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HEALTHCARE SENSOR –BASED PHYSIOLOGICAL PARAMETERS DATA AGGREGATION AND ANALYTICS SCHEME FOR MONITORING OF PATIENTS IN INTERNET OF MEDICAL THINGS (IOMT) ENABLED E-HEALTHCARE PLATFORM

Ekoro Ekoro Igo (Ph.D.)[1] and Moses A. Agana (Ph.D.)[2]

[1] Department of Computer Science, Cross River State College of Education Akamkpa.
Email: eekoro80@gmail.com; ekoro.ekoro@crs-coeakamkpa.edu.ng; Tel.: +2348039516783

[2]Department of Computer Science, University of Calabar.
Email: mosesagana@unical.edu.ng

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ABSTRACT: *Inadequate mechanism for efficient patient health monitoring and data aggregation mechanism in healthcare services has posed a serious bottleneck to healthcare delivery the world over. Healthcare sensors have become an accessible means for the communication of data from patients to medical personnel. The use of healthcare sensors is also an invention in medical practice which involves measuring vital physiological parameters of patients with the objectives of detecting disorders to mitigating them and preventing severe complications. In this research, a system architecture for effective tracking of patients' health by deploying the Internet of Medical things (IoMT) as an approach is developed. The methodology used for this research was the Design Science research methodology. The choice of the methodology was born out of the fact that the methodology involves the construction and evaluation of the prototype (artefacts) that address a considerably acknowledged problem. In this adopted approach, real-time data is sent to a local server through communication channels (Wi-Fi) and then transmitted to the Internet of Things (IoT) server through a designated network route using a Wi-Fi module. For efficient transmission of vital signs to the cloud, a Blynk IoT- server was used as a platform. Two types of sensors DS18B20 and AD8232 ECG were deployed in monitoring and tracking body temperature and heart rate respectively, the XAMPP server was used as the local server platform. The outcome of this research includes developed artefacts and a mechanism where real-time numerical data is communicated to the report platform which is further transformed into ordered numbers. The novelty in this work involves collating real-time data from sensors attached to patients in IoMT-enabled environments, thereafter a simple linear regression model was deployed to convert these real-time data to ordered numbers which indicate the level of severity of the vital signals collated. These ordered numbers are converted to visuals to enhance ease of view. To the best of our knowledge, this approach has not been implemented by previous research studies reviewed. Based on our findings, we recommend that the prototype system be developed and deployed in healthcare facilities and the designed web applications be plugged into an existing web domains of healthcare facilities to enhance timely intervention by the healthcare experts.*

KEYWORDS: Healthcare sensors, Blynk, Temperature, Internet, Healthcare, IoT.

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INTRODUCTION

Clinics and hospitals have been active in deploying suitable technologies to enhance effective healthcare delivery; conversely, there are still several areas that need further advancement. There are inadequacies in patient monitoring, particularly in primary and secondary healthcare facilities. This observation is supported by frequent complaints by caregivers in some of the healthcare facilities in both urban and rural settings where it is obvious that patients in general wards suffered from inadequate monitoring. This implies that most patients felt neglected whereas others experienced being left unattended for varying lengths of time. It was discovered that the medical care systems have long been beleaguered with issues, such as diagnoses written illegibly on pieces of paper, physicians not being able to gain easy access to patient data, and limited time, space and personnel for tracking patients' conditions [1]. These problems are compounded as medical care organizations have to deliver effective quality services to an incessantly increasing number of patients within hospitals and clinical homes. Also, the rate of contact by nurses is dependent on the patients' needs, based upon the criticality of their condition, which can be biased. Further, quick observation of anomalies of patients on clinical wards can enhance recovery and minimize mortality occurrences during hospitalization. It is observed that hospitalized patients with cases of cardiac arrest and require unexpected admission to an intensive care unit (ICU) often exhibit psychic anomalies in vital signs [2]. Early detection of anomalies of vital signs has significance in healthcare delivery, particularly in-patient monitoring. Many healthcare facilities are now using a process called early warning scores (EWS) in order to assist the early detection of patient deterioration; these schemes operate by observing vital signs changes in patients' vital signs. However, it is debated that monitoring vital signs is normally seen as a non-challenging aspect of nursing care which is usually delegated to healthcare assistants whose varying levels of training provokes concerns regarding precisions and interpretations of data [1]. It can be debated that invention in medical care ultimately has to be assessed on three grounds, namely: efficacy, efficiency and safety (EES). To further enhance patient monitoring and address these three aforementioned aspects, the requirements for general wards must be evaluated.

