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Internet of Things in E-Healthcare System

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Abstract - **Health awareness is important with increasingly complex challenges towards maintaining good health, especially during the COVID-19 pandemic. Regular health monitoring is a must for everyone during the pandemic. This project proposed an IoT based E-Healthcare system to monitor the body temperature, blood pressure and heartbeat rate. The temperature sensor was connected to a Raspberry Pi microcontroller and the readings were stored in the SQLite database management system. The blood pressure and heartbeat rate readings were retrieved from the wrist blood pressure sensor and the readings were entered into the database. The user can access the health data record through a smartphone.**

Keywords—E-Healthcare, IoT, blood pressure, temperature

I. Introduction

In the 21st century, health awareness is the need towards maintaining good health. However, some of them still take it for granted without realizing that life becomes difficult and loses its quality without a good health condition. The public has to be aware of the early signs of each type of disease and sickness so that it can be prevented in the early stage. Some of the common health issues nowadays are high blood pressure, heart disease, and many more. Some of these health problems can be prevented or monitored with a regular monitoring process from the patient.

Body temperature is one of the important indicators that is used to determine the risk of a person infected by COVID-19 since fever is one of the most common symptoms of COVID-19 patients. The public is required to measure their body temperature to ensure that they are healthy and not fever before entering a premise. Patients under investigation are advised to undergo self-quarantine and seek medical advice when their body temperature is more than 37.5 ^{o}C.

Blood pressure is one of the common health issues among the public. Blood pressure is defined as the heart's contraction when blood will be pumped all around the body to provide nutrients and oxygen. The movement of blood creates pressure at the sides of the blood vessels. Extra strain will be exerted on the arteries if this pressure is too high. This could result in strokes and heart attacks. Table I shows the chart for the blood pressure range and its medical categorization.

Table I. Blood Pressure Chart.

Systolic	Diastolic	Your Category
Below 120	Below 80	Normal Blood Pressure
Between 120 - 139	Between 80-89	Prehypertension
Between 140 - 159	Between 90-99	Stage 1 Hypertension
160 or higher	100 or higher	Stage 2 Hypertension

E-health is a fast-growing sector in the interchange of business and public health, medical informatics based on the data conveyed and health services via the Internet. In simple words, e-health uses communication technology and information in healthcare. The World Health Organization (WHO) defines e-Health as the cost-effective and secure use of information and communication technologies to support the health and health-related fields including healthcare, health surveillance, health education, knowledge and research.

E-Health covers a broad variety of subsets of digital health such as Electronic Health Records (EHR), Electronic Medical Records (EMR), Telehealth and Telemedicine, Health IT systems, Consumer health IT data, Virtual healthcare, Mobile Health and big data systems used in digital health. EHR and EMR keep the patient records for regular monitoring, e-booking, e-prescribing, clinical administration systems, archiving systems and digital imaging. Clinical health IT systems such as nursing, radiology, medical imaging, computer-assisted diagnostics, surgery training and planning systems help physicians in providing more exact diagnoses and treatments. IoT has played a major transformation in the healthcare field and improved the lives of millions of patients.

Most patients are not aware of their health condition due to low access to health monitoring. In this modern life, most of us are taking health issues for granted. Moreover, it is an

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arduous task for a doctor to keep track of the patient's health at home. Moreover, regular monitoring is very important for old age patients so that their loved ones are aware of their health condition from time to time even though they are busy in working place. Senior citizens might face transportation problems for regular checkups at healthcare centers. Hence, an automated IoT system was proposed in this project to ease this situation.

IoT is used to overcome and monitor health problems since it is a small and powerful wireless solution. Patients' health data from various sensors will be securely captured and uploaded to the cloud or stored in the database and make them aware of their records and current health status. Data capturing and analysing involve some complex algorithms and codes because they need to be shared through wireless connectivity. Sensors were used to track the patient health and the patients can access the data collected wirelessly. The temperature sensor was connected to a microcontroller and the data was transmitted to the database. The IoT E-health used internet connectivity effectively to save lives on time and monitor the patients' health status.

This paper is reported as follows. A literature review is presented in section II and the research methodology is reported in section III. Extensive results are reported and discussed in section IV and finally, a conclusion is drawn in the last section V.

