotely, reducing the chance of people suffering from cardiovascular diseases losing their lives. Fig. 4 shows the flow diagram of the proposed system, first, the sensors detect the readings from the patients and send them to the microcontroller.

The microcontroller sends these results to the Firebase server through Firebase hosting using Node.JS API and stores it in Firebase-firestone. The Mobile app is always synced with the firebase server through the internet; so, when the results update from Node.JS API, then the App receives the latest data immediately. Various parameters such as pulse, temp, ECG, and SpO_2 are tested by the proposed system. The DS18B20 measures the body's temperature. When the Max 30100 is linked with the tip of the finger, then it reads SpO_2 and pulses in the human body. The ECG may also be calculated using the (AD8232) sensor. The duration among two successive QRS complexes can be used to measure the heart rate when the cardiac pulse is continuous. The heartbeat is computed on the ordinary sheet using the most popular recording parameters by dividing the number of big boxes (5 mm or 0.2 s) among two consecutive QRS complexes by 300. The entire pseudo code is presented in Algorithm 1.

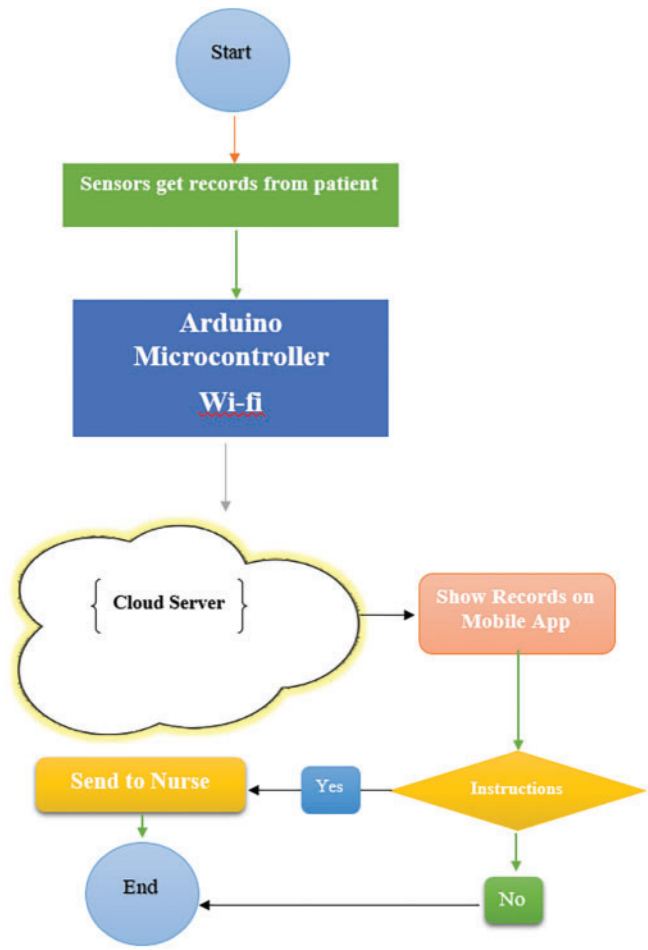

Figure 4: Architecture of the proposed system

Algorithm 1: Pseudo code of the proposed system

Input: Attached the sensors to the patient's body
Output: BPM results on mobile App

```
Step1: Start
Step2: Attach sensors to the Patient's body
Step3: Connect Sensors with the microcontroller
    {
    #include "MAX30105.h"
    #include <DallasTemperature.h>
    #include "heartRate.h"
    }
Step4: Detect results from sensors
    {
    float sensor = analogRead(SENSORPIN);
```

(Continued)