The main components of IoT technology include cloud properties like flexibility, resource pooling, and pervasive network connectivity. The on-demand and elastic nature of the exertion service improves service reliability, which is further improved by massive resource pooled storage. All of these strong debates support the inevitability to combine IoT with healthcare infrastructure to deliver the needed objectives of providing appropriate services to both patients and healthcare providers seamlessly [3].

Aim and Objectives of Study

The aim of this research is to design a prototype of healthcare-based data capturing and monitoring for patient monitoring and in internet of medical things (IoMT) enabled e-healthcare applications.

The objectives are:

a. To design an algorithm to monitor patients' conditions based on changes in their vital signs; and

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b. To formulate an artifact to test the algorithm designed and integrate into an IoMT-enabled system that can identify physiological signals such as heart rate and temperature using web platform

RELATED WORK

This section reviewed related research done on the usage of IoT in monitoring human vital signs in real time. In the works of [4], a wireless implantable sensor artifact with elastic subcutaneous solar energy capturing as a self-powered system that has the capacity to reinforce in battery discharge situations was developed. Although the artefact incorporated Bluetooth low energy module and temperature sensor, the system could only send data within a close proximity. The works of [5] presented a self-powered non-reusable supply-sensing healthcare sensor platform using an organic biofuel cell for big data-based medical applications in Internet of Things, which was ecologically friendly and had optimal performance. The research by [6] introduced a real-time QRS (Q, R, and S are waves on an Electrocardiogram (ECG) line) detector and an ECG compression architecture for energy consumption for IoT healthcare wearable devices. Moreover, the experimental results showed high sensitivity and predictivity of the presented architecture. However, security and privacy were ignored. In a research conducted by [7], the research presented the characterization, construction, and validation of composite fabric ECG self-powered wearable IoT-based sensors that were made of nylon with reduced graphene oxide (rGOx). Based on the experimental results, the rGOx showed high performance in terms of noise level for ECG signal amplitudes.

Further, [8] presented a lightweight sensing architecture for body area networks that tags patients' data based on a priority scheme and provide services to patients with low latency. [9] designed an IoT-connected wearable sensors propelled with artificial intelligence (AI) and machine learning, which predict diseases, inform patients, and provide prescriptions. [10] presented IoT-based wearable sensors and machine learning that repeatedly collects the health vital signs and traces the exercises to monitor the sport person's health condition. [11] designed a compact wearable sensor patch to detect various physiological parameters such as ECG, PPG, and body temperature that facilitates remote health monitoring providing security and privacy. Connected healthcare is becoming an essential solution for hospitals that permits the recording and examination of patients' data, enforce appropriate decisions and subsequently save lives and funds. Some previous research in connected healthcare is geared towards reducing big data harvesting using aggregation, compression and prediction methods.

In a research conducted by [12], a Priority-based Compressed Data Aggregation (PCDA) technique was presented in order to reduce the quantity of healthcare data transmitted. PCDA applied a compressed sensing approach followed by a cryptographic hash algorithm to save information accuracy before transmitting data for diagnosis. [13] proposed a two-level anomaly detection scheme to remove false alarms and detect an emergency situation of a patient. The first tier uses a game-theoretic approach in order to search for spatiotemporal correlation among observed features. In the second tier, the Mahalanobis distance has been used to ensure a general view for multivariate analysis. In [14], a cloud-based connected healthcare system, called

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BigReduce, was proposed. The objective of BigReduce is to minimize the data processing cost at the base station according to two schemes applied locally at the IoT sensors: reduction and decision schemes. In [15], the authors proposed a classification technique based on a defined threshold where the sensor's readings are classified into three types: critical (above threshold), partial critical (close to threshold) and non-critical (less than threshold). Furthermore, the authors introduced a routing protocol for a medical sensor that enables transmitting packets during gateway failure.