II. Literature Review

In order to embed the idea of IoT into medical devices, first, the accessibility to the device by common users should be increased dramatically. Consequently, this would increase the efficiency and usage of the data gathered. For instance, it allows every diabetic patient to record and upload their glucose level to the cloud. This would allow medical personnel to predict the nature, demography, effect and complication of that condition whereas data from a low amount of users would not help in formulating a statistical condition. Therefore, producing a multidevice, low cost, user-friendly IoT based e-health system is important. This idea has been further supported by arising research and the creation of such devices.

Gupta *et al.* [1] developed a healthcare system based on IoT using the transmission protocol on Raspberry Pi. This research produces an inexpensive system that could monitor multiple electrocardiogram (ECG) machines automatically. The raw data will be extracted from the ECG machines and updated to the website continuously using Global System for Mobile (GSM) module via RS232 serial port. Moreover, doctors and medical officials will be alerted by a message if the readings fall beyond the norms.

Gupta *et. al*'s research is similar to this project in terms of the transmission protocol device selection and final user interface whereby Raspberry Pi is used and users will be presented with health parameter data. However, in the proposed project more than one type of device is considered to maximize the efficiency of the system. Blood pressure and temperature will be measured using a digital blood pressure cuff and temperature sensor respectively.

Another similar research was done in [2] on a low-cost IoT system. This project focused on maximizing the number of devices connected to the central system to increase its efficiency. In this case, the Zigbee protocol was used as the transmission protocol. This research, similar to the study by Gupta et.al, focused only on ECG.

In addition to that, this system enables multiple users to access the data via different devices. The extracted data will be stored in a server that different parties such as administrators, doctors, and patients are allowed to access. The administrators can observe and manipulate the data, doctors can observe, manipulate and communicate with patients whereas patients are allowed to observe their data and communicate with doctors.

Unlike other researches, this study focused on the amount of incoming data that could be handled by a low-cost transmission protocol system. The study revealed that the system was able to handle data from 20 different ECG machines without any errors. However, increasing the number of integrated ECG machines amplifies the amount of error after exceeding the threshold number of machines which is 20.

Therefore, it is apparent that a project involving a low-cost transmission protocol system that uses a simple mechanism such as Raspberry Pi possesses a clear limitation in terms of its maximum number of integrated sensors feeding data to the system. It would be crucial to identify the threshold value to prevent the collection of unreliable data from different medical equipment.

Different researches done by J. Mohammed *et al.* [3], proposed the integration of IoT into health monitoring systems from the aspect of user-friendliness. An android based mobile application called ECG Android App was developed on top of a health monitoring system to enable wave visualization on mobile phones. J. Mohammed et.al claimed that the android app that transfers data wirelessly would help users in different ways such as:

1. Reducing the cost of medical equipment.
2. Making health issue prediction more feasible.
3. Reducing the number of trips to the doctor.
4. Reducing waiting time.
5. Reducing the cost of personnel and admin operation.
6. Applying pattern recognition and analysis of serious illness in real-time.

This system undergoes ECG data logging, extracts the data from the machine to the SD card of the IOIO (yoyo) transmission controller. The data is then uploaded to a private centralized server and managed using Microsoft SQL Server 2012. This private server is protected using FTPES (file transfer protocol support) protocol.

J. Mohammed *et al.* also used the OTG (on-the-go) added on the IOIO transmission controller to make it completely user friendly. Adding this system requires the users to connect a USB OTG cable to an android based mobile phone and the ECG Android App. This system stores the data on the server with effective usage of the storage space on the cloud. The data is processed to filter the redundancy and different users' data are stored in a centralized system. However, the disadvantages are that the data might not provide adequate service to the user and the introduction of the additional overhead of managing user authentication for multiple users.

Besides further justifying the concept of using low-cost, easily accessible technology, this paper focussed and emphasized that smartphones with wireless network capability would serve as the best monitoring devices in terms of user-friendliness. Another crucial point highlighted in this study was the security of the data collected. Since the medical data of a person are often classified as personal and confidential information, protecting it from unauthorized accessors should be monitored carefully and prohibited. Although this aspect was not studied or developed in the proposed project, it would be a great add on for future studies.