Algorithm 1 (continued)

```
        dtostrf(sensor,4,2,str_sensor);
        current_millis_at_sensordata = millis();
        dtostrf(current_millis_at_sensordata,10,0,str_millis);
        }
    Step5: Connect Microcontroller to the internet through Wifi
        {
        WiFi.setAutoConnect (true);
        WiFi.setAutoReconnect (true);
        WiFi.begin(STASSID, STAPSK);
        }
    Step6: Send the results to Firebase
        {
        HTTPClient http;
        Serial.print("[HTTP] begin . . . \n");
        http.begin("https://us-central1-xamadukan.cloudfunctions.net/app/api/create/");
        http.addHeader("Content-Type", "application/json");
        StaticJsonDocument<2000>jsonBuffer;
        JsonObject root = jsonBuffer.to ();
        root["patient"] = "IDX21NM788";
        String output;
        serializeJson(jsonBuffer, output);
        int HTTPCode = http.POST(output);
        if(HTTPCode > 0)
        {
        Serial.printf("[HTTP] GET . . . code: %d\n", HTTPCode);
        if(HTTPCode == HTTP_CODE_OK)
        {
        String payload = http.getString();
        Serial.println(payload);
        }
        }
        Else
        {
        Serial.printf("[HTTP] GET . . . failed, error: %s\n", http.errorToString(httpCode).
c_str());
        }
        http.end();
        }
    Step7: Get Results from Firebase and show them on the Mobile app
        {
        FirebaseFirestore.instance
        .collection("Patients")
```

(Continued)

Algorithm 1 (continued)

```
                .doc(pID)
                .collection("results")
                .snapshots();
                }
        Step8: End
```

Initially, sensors are connected to the NodeMCU Microcontroller Esp32 (Wire configurations). Then the sensors are attached to the patient's body. And connect the built-in WIFI in NodeMCU Microcontroller Esp32 to the WIFI adapter. The sensors get results from the patient's body and send the records to the Firebase Fire store by calling the API from the Firebase host. This study also made a dedicated mobile application for this research. Which was made using the Flutter framework using Dart language. The mobile applications are connected to the Firebase fire store in real-time. When the data is uploaded through API from the device it automatically updates the app records.

5 Results

5.1 Preliminaries Studies

Arduino is programmed using the C programming language. The Flutter framework and the Dart programming language were used to create an Android App for our proposed system. An API in JavaScript links the device to the Firebase server. After connecting and programming all the systems, this study designed a prototype IoT android-based health monitoring system. A tangle of wires connects all of the sensors. The device through these sensors obtains data from the human body and uploads it to the Firebase server.

5.2 BPM (Beats Per Minute)

To measure the heartbeat of the patient, this study proposed a max30102 sensor that is connected to the esp32 microcontroller through wires. Ground GND to GND, VIN to 3v3, SDA to 21, and SCL to SCL. The BPM parameters are tested, validated, and compared on real patients at the central hospital Saidu Sharif Mingora Swat. Table 2 shows the BPM result of the proposed system with the BPM of the cardiac monitor age-wise on a different patient.

Table 2: BPM results

Patient	Age	Cardiac monitor BPM	BPM device	Thermometer temp C°	Device temp C°	Cardiac monitor SpO_2	Device SpO_2
01	34	68	65	36.4	36	94	97
02	36	80	62	36.5	36	97	99
03	38	82	115	37.4	37	96	94
04	40	120	115	37.2	37	99	94
05	42	63	63	37.3	37	97	98
06	45	60	62	36.5	36	98	99
07	47	82	82	36.3	36	96	95

(Continued)

Table 2 (continued)

Patient	Age	Cardiac monitor BPM	BPM device	Thermometer temp C°	Device temp C°	Cardiac monitor SpO_2	Device SpO_2
08	48	63	60	36.4	36	96	98
09	49	78	75	37.2	37	100	99
10	56	60	65	36.3	36	98	97

In this study first check the cardiac monitor of the patient then test our device and record the results of our device. The performance of the proposed device is tested on ten numbers of different patients age-wise. The simulation shows that the BPM reading is not much different than the BPM of the cardiac monitor. Fig. 5 shows the proposed system images as compared to the BPM of the cardiac monitor. Both show the BPM results of the same patients. Fig. 5a is the main page of the mobile app's main screen for the proposed model. Fig. 5b is the image of the cardiac monitor in the hospital. The results are recorded from the cardiac monitor first after that the patient was tested on our device. The proposed system was tested on various patients.

5.3 ECG (Electrocardiogram)

To measure the electrocardiogram of the patient, this study proposed the AD8232 KEYES single lead heart rate monitor sensor, which is connected to the esp32 microcontroller through wires. Ground GND to GND, 3.3v to 3v3, Lo− to D35, Lo+ to D34, and output to VP. The above-mentioned devices are being tested on real patients. The same patients were monitored by a cardiac monitor and our proposed device at the same time. This study compared the proposed device ECG with the heart's rhythm and electrical activity of the cardiac monitor age-wise. This study first checked the cardiac monitor of the patient then test the proposed device and record the results of the proposed device. According to the doctor, the ECG Graph was normal at the time of testing the graph given in Fig. 5 shows the ECG results of the different patients as well. The first one is the main page of the mobile app's main screen which is specially designed for the proposed model. The results are recorded from the cardiac monitor first after that the patient was tested on our device.