In all the works presented, the technology of using an algorithm such as linear regression to normalized data and subsequently visualized data for healthcare practitioners and patients in collaboration with the blynk IoT platform has not been presented.

Problem Formulation

The Wireless Body Area Network (WBAN) model is a remote health patient monitoring system that is available for remote human health vital variables monitoring like human body temperature, pressure, and pulse rate/heartbeat. It is made up of wireless body sensor nodes, which is deployed for human vital physiological parameters readings and monitoring. Wireless technology based IoT are used for data transmission (Wi-Fi) and the central node database. The total number of sensors deployed for monitoring and acquisition of different human physiological parameters, S_{total} can be represented in equation 1. S_{Hvpp} represents the sensor nodes deployed to monitor various human vital physiological parameters within the human body and n is the sensor node density (that is number of sensor nodes). Thus, equation 1 can also be represented as equation 2 where *S*, *β,* and *LH/B* denote sensors, *Wi-Fi* transmission mode for wireless body area network and the web server which stores the database location respectively.

$$S_{total} = \sum_{i=1}^{n} S_{Hvpp} \qquad (1)$$

$$[S]^{HR}[\beta] = [LH/B] \qquad (2)$$

Given that the local host and Blynk IoT Platform stores several database locations of the various sensors deployed in the network as D*Lb*……. Equation 2 can now be rewritten as:

$$\begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}^{HR} \begin{bmatrix} \beta \\ \beta \\ \beta \\ \beta \end{bmatrix} = \begin{bmatrix} D_{LB} \\ D_{LB} \\ D_{LB} \\ D_{LB} \end{bmatrix} \qquad (3)$$

The database location is the point where the measured parameter is domiciled in both the Blynk and the local server. The eventual function is represented in Equation 4. Thus, the equation for different patients with parameters to be measured is given in Equation 5.

$$F(S, \beta, D_{LB}) = S_1\beta + S_2\beta + \ldots + S_n\beta \qquad (4)$$

$$S_{11}\beta + S_{12}\beta + S_{13}\beta + \ldots + S_{1n}\beta = D_{LB}$$

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$S_{21}\beta + S_{22}\beta + S_{23}\beta + . .. + S_{2n}\beta = Dl_B$

$S_{31}\beta + S_{32}\beta + S_{33}\beta + .. . + S_{3n}\beta = D_{LB}$ (5)

$S_{41}\beta + S_{42}\beta + S_{43}\beta + ... + S_{4n}\beta = D_{LB}$

⋮

$S_{n1}\beta + S_{n2}\beta + S_{n3}\beta + ... + S_{nn}\beta = D_{LB}$

Where β represents the Wi-Fi technology for data transfer so storage locations.

The Algorithm

The algorithm presented in this section was used to enhance the transfer of signal from the sensors to the servers and visualized data in a form that will attract medical experts' attention.

Emergency detection and patients' monitoring algorithm:

Requirements: Set of healthcare sensors for each patients' vital parameters ($B^p{}_v$), set of patients to get physiological parameters, a time stamp (t), ordered digits for interpretation:

[1→ $green(N)$], [2→ $yellow\ (AB)$], [3→ $red(CR)$], packets aggregated at t: ${}_tR^p{}_v = [r1, r2. . . rn]$.

i. *For every packet* ($r_i \in {}_tR^p{}_v$) *do*

ii. *Compute the records(ri) → scores(si) &colour(ci) using SLR*
iii. *If (si)>1 then*
iv. *Indicate patients need attention*
v. *Else*
vi. *Display patients signal on the dashboard*
vii. *end if*
viii. end for
ix. if (Si+1)>Si ∀ Si>1 then
x. additional patient needs attention
xi. else
xii. redisplay patients conditions on the dashboard
xiii. end if
xiv. end

