2021 International Conference on Automation, Control and Mechatronics for Industry 4.0 (ACMI) | 978-1-6654-3843-8/21/$31.00 ©2021 IEEE | DOI: 10.1109/ACMI53878.2021.9528227

An IoT Enabled Health Monitoring Kit Using Non-Invasive Health Parameters

Arpita Das[1,1], Shimul Dey Katha[1,2], Muhammad Sheikh Sadi[1,3] and Ferdib-Al-Islam[1,4]
[1]*Department of Computer Science and Engineering, Khulna University of Engineering & Technology*
Khulna-9203, Bangladesh
Email: [1]das1607067@stud.kuet.ac.bd, [2]katha16070@stud.kuet.ac.bd, [3]sadi@cse.kuet.ac.bd, [4]ferdib.bsmrstu@gmail.com

***Abstract*—Health is a primary concern of every human being. Continuous health monitoring is becoming more important nowadays. But going to the hospitals or doctors for a routine checkup can be costly and most of the time difficult for human being. Hence, a cost-effective and wireless health condition monitoring system can be an effective solution that can be monitored anytime from anywhere. Nowadays, IoT-enabled health monitoring system plays the critical role by the observation of health conditions and detecting early vital signs of diseases or ill-conditions through IoT. In this paper, we have proposed a health monitoring device on the amalgamation of Raspberry pi, and cloud IoT platform which is based on the Thingspeak server. The system monitors body temperature, heartbeat, Electrocardiogram (ECG), the variations of the electrical characteristics of the skin, motions, and blood oxygen level of every individual. The system is designed as user-friendly with low cost and potency. Experimental studies show the reliance and effectiveness of the proposed system concerning the existing models.**

***Index Terms*—Health Monitoring Sensors, Health Tracking, Non-Invasive Parameters, Internet of Things (IoT), Automated Control of Health Monitoring Devices.**

I. INTRODUCTION

The proper health monitoring system is one of the necessities for human beings. On the report of the World Health Organization (WHO), health is the condition of physical and mental capability in the destitute of illness and infirmity [1]. Several life-threatening diseases can be easily monitored by IoT-based systems. Nowadays, the routine health monitoring system has supported every community to reduce the works of doctors and nurses [2].

Monitoring different health parameters could serve as one of the most effective prevention systems to lead a healthy life without diseases. Internet of Things (IoT) is now a reliable technological standard and a heavily researched field. The recent development of the IoT makes all objects interconnected and it has been recognized as the next technical revolution. The use of IoT and sensor-based intensive health care systems are increasing rapidly. IoT makes our life smarter, more efficient, and easier. The unexpected occurrence in the patients' bodies can be monitored using IoT. Cardiovascular disease (CVD) is a threatening disease that is the root behind most of the demises [3]. If any abnormalities happen in any health parameter then one can take immediate action without any delay [4]. Different types of methods are implemented for health monitoring for many years now.

Different health monitoring systems consist of different types of sensors to measure values of different health parameters and many health monitoring kits have been developed which can expand the life quality with better health [5]. Health monitoring can be automated by using the computer and electronic circuits [6]. For automation, different types of sensors are connected with microcontrollers, Arduino, Raspberry pi, etc.

The idea of the paper is mainly developed with the combination of raspberry pi and ThingSpeak cloud to collect data and analyze the sensor data. The amalgamation of Raspberry pi and IoT becomes an innovative technology in the health care system. Raspberry Pi acts as a small clinic after connecting temperature sensor, heartbeat sensor, ECG sensor, SPO2 sensor, accelerometer sensor, and GSR sensor.

The paper has been organized as follows. Section 2 describes the related work done previously on health monitoring. Section 3 explains the hardware components used in the system. Then, section 4 explains the proposed methodology of the system and section 5 details the experimental analysis to evaluate the proposed methodology and finally, section 5 has the conclusion of the paper.

II. RELATED WORK

Nookhao et al. [2] discussed about a method that uses a arduino board to connect the temperature sensor and heart beat (Easy pulse V 1.1) sensor which shows the measurement on LCD display and at the same time sends them to ThingSpeak IoT platform in real-time via WiFi. When both readings are uncommon, the system will send the notification to Line application with storing data in firebase database and showing the graph of heart rate and temperature values in real-time.