5.4 Temperature

To measure the Temperature of the patient, this study proposed a DS18B20 1-Wire advanced temperature sensor, which is connected to the esp32 microcontroller through wires. Ground GND to GND, 3.3v to 3v3, and output to D23. The validation is done against real patients, and the same patients were monitored with a thermometer and our proposed device at the same time. Table 1 compared the proposed device temperature with the temperature of the thermometer age-wise. This study first checks the cardiac monitor of the patients, then test the proposed device and records the results of the proposed device. Fig. 5 shows two images, both show the temperature results of the same patients. Fig. 5a is the main page of the mobile app's main screen that is specially designed for the proposed model; while Fig. 5b is the image of the thermometer in the hospital. The results are recorded from the thermometer first after that the patient was tested on our device.

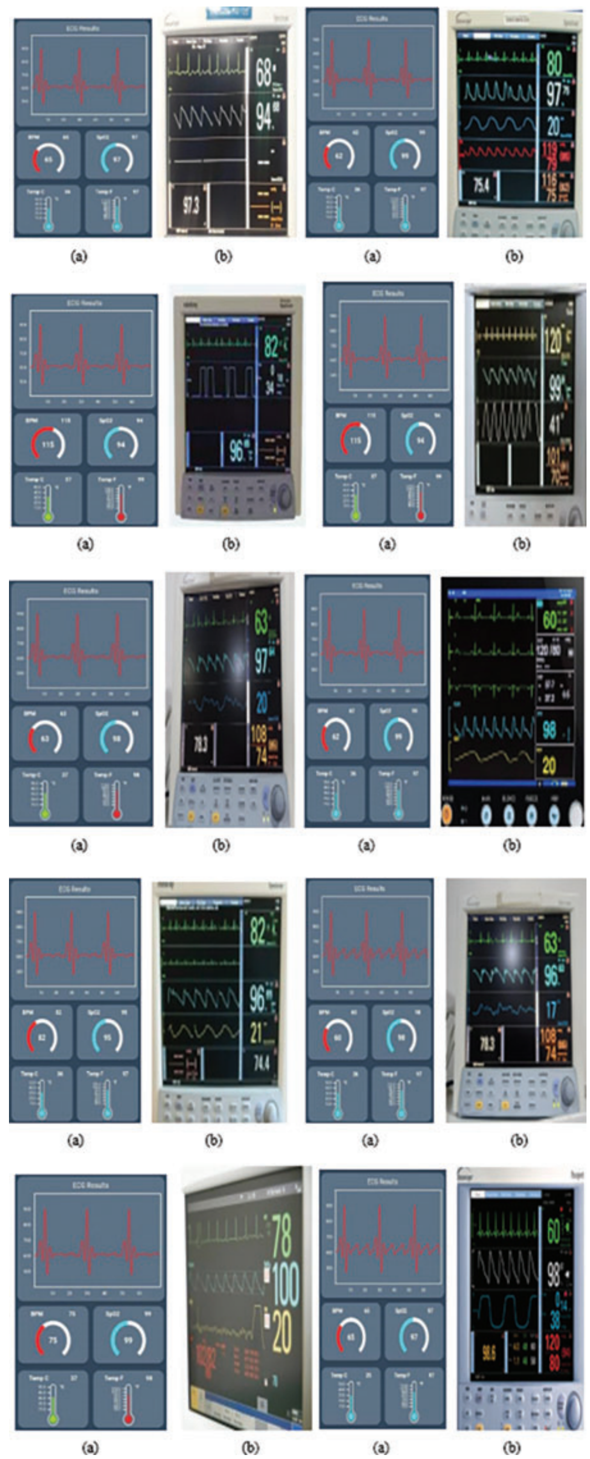

Figure 5: (a) Patients proposed system records; while (b) cardiac device records

5.5 SpO_2 (Oxygen Saturation)

The equipment listed above is tested on real patients at the major hospital, and at the same time, those patients were tracked with a cardiac monitor via our proposed device. In Table 2, this study also compared the proposed device's Oxygen saturation with the Oxygen saturation of the cardiac monitor age-wise. This study first checks the cardiac monitor of the patient, then test the proposed device and record the results of the proposed device. Fig. 5 shows the whole validation results of the proposed system using an Android mobile phone.