The simple linear regression equation is given by the relationship

$y = ax + b$ (1)

The values of a and b are obtained from Eqn (2) and Eqn (3) respectively

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$$a = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^{\,2} - \left(\sum_{i=1}^{n} x_i\right)^2} \qquad (2)$$

$$b = \bar{y} - a\bar{x} \qquad (3)$$

$\bar{y}$ and $\bar{x}$ are the mean of the computed (patients variable sent to doctor) and sensed (sensor generated variables) respectively. They are computed using Eqn (4) and Eqn (5) respectively

$$\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \qquad (4)$$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (5)$$

Building the Hardware

The hardware consists of different wireless body sensors which are implemented for the physiological patient parameter monitoring. AD8232 ECG is a pulse/heartbeat sensor and DS18B20 is a temperature sensor used in this work. The pulse sensor consists of an embedded microchip front and back view that makes contact with the human skin for reading purposes. AD8232 ECG Sensor is the most commonly used and available ECG sensor that is affordable and can be used for heart rate measurement. The figures below show the hardware components of the sensors used in this study**.**

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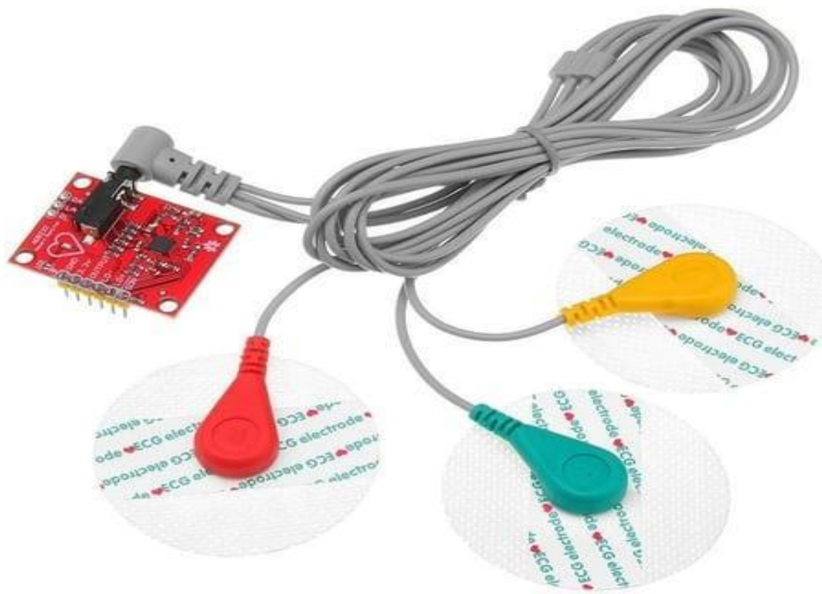