Research by T.N. Gia *et al.* [4] was targeted on IoT based health monitoring systems but was approached from the perspective of the energy consumption of the system itself. Although the energy consumption of different controllers and systems would not affect the output of the system dramatically, it could optimize the battery life and data transfer efficiency of the system. This paper also highlighted the common limitations of similar IoT based health monitoring system which are listed as follow:

1. Interoperability of devices is limited as they are not built upon an IP based system, whereas an IP based system would allow the system to be easily scalable, mobile, lower-cost than Non-IP based systems, and requires lesser power consumption.
2. An intermediate computer would be required to extract and channel information.
3. A specific application software will be required by the processor and user to view and utilize the data.

Extensive research done by A. Archip *et al.* [5] has revealed much detailed information that should be considered to build a multi parameters (with multi-sensors), that consumes minimal processing power, sends information wirelessly to web-server through IP protocol and displays information in mobile phones. The low-cost sensors are used in this project to capture ECG, SpO2, respiratory, non-invasive blood pressure and temperature data from different devices of multiple patients. It was crucial to tabulate all these readings in order to develop a completely flexible system that allows fair resource distribution.

The deployment of the IoTs, edge or frog computing in the e-healthcare systems is proposed in [6, 7]. However, the design of the e-healthcare systems with edge or frog computing is complex and the cost is much higher. The IoTs are also used in e-healthcare to control the fast-spreading disease [8, 9]. This has motivated us to propose a low-cost IoT E-health system that is affordable for all users to monitor body temperature (which is one of the most common symptoms of COVID-19), blood pressure and heartbeat rate.

III. IoT Integration in Medical Device

The objective of this project is to monitor the body temperature, heartbeat rate and blood pressure through a web-based database. A comprehensive user's health database can be created when the user has continually updated the database and the user can access the data collected on the webpage. The temperature sensor was connected to Raspberry pi to collect the body temperature reading of the user.

The SQLite module was used to update the website database continuously. High-Definition Multimedia Interface (HDMI) port in Raspberry pi was used to connect a display monitor so that the clear examination can be done directly from the Raspberry pi. Figure 1 shows the flow chart of the system proposed.

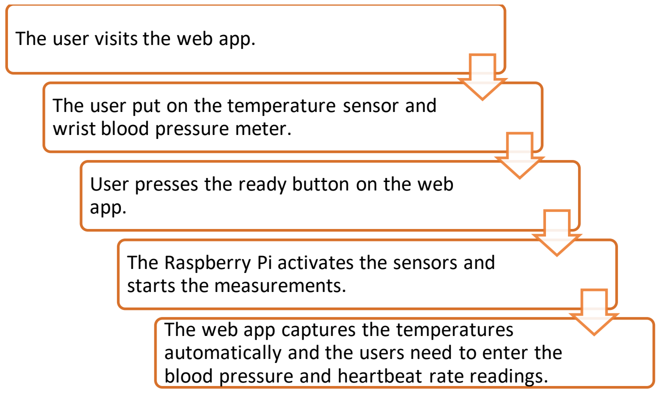

Fig. 1. Overview of the proposed system.

The data from the temperature sensor was collected by Raspberry pi and sent through the WiFi network. The user needs to enter the blood pressure and heartbeat rate readings into the web app. The user can access the protected data anytime by accessing the corresponding IP address in any of the internet browsers such as desktop, laptop, tablet or mobile phones. The user interfaces HyperText Markup Language (HTML) webpage can be refreshed and the user can access the updated data.

The prototype developed was operated under the client/server philosophy. The features of the server and client components play a significant role in the project flow. There are three basic components in a server. First is the detector context. This component is responsible for getting the data. Once the web services give feedback, the data will be captured. This process shows that communication is available between the database and patients. The second component is the reasoning engine. Detector context will provide contextual information. The inference will be made based on the information collected. The third element is the server. The mobile client consumes naturally the request from a smartphone of the patient. Hence, the application is made through the generated interaction at the respective time.

The client consists of two important layers and it is a system developed on Android. The first layer is the Visual Interface which invocates the web server regularly. This invocation makes the reading of blood pressure, heartbeat rate and temperature displayed on the screens. The patient can check the history of their health records for the past 30 days. Figure 2 shows the architecture of the system proposed and the prototype of the system proposed is shown in Fig. 3.