Priya et al. [4] presents a project which uses pulse rate sensor, temperature sensor to measure pulse rate which is attached to the patient's body. The pulse sensor operates on the principle of photo plethysmography (PPG) technique. From sensor data will be collected and the raspberry pi processes the data, then data is stored and updated on database.

Reddy et al. [5] proposes an IoT based health monitor system which is developed to measure body temperature and heartbeat. The digital DS18B20 sensor and SEN-11574 sensor are used respectively by connecting with Raspberry Pi. The measured sensor data is uploaded to cloud using ThingSpeak where data can be seen using graph for each person. An android application is also developed to show the data with the facility of emergency call and text message to the respected given number.

Thomas et al. [6] proposed a method which uses LM35 body temperature sensor and pulse sensor to measure body temperature and heart rate (diastolic and systolic) using Arduino. Using HC-05 bluetooth module, the sensor data are sent to the android application. The temperature is shown in Fahrenheit scale and heart beat sensor measure the heart pulse in each minute which is displayed on the android.

Kumar et al. [7] proposed a method which monitors body temperature, heart beat, respiration and accelerometer sensor using raspberry pi which is connected to the internet to IoT website by adding with a transformer. It can be monitored in the monitor screen of the computer from anywhere.

Girhepunje et al. [8] monitored patient's body temperature using DS18B20 temperature sensor and heart beat using heart beat sensor which consists of a super bright red LED and light detector which are attached to the LPC2148 micro controller. Bluetooth and GSM module were used because of real time wireless communication.

Ahmed et al. [9] proposed a system of patient health monitoring. The system monitors a patient's body temperature, heartbeat and electrocardiography by using LM-35 sensor and ECG sensor. These sensors were connected with Arduino Uno and this micro controller was programmed to get heart rate of a patient from the electrocardiograph signal obtained by ECG sensor. The collected data from the sensors processed by the micro controller was then transferred to a physician by using wireless communication established by connecting bluetooth HC-05 module to the Arduino.

Sharma et al. [10] proposed a system of health monitoring called Wireless Body Area Network (WBAN) which was wearable for the patient while moving. The system monitors body temperature, ECG and respiration signal by using temperature sensor, ECG sensor and respiration sensor. These sensors are connected to a network coordinator which controls the whole system. It had two data communication interface. One is connected using KC21 bluetooth interface to display sensor data in PDA (Personal Digital Assistant) and other one is nRF24L01 Nordic's link. One graphic LCD display is used as an additional feature for displaying sensor data.

III. Hardware Components

This section illustrates the hardware components that are used in the proposed system for measuring different health parameters. Fig. 2. shows the sensors which are used to track the health condition of a user. The following biomedical sensors are used for the proposed system.

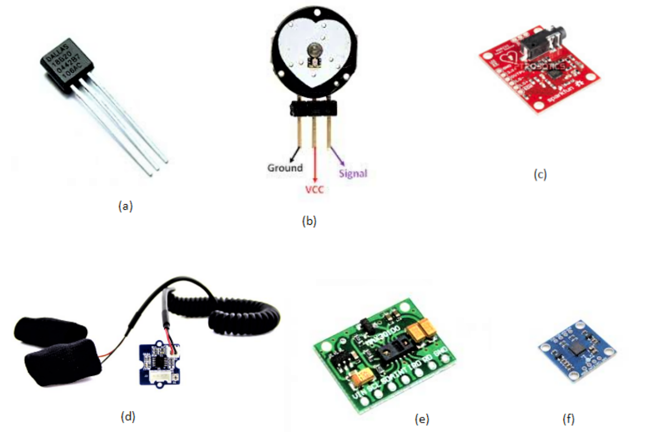

Fig. 1. Sensors used in the system: a) LM35 temperature sensor, b) Pulse sensor, c) AD8232 ECG sensor, d) GSR sensor, e) MAX30100 sensor f) ADXSL345 sensor.

A. Temperature sensor

LM35 temperature sensor is used in our project. It is placed in the user's finger for measuring the body temperature of the user. LM35 sensor's output range is -40°C to 110°C.

B. Heartbeat sensor

Heartbeat is measured using a pulse sensor. It measures the heartbeat of the user continuously after every 1minute. Its operating voltage is +5V or +3.3V and current consumption is 4mA.

C. ECG sensor

ECG is mainly called electrocardiography. ECG sensor shows the real-time electrocardiography signal of a user. AD8232 sensor is used as an ECG sensor. This sensor measures up to ±300 mV and it gives analog output.