Figure 1: Three leads sensor end of AD8232 ECG Sensor

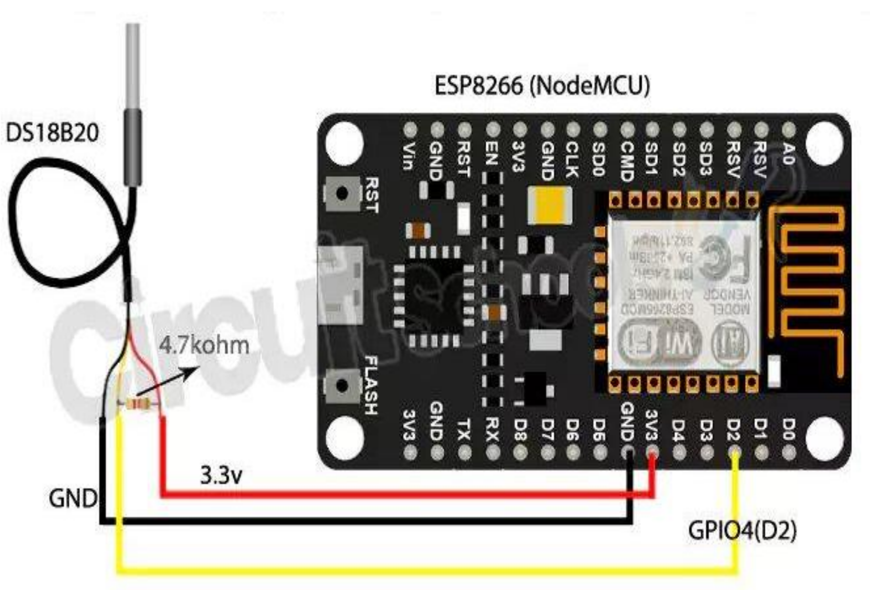

Figure 2**:** Main components of the DS18B20

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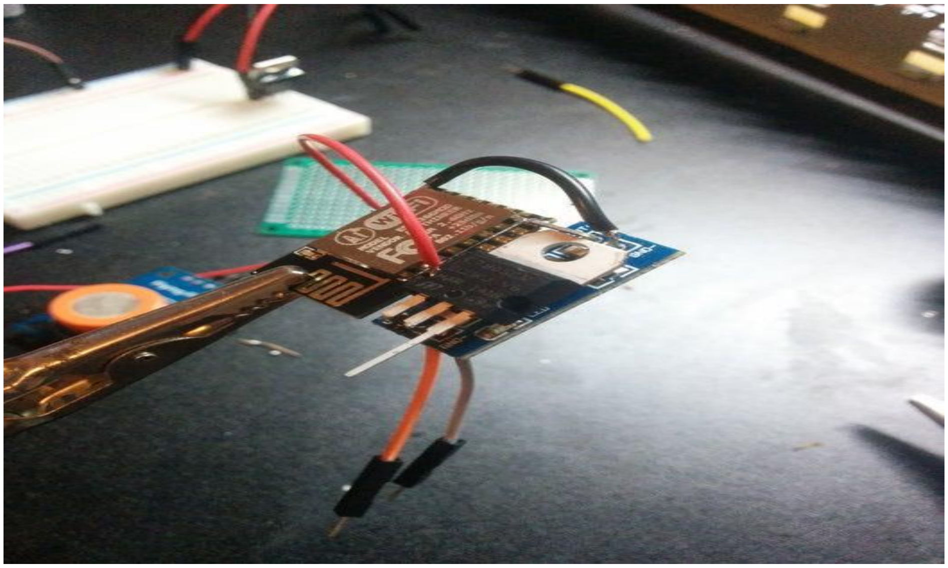

Figure 3: Coupling of DS18B20 temperature sensor

Figure 4: Internal components of the DS18B20 temperature sensor

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Software Development

A web application was designed to provide a graphical user interface (GUI) for patients and a computer visual display unit was used as a medical dashboard for any related physiological parameters acquired from the wearable health device. The software was designed using PHP, Html, CSS and JavaScript as programming language and JQuery, bootstrap, Typescript, Jason and APIs as framework. Blynk was then used as an IoT-server platform. Blynk was used as an IoT platform because it enables the prototyping, deployment, and remote management of connected electronic devices and sensors at any scale. Figure 5 is a flowchart showing how devices are connected with IoT. The main components of the blynk IoT platform are: Blynk console, which key functionalities include configuration of connected devices on the platform, including application settings. Blynk app, whose main functions include remote monitoring and control of connected devices that work with Blynk platform, automation of connected device operations. Others are blynk clouds and blynk libraries.