A waterproof DS18B20 digital temperature sensor was used in this project. DS18B20 sensor can measure the body temperature in wet conditions. The cable is sealed with PVC and the sensor sensitivity range is up to 125°C. Signal degradation will not happen even over long distances since it is digital. This 1-wire digital temperature sensor is fairly precise and can give up to 12 bits of precision from the onboard digital-to-analog converter. It can work with any microcontroller by using a single digital pin. A 4.7 kΩ resistor was used with this temperature sensor as a pull-up resistor from the DATA to the VCC line.

Analog output is produced by the temperature sensor. Hence, the output of the temperature sensor is connected to the analog-to-digital converter pin of Raspberry pi. The Raspberry pi will read the data, process it and send it to the server through WiFi once the data is ready. The Android-based application (web app) in the smartphone will monitor the readings taken from the user. The data collected are displayed on the smartphone screen. The readings of blood pressure and heartbeat rate are updated in the SQLite database once the readings are entered manually.

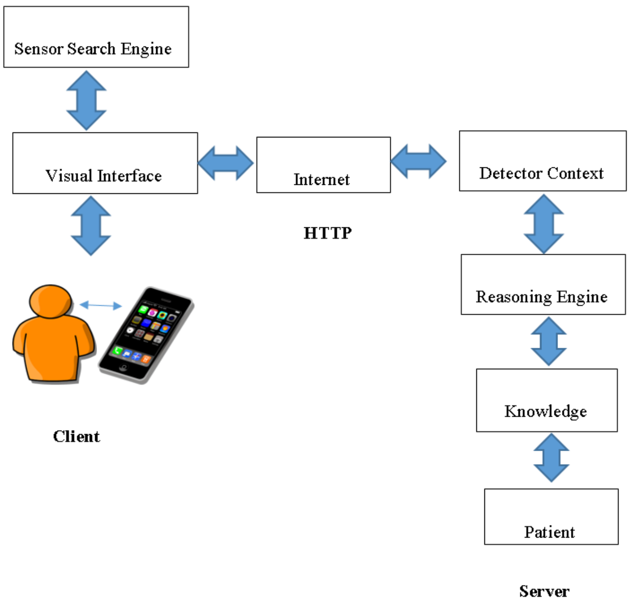

Fig. 2. The architecture of the proposed system.

Fig. 3. The prototype of the proposed system.

Raspbian Operating System (OS) is installed in the Raspberry pi. An embedded web server is developed in the Raspbian OS to monitor the readings of every patient. The temperature, blood pressure and heartbeat rate readings are displayed in the embedded web server through the embedded web with the encryption algorithm. The blood pressure sensor and temperature sensor show the patient's health condition.

The encrypted password is used for security purposes of the embedded web server. Secure Sockets Layer (SSL) encryption method is used for the encryption technique. SSL transmits private documents through the Internet and it was developed by Netscape. A cryptographic system was used by SSL to encrypt data. This system has two keys which are the public key and private key. The private key is known only to the recipient of the message; meanwhile, the public key is known to everyone. URLs that require an SSL connection start with Hypertext Transfer Protocol Secure (HTTPS): instead of HTTP.

IV. Experimental Results

The Python program, Temp.py shown in Fig. 4 is used to capture the reading from the temperature sensor that use the 1-wire protocol. The reading captured is displayed on the standard output (stdout) of the Linux system. This program reads the raw data captured from the temperature sensor. The raw data is decoded into readable values. The program will display the output values on the terminal (stdout).

The user temperature, heartbeat rate and blood pressure readings can be visualized in real-time using the page developed. All data were stored locally using the SQLite database management system. This storage eases the project and eliminates any internet connectivity problems during the presentation or demonstration stage. Data handling and storage is done in PHP, Hypertext Preprocessor.

```
def temp_raw() :
        f = open(temp_sensor, ‘r’)
        lines = f.readlines()
        f.close()
        return lines
def read_temp() :
        lines = temp_raw()
        while lines [0].strip()[-3:]  | = ‘YES’ :
                time.sleep (0.2)
                lines= temp_raw()
temp_output = lines[1].find(‘t = ‘)
        if temp_output  | =-1|;
        temp_string = lines[1].strip() [temp_output +3:]
        temp_c = float(temp_string)/1000.0
        return temp_c
reading = read_temp()
print reading
```

Fig. 4. Temp.py - Python program code.