D. Accelerometer sensor

ADXSL345 is the accelerometer sensor that works on the principle of the piezoelectric effect. It is a triple-axis accelerometer. It will give three values of output on the x, y, z-axis.

E. SpO2 sensor

For measuring oxygen level, the MAX30102 pulse oximeter is used. It can also be used as a pulse sensor. Its operating temperature range is -40°C to +85°C.

F. GSR sensor

GSR is the measure of the continuous variations in the electrical characteristics of the skin for the instance caused by the variation of the human body sweating. The GSR sensor applies a constant voltage at 0.5V to the two electrodes which are in contact with the skin.

Calibration is the process of determining the true values of voltage and resistance. The sensors' calibration was verified prior to the start of the experiment. The manufacturer calibrated the sensors, making it simple to connect to microcontrollers.

IV. Methodology

The health tracking kit proposed in this paper is mainly developed in three parts. They are:

1) Sensors' Data Acquisition
2) Data Visualization to the Thingspeak cloud
3) Data Analysis to the Thingspeak server

At first, many biomedical sensors are used to measure different health parameters like body temperature, heartbeat, movement of the body, blood oxygen, and sweat gland activity related to emotional arousal. These sensors collected data from the users. The sensors are connected to the raspberry pi. It is controlling the whole system. The data is updated and stored on the Thingspeak platform using IoT for visualization and analysis. Fig. 1 shows the flow diagram of the proposed system.

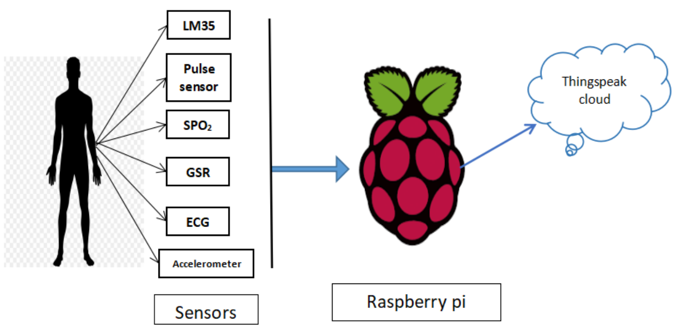

Fig. 2. The flow diagram of the proposed system.

A. Hardware Module

Fig. 3. shows the circuit diagram of the hardware connection of the health monitoring system proposed in this paper. The entire hardware system is developed by using a breadboard for connecting the sensors. The breadboard is connected with the Arduino Uno instead of an analog to digital converter for taking analog sensor data and the whole system is controlled using Raspberry pi. The Arduino is connected with Raspberry pi using serial communication with USB cable. The temperature sensor output pin is connected with Arduino analog PIN A2. Again, the other analog output sensors are connected with the Arduino analog pins. Such as the heartbeat sensor is connected with analog pin A1, the GSR sensor is connected with Arduino analog pin A3, the accelerometer is connected with A4 and A5, etc. The breadboard VCC and Ground are connected with the Arduino VCC and GND pin. The MAX30100 sensor is connected with the other SDA and SCL pin of the Arduino Uno.

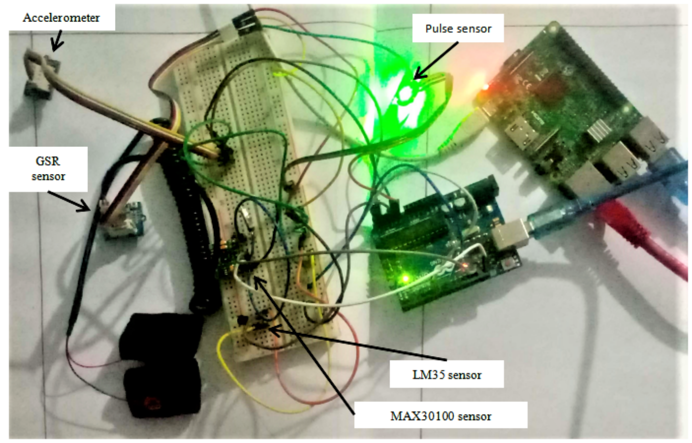

Fig. 3. Circuit diagram of the proposed system.