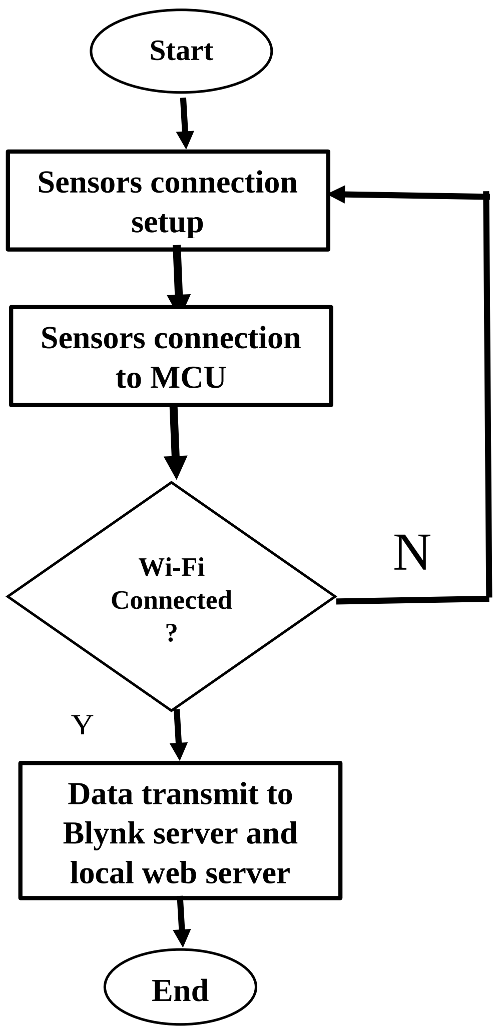

Figure 5. Flowchart showing device connection with Blynk IoT

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RESULTS

Physiological signals were collected from the temperature sensor by placing the sensitive end of the sensors on the arms and armpits of "PATIENT" over a duration of 5 minutes on the first day and the same procedure was repeated on the second day to confirm the effectiveness of the developed system. In each case, data were collated and presented in chart and tabular form. The same procedure was done with the ECG sensor by placing the three lead heads sensors in their appropriate locations. Figure 6, figure 7 figure 8 and figure 9 shows the outcome of the sensor output in a local server.