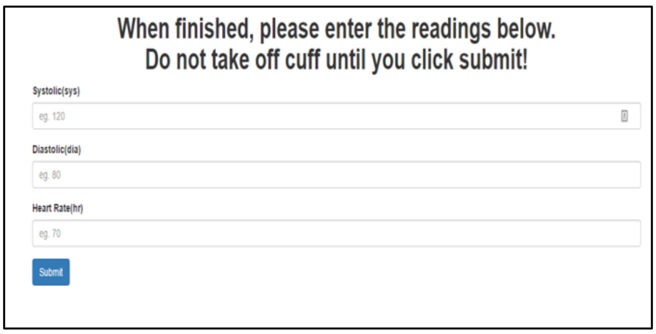

Fig. 5. Webpage to enter the values of blood pressure and heartbeat rate.

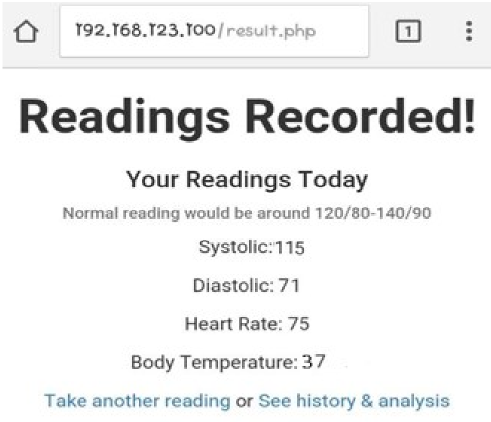

Fig. 6. Health data collected.

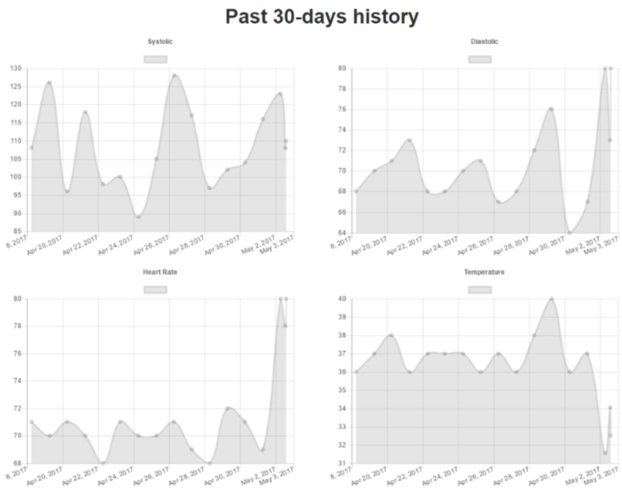

Fig. 7. The past 30 days records of the data collected.

Table II. Temperature Readings Taken from Digital Thermometer and IoT Temperature Sensor Used.

Time	Digital Thermometer (Celsius)	IoT Temperature Sensor (Celsius)
08.00 a.m.	36.90	36.81
09.00 a.m.	36.80	36.73
09.30 a.m.	36.99	36.89
10.00 a.m.	37.10	37.00
10.30 a.m.	37.00	36.87
10.45 a.m.	37.11	37.01
11.00 a.m.	37.10	37.00
11.15 a.m.	36.90	36.85
12.30 p.m.	36.99	36.85
12.45 p.m.	37.11	36.98
01.15 p.m.	36.99	37.00
01.30 p.m.	36.99	36.83
02.05 p.m.	36.98	36.80
02.30 p.m.	36.97	36.87
03.05 p.m.	36.95	36.82
03.45 p.m.	36.99	36.86
04.10 p.m.	37.00	36.87
04.30 p.m.	37.05	36.96
05.00 p.m.	37.02	36.89
05.30 p.m.	36.99	36.86
06.05 p.m.	36.98	36.80
07.30 p.m.	36.99	36.86

The daily health data (blood pressure, heartbeat rate, and body temperature) collected is accessible through the smartphone. Figure 5 shows the webpage to enter the values of systolic, diastolic and heart rate. Figure 6 shows an example of the readings recorded through the smartphone. Figure 7 shows the example of the past 30 days readings record of the users.

Extensive experimental works are carried out to ensure the accuracy of the system proposed. Table II shows the temperature readings taken from the commercial digital thermometer and IoT temperature sensor at various times. The commercial digital thermometer is compared with the measurement taken from the IoT temperature sensor. The reading's difference between the digital thermometer and IoT temperature sensor ranged from 0.07 to 0.17°C.