B. Software Modules

Fig. 4. shows the entire software and hardware interaction of the whole developed system. It illustrates the communication interface between the hardware part and the software part. It uses internet/wi-fi to send the sensors readings to the Thingspeak platform. ThingSpeak mainly visualizes the sensor's data collected after processing from the Raspberry Pi. The received data is visualized in the chart as real-time data for each sensor. This platform also facilitates a login system with a password for the particular user. The data also updates to the Thingspeak for analytical working.

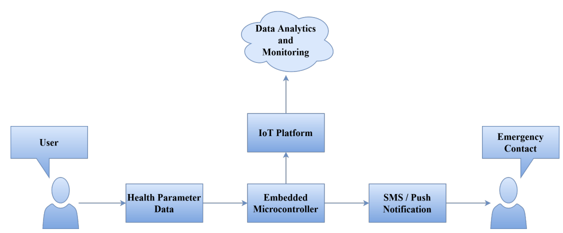

Fig. 4. Proposed system interaction.

The figure shows the entire software and hardware interaction of the whole developed system. It illustrates the communication interface between the hardware part and the software part. It uses internet/wi-fi to send the sensors readings to the Thingspeak platform. ThingSpeak mainly visualizes the sensor's data collected after processing from the Arduino Uno. The received data is visualized in the chart as a real time data for each sensor. This platform also facilitates login system with a password for the particular user and also able to send the notification when it is required. The emergency alert system is also developed by sending SMS to the given mobile number if the data crosses a certain threshold value. The patient can also make any call by accessing the contact list available in the mobile. For making call, the user has to give permission to the app to access person's contact list.

TABLE I
COMPARISON BETWEEN MEASURED TEMPERATURE AND ACTUAL TEMPERATURE

Users	Temperature using LM35, F	Temperature using thermometer, F	Average Accuracy
User 1	95.3	98.5	96.67%
User 2	94.0	98.2	
User 3	96.6	99.7	
User 4	97.5	100.4	
User 5	96.2	99.3	

V. RESULTS AND DISCUSSION

The evaluation of the research to check the performance is done by several experiments. The body temperature, heartbeat, EGG of the heart, blood oxygen level, motion, and GSR value of the patients have been monitored during the working of the projects. Several tests are done to examine the system. The patient's health parameters are shown in the evaluation of the quality of the research. LM35 body temperature sensor measures the patient's body temperature which is shown in the second column of Table 1. The table shows the comparison of the measured temperature by our system with the actual temperature of different users measured by using the thermometer. Average accuracy is measured using (1).

$$Av = \frac{1}{n}\sum_{1}^{n}\frac{Ts}{Tt} \times 100\% \qquad (1)$$

Here, Av= Average accuracy
n = Number of users
Ts = Temperature measured by the system
Tt = Temperature measured manually by thermometer

Fig. 5 shows the comparison of the measured temperature using the LM35 sensor and the actual temperature using a thermometer of five users in Fahrenheit where the x-axis contains the number of users and the y-axis contains the values of temperature for each user. Again, the red line indicates measured values by our system and the blue line indicates actual temperature. To observe the performance of the used temperature sensor, the thermometer is used to measure the actual temperature. And the results are almost closed and the outputs are satisfactory.

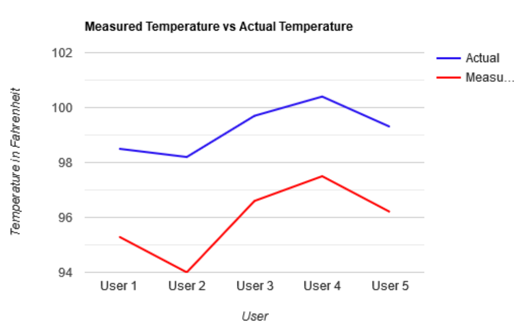

Fig. 5. Comparison of the measured and actual temperature.

Fig. 6(a) shows the ECG of the patient which records the timing and the strength of electrical activity in the heart using single lead heart rate monitor-AD8232. It presents every phase of the electrical signal of the patient. Fig. 6(b) shows the ECG signal with P wave which is the first wave. It is indicating atrial depolarization by atrial systole and the QRS complex indicates the ventricular depolarization and contraction where Q, S are downward wave and R is an upward wave. The T Wave indicates ventricular re-polarization. The ST segment refers to the time between ventricular depolarization and re-polarization. This ST-segment and QRS complex information of ECG signal can be used for classification, investigation, diagnosis, and detection of different heart diseases [11]. The QRS complex can also be used for the heartbeat estimation of a patient.