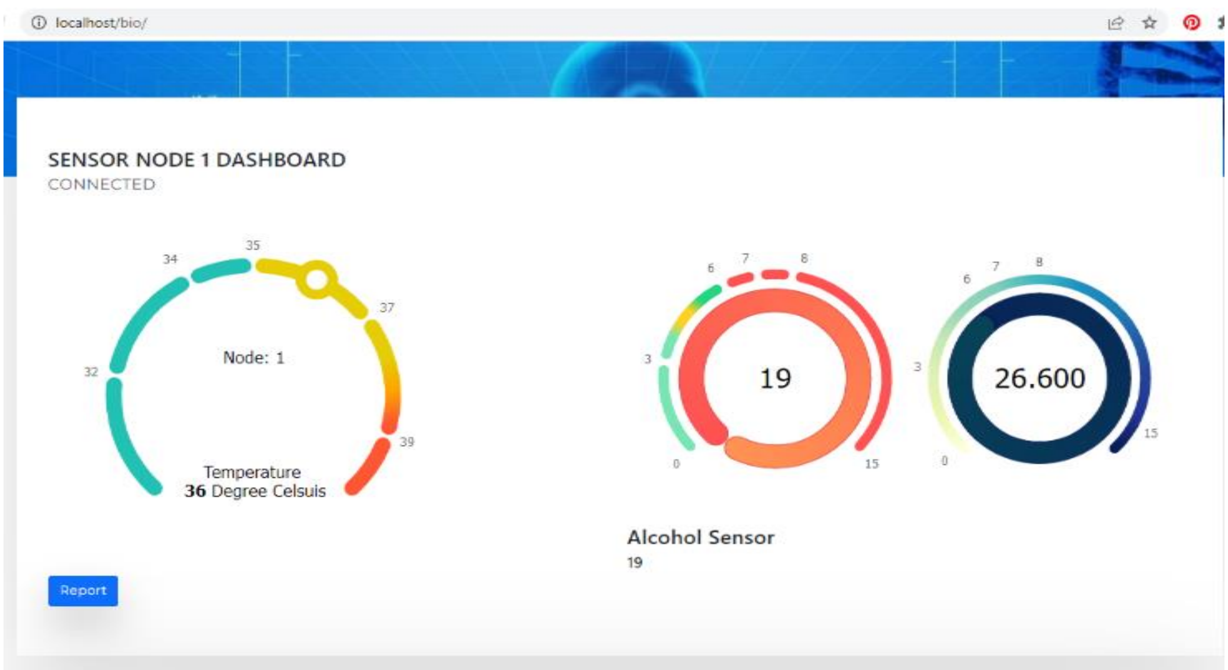

Figure 6: Screenshot of the temperature sensor output

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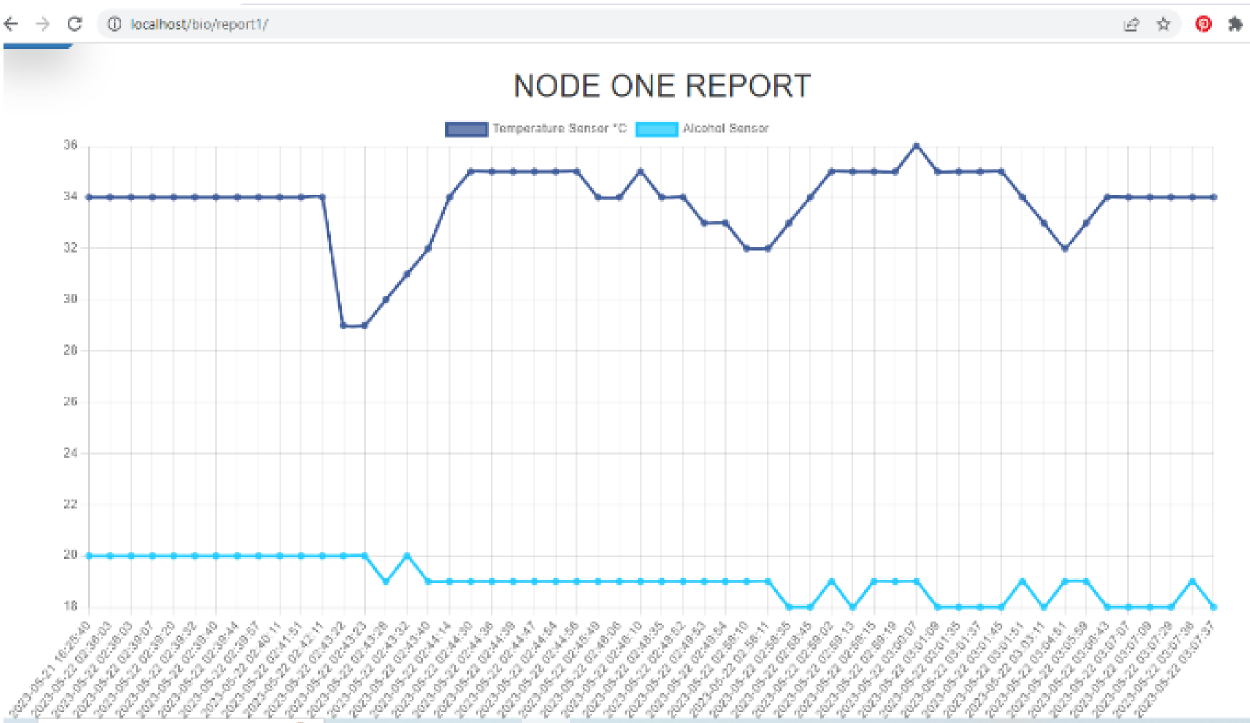