The average temperature difference between the digital thermometer and IoT temperature sensor is 0.13°C. A correction factor of 0.13 is added to the temperature reading measured by the IoT temperature. The accuracy of the IoT temperature sensor is significantly improved after the correction factor is added. Figure 8 shows the temperature readings of the Digital Thermometer and IoT Temperature Sensor after calibration.

An experiment is carried out to evaluate the consistency of the blood pressure meter used in this project. As shown in Fig. 9 and Fig. 10, multiple readings were taken from 07.01 a.m. to 07.20 a.m. It is shown that the diastolic, systolic and heartbeat rate readings are consistent throughout the time duration The blood pressure meter functions properly and the data collected are accurate and consistent throughout the test.

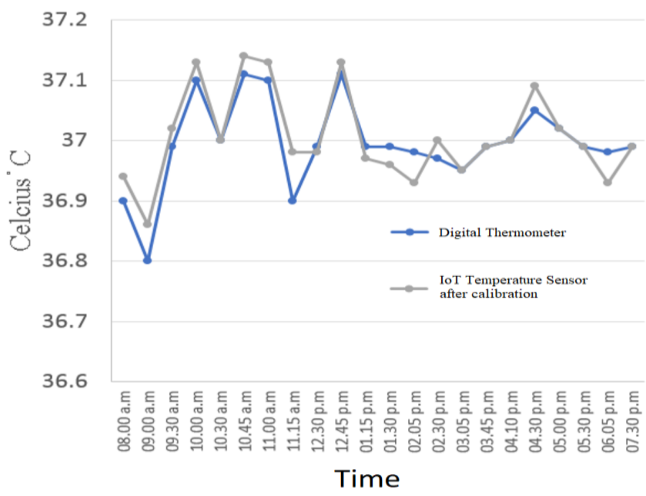

Fig. 8. Temperature readings for digital thermometer and IoT temperature sensor after calibration.

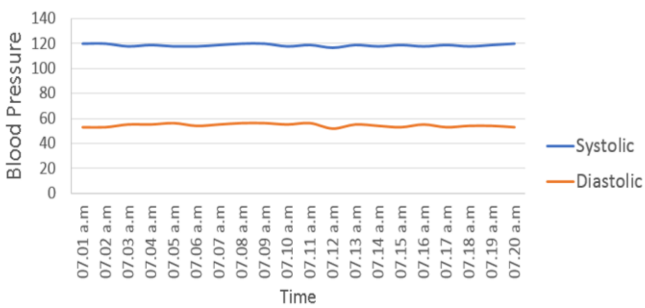

Fig. 9. Diastolic and systolic readings from the meter.

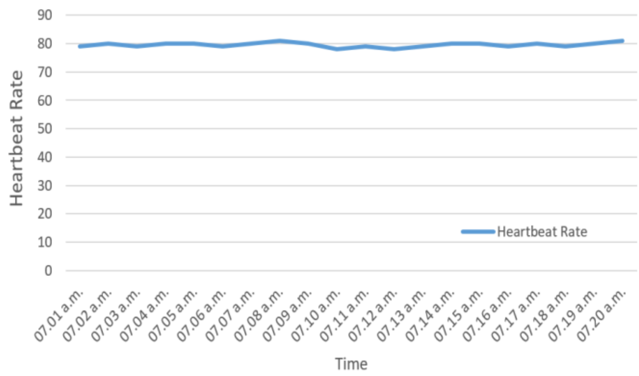

Fig. 10. Heartbeat rate readings from the meter.

V. CONCLUSION

A low-cost E-healthcare system is designed with the IoT sensor and Raspberry Pi. The system proposed monitors the body temperature, heartbeat rate and blood pressure. A waterproof DS18B20 temperature sensor was used to measure the body temperature and a blood pressure meter was used to measure the blood pressure and heartbeat rate of the patients. Extensive experimental works are carried out to ensure the accuracy and precision of the system proposed. The accuracy of the system is significantly improved after the calibration by adding the correction factor to the temperature reading measured. The data collected are accessible through a web-based database. The user can access the protected health data anytime by accessing the IP address through the smartphone. More IoT sensors can be added to the E-healthcare system in future to monitor more health data (such as Oxygen saturation level, cough detector, etc.) in order to strengthen the E-healthcare system.

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