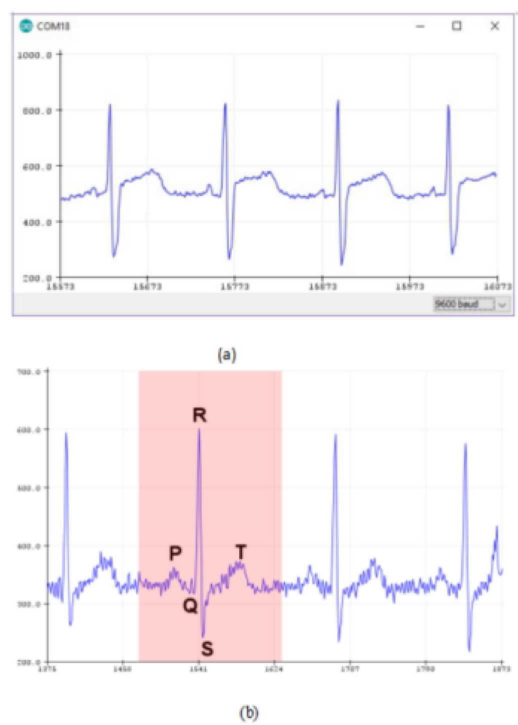

Fig. 6. a) ECG signal from ECG sensor and b) ECG Signal with P wave, QRS complex, and T wave.

Table 2. shows the data of heartbeat, SpO2, and the comparison between the measured and actual heartbeat of five users. The average accuracy is derived using (2).

$$Av = \frac{1}{n}\sum_{1}^{n}\frac{Hs}{Hn} \times 100\% \qquad (2)$$

Here, Av= Average accuracy
n = Number of users
Hs = Heartbeat measured by the system

TABLE II
THE VALUES OF SPO2, HEARTBEAT, AND COMPARISON BETWEEN MEASURED HEARTBEAT AND ACTUAL HEARTBEAT

Users	SPO2	Heartbeat using Pulse Sensor (bpm)	Normal Heartbeat (bpm)	Average Accuracy
User 1	93%	76	78	96.77%
User 2	94%	79	82	
User 3	94%	88	89	
User 4	93%	81	84	
User 5	95%	90	95	

TABLE III
THE VALUES OF MOTION AND GSR VALUES OF A USER

Accelerometer			GSR
X-axis	Y-axis	Z-axis	
0.90	7.14	0.39	190
0.86	7.10	0.39	210
-6.83	-7.18	2.35	250
-6.86	-7.18	2.39	200
-6.90	-7.10	2.31	201

Hn = Normal Heartbeat

Fig. 7 shows the comparison between measured heartbeat using pulse sensor and actual heartbeat where x-axis contains the number of users and y-axis contains the heartbeat values for each user. Again, the red line indicates measured values by our system and the blue line indicates the actual heartbeat. The performance of the used heartbeat sensor in the model is compared to the actual heartbeat. The outputs are very satisfactory and almost closed. The Five samples are used for comparison of the used sensor in the system.

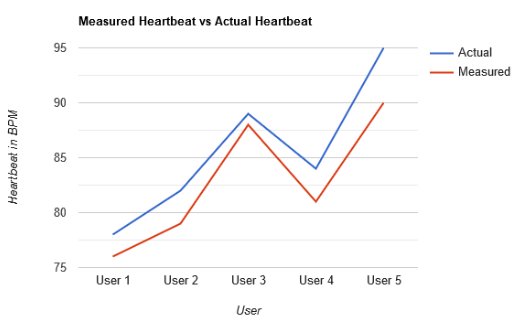

Fig. 7. Comparison of the measured and actual heartbeat.

Table 3 shows the accelerometer value in the x, y, z axes and the GSR value of a user after a certain period. The 3 axes values are changing according to the movement of the user in X,Y,Z axis respectively.

Fig. 8 shows the measured body temperature and BPM values from the Thingspeak server and Fig. 9 shows the GSR value in the Thingspeak server.