Figure 7: Graphical display of the readings from the temperature sensor

NODE ONE SENSOR RAW DATA TABLE

Time	Temperature Sensor °C	Alcohol Sensor
2023-05-22 03:07:37	34	18
2023-05-22 03:07:36	34	19
2023-05-22 03:07:29	34	18
2023-05-22 03:07:09	34	18
2023-05-22 03:07:07	34	18
2023-05-22 03:06:43	34	18
2023-05-22 03:05:59	33	19
2023-05-22 03:04:51	32	19
2023-05-22 03:03:11	33	18
2023-05-22 03:01:51	34	19
2023-05-22 03:01:45	35	18
2023-05-22 03:01:37	35	18
2023-05-22 03:01:35	35	18
2023-05-22 03:01:09	35	18
2023-05-22 03:00:07	36	19

Figure 8. Tabular representation of temperature sensor data

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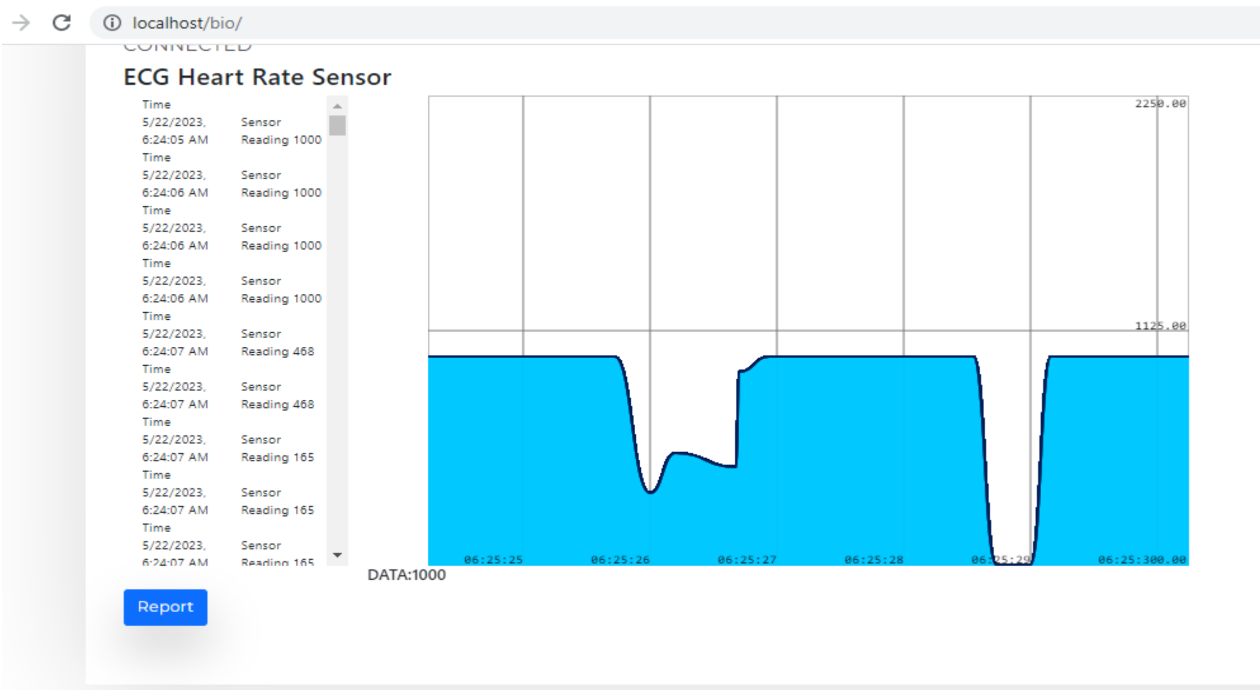

Figure 9.Screenshot from ECG AD8232 sensor

CONCLUSION

Wireless sensor networks are designed for different types of applications used in daily life. The main interest of wireless sensors in this work is on healthcare monitoring of physiological parameters of patients in healthcare facilities. To address the aforementioned issues, this research built a prototype of sensors to collate data from patients in real time. The two main physiological variables considered in this research are body temperature and heart rate. The results of this study are similar to that of [16]. However, this study used an IoT web-based platform (Blynk) which gives it a more scalability and accessibility advantage over the former.

Conflict of Interest (CoI)

We hereby declare that there is no conflict of interest in this research.

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Ethical Statement: No ethical issues

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