6 Discussion

The performance of the proposed device is tested on ten numbers of different patients age-wise in terms of BPM, ECG, Temperature, and SpO_2. First, the BPM parameter was checked. The simulation shows that the BPM reading is not much different than the BPM of the cardiac monitor. Then checked ECG with the heart's rhythm and electrical activity of the cardiac monitor age-wise. This study first checks the cardiac monitor of the patient then test our device and record the results of our device. According to the doctor, the ECG Graph was normal at the time of testing the graph is given in Fig. 5, which shows the ECG results of the different patients as well. The results are recorded from the thermometer first after that the patient was tested on our device. Similarly, to measure the temperature of the patient, a temperature sensor, is connected to the esp32 microcontroller through wires. The validation is done against real patients, and the same patients were monitored with a thermometer and our proposed device at the same time. Further to test our device's Oxygen saturation with the Oxygen saturation of the cardiac monitor age-wise. Fig. 5 is the main page of the mobile app's main screen which is specially designed for the proposed model. The results are recorded from the cardiac monitor first after that the patient was tested on our device. Fig. 5 shows the whole validation results of the proposed system using an Android mobile phone. It shows the proposed system images as compared to the BPM of the cardiac monitor. (Bhardwaj et al., 2022) in [12] a proposed model used sensors Like Heartbeat, eye blink, and temperature SpO_2 with GSM, and the result was displayed on LCD. No real-time detection is used. In [13] the author proposed a model which used Arduino Uno-based system with sensors for body temperature, oxygen saturation, and pulse rate. The results were displayed on LCD and there is no mobile app is available for this model. In [14] has proposed a model in which The MCU is linked to the detectors and the results are kept in the cloud. It has GSM capability, one sensor in operation, and a single-core CPU with a limited speed. Similarly, [38] proposed model used Arduino Uno-based system with sensors for body temperature, oxygen saturation, and pulse rate. The results were displayed on LCD. A mobile app is working through Bluetooth which is not proper remotely. This study also has some limitations such as blood pressure. A blood pressure sensor will be used to detect the patient's blood pressure in the hardware section. As a result, a personal fall detection function will be implemented, which will benefit senior citizens.

7 Conclusion

This study develops an IoT-based patient monitoring system, which utilized various technologies such as smartphones and wearables, as well as monitoring medical patients necessitates continuous remote observation. In terms of heartbeat, temperature, ECG, and SpO_2, the suggested model is tested. The sensor (DS18B20) measures the body's temperature. The sensor (Max 30100) is also known as an Oximeter sensor. When it is linked to the tip of the finger, it reads SpO_2 and heartbeat in the human body. The ECG may also be calculated using the (AD8232) sensor. The Flutter App is designed expressly for this proposed technique. Moreover, in this study, the early medical system was compared to modern health monitoring. The performance of the proposed device is tested on ten numbers of different patients age-wise in terms of BPM, ECG, Temperature, and SpO_2. First, the BPM parameter was checked. The simulation shows that the BPM reading is not much different than the BPM of the cardiac monitor. Then checked ECG with the heart's rhythm and electrical activity of the cardiac monitor age-wise. This study first checked the cardiac monitor of the patient then test the proposed device and record the results of the proposed device. According to the doctor, the ECG Graph was normal at the time of testing the graph is given in Fig. 5, which shows the ECG results of the different patients as well. This study makes a significant contribution to the development of an IoT-based health monitoring system that can remotely monitor the sugar levels of patients, particularly those in their senior years. Time consumption, operating costs, human interface, efforts expended, real-time, resource utilization, user-friendliness, smartness, and automation are only a few of the advantages of the proposed framework over traditional systems.

In this proposed system, first monitor the patient's status, particularly for ICU or cardiac patients; however, this study will enhance both the hardware and software components in the future. This study will use a blood pressure sensor to detect the blood pressure of the patient in the hardware section. As a result, a personal fall detection function will be implemented, which will benefit senior citizens.

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