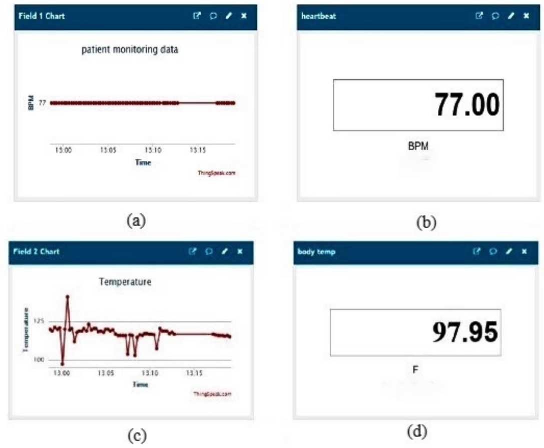

Fig. 8. a) BPM data graph b) Numerical BPM data and c) Temperature data graph d) Temperature numerical data from Thingspeak platform.

Fig. 9. GSR data from Thingspeak platform: a)GSR graph b)Numerial value

VI. CONCLUSIONS

Nowadays, health treatment is very expensive and it is mandatory to do daily check-ups of their health condition. Hence. the health monitoring system is very important to know the health condition of the patients earlier which can reduce sufferings and medical costs. If any abnormalities are noticed, then one can take proper medication. The goal of this paper is to implement an automatic system that can measure the body temperature, heartbeat, ECG, blood oxygen level, motion, etc of the patient in real-time. There are many sensors to measure these health parameters. Our proposed system is developed with the application of Raspberry Pi for enabling IoT communication. The method is based on the implementation of the ThingSpeak server in the cloud which is user-friendly and easily usable. The user can wear the kit according to his/her requirements. For emergency the user can wear the kit whole time. In the future, the system can be enriched with proper medication arrangement and data storage system with ensuring data security. Though this method is constructive, more health vital signs can be added to the system for the betterment of detection of the health condition of every individual.

REFERENCES

[1] S. Vishnu, S. R. J. Ramson and R. Jegan, "Internet of Medical Things (IoMT) - An overview," *2020 5th International Conference on Devices, Circuits and Systems (ICDCS)*, 2020, pp. 101-104.

[2] S. Nookhao, V. Thananant and T. Khunkhao, ”Development of IoT Heartbeat and Body Temperature Monitoring System for Community Health Volunteer,” *2020 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON)*, 2020, pp. 106-109.

[3] A. Rahaman, M. Islam, M. Islam, M. Sadi and S. Nooruddin, ”Developing IoT Based Smart Health Monitoring Systems: A Review”, *Revue d'Intelligence Artificielle*, vol. 33, no. 6, pp. 435-440, 2019.

[4] A. D. Priya and S. Sundar, ”Health Monitoring System using IoT,” *2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN)*, 2019, pp. 1-3.

[5] A. N. Reddy, A. M. Marks, S. R. S. Prabaharan and S. Muthulakshmi, ”IoT augmented health monitoring system,” *2017 International Conference on Nextgen Electronic Technologies: Silicon to Software (ICNETS2)*, 2017, pp. 251-254.

[6] S. S. Thomas, A. Saraswat, A. Shashwat and V. Bharti, ”Sensing heart beat and body temperature digitally using Arduino,” *2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)*, 2016, pp. 1721-1724.

[7] R. Kumar and M. P. Rajasekaran, ”An IoT based patient monitoring system using raspberry Pi,” *2016 International Conference on Computing Technologies and Intelligent Data Engineering (ICCTIDE'16)*, 2016, pp. 1-4.

[8] V. G. Girhepunje and S. D. Chede, ”Realization of low power telemedicine system to monitor temperature and heart beats,” *2015 International Conference on Energy Systems and Applications*, 2015, pp. 650-654.

[9] S. Ahmed, S. Millat, M. A. Rahman, S. N. Alam and M. S. R. Zishan, ”Wireless health monitoring system for patients,” *2015 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE)*, 2015, pp. 164-167.

[10] S. Sharma, A. L. Vyas, B. Thakker, D. Mulvaney and S. Datta, ”Wireless Body Area Network for health monitoring,” *2011 4th International Conference on Biomedical Engineering and Informatics (BMEI)*, 2011, pp. 2183-2186.

[11] Muhammad Sheikh Sadi, S. Debnath, Fahim Feroje Al Jami and G. M. Mahmudur Rahman, ”A new approach to extract features from ECG signals,” *2015 2nd International Conference on Electrical Information and Communication Technologies (EICT)*, 2015, pp. 189-194.