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Development of a Miniature and Low-Cost IoT-Based Remote Health Monitoring Device

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***Abstract*—**The modern busy world is running behind new embedded technologies based on computers and software meanwhile some people are unable to monitor their health condition and regular medical check-ups. Some of them postpone medical check-ups due to a lack of time and convenience while others skip these regular evaluations and medical examinations due to huge medical bills and hospital expenses. In this research, we present a device in the telemonitoring system capable of monitoring, checking, and evaluating the health status of the human body remotely through the internet for the needs of all kinds of people. The remote health monitoring device is a microcontroller-based embedded unit. The various types of sensors in this device are connected to the human body, and with the help of an Arduino UNO board, the required analogue data are collected from the sensors. The microcontroller on the Arduino board processes the analogue data collected in this way into digital data and transfers that information to the cloud and stores it there; the processed digital data are then instantly displayed through the LCD attached to the machine. By accessing the cloud storage with a username and password, the concerned person's health care teams/doctors, and other health staff can collect these data for the assessment and follow-up of that patient. Besides that, the family members/guardians can use and evaluate these data for awareness of the patient's current health status. Moreover, the system is connected to a GPS module. In emergencies, the concerned team can be positioning the patient or the person with this device. The setup continuously evaluates and transfers the data to the cloud and also the user can prefix a normal value range for the evaluation. For example, the blood pressure normal value is universally prefixed between 80/120 mmHg. Similarly, the Remote Health Monitoring System (RHMS) is also allowed to fix the range of values referred to as normal coefficients. This IoT-based miniature system 11×10×10 cm^3 with a low weight of 500 gr only consumes 10 mW. This smart monitoring system is manufactured for 100 GBP (British Pound Sterling), and can facilitate the communication between patients and health systems, but also it can be employed for numerous other uses including communication sectors in the aerospace and transportation systems.

***Keywords*—**Embedded Technology, Telemonitoring system, Microcontroller, Arduino UNO, Cloud storage, GPS, RHMS, Remote Health Monitoring System, Alert system.

I. INTRODUCTION

THIS is the time when modern society gives more importance to IoT-based mobile devices and gadgets. Humans today rely on such devices for 60% of the tasks in daily life. Therefore, there is a situation where they cannot be replaced. Time constraints and financial gain attract people to such devices [1]. But for the same reasons, people forget or deliberately omit many important things related to their health. One of the most important things is health [2].

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Skyrocketing medical bills and long queues at hospitals are preventing from regular health check-ups. Such omissions lead to chronic illnesses combined with pain. IoT-based Remote Health Monitoring System (RHMS) is a solution to this situation to some extent. RHMS is an embedded system that includes sensors and microprocessors [3]. The patient's health information is collected and stored in the cloud memory over the internet. The patient's doctor or other healthcare workers can access this information and use it for medical purposes [4]. Also, family members are always updated about a patient's health condition in the hospital [5] through this tool. They can know the patient's current condition in real-time. This system is effective not only in the health sector but also in the defence and transport sectors [6]-[9]. Another significant issue of current health monitoring systems is their high-power consumption. Many researchers developed various types of kinetic harvesters [10]-[12] to energize monitoring sensors [13]-[15]. In this research, we developed a low-power consumption monitoring device using efficient sensors to reduce battery replacement.

II. PROPOSED SYSTEM

IoT (the Internet of Things) is a communication facility that connects devices to devices and devices to the cloud [16]. Such technologies that can transfer data to another platform through the internet or other communication channel, are the backbone of the RHMS. This IoT-based project can be divided into two parts [17]. First is data collection and transmission, and then the receiver section and storage. Sensors and microcontrollers work hand in hand to send and store information from the transmission side to the cloud over the internet. These data are then displayed in the cloud for medical analysis [18]. LM35 and pulse sensor are planned to be included in this project as a first phase test. LM35 is a diode-connected transistor circuitry arrangement. It operates based on the base-emitter voltage which is the forward voltage [19]. Whenever the temperature changes, the voltage drop between the base-emitter terminals changes. In other words, the measured temperature is always linear to the induced voltage. Similarly, the green colour LED attached to the pulse sensor and a photodetector are the main parts of the sensor used to measure the pulse from the human body. Haemoglobin in human blood is the oxygen carrier in the body [20]. Haemoglobin can absorb green light. The amount of light absorbed in the blood is proportional to the haemoglobin concentration in the blood flowing from the heart through the arteries. After absorption, the reflected light intensity is evaluated by a photodetector and produces an analogue signal corresponding to the pulse rate [21]. This type of analogue data are converted using a 10-bit ADC and fed to the microcontroller. After the process, the output will be displayed on the LCD. The processed information is then transmitted to the cloud via the ESP8266 over the internet. These data can be used for health monitoring and evaluations [22]. Also, the AI system installed in cloud will keep comparing the updated information with the normal value range [23]. When the measured value goes out of the predestined range, an alert system is triggered and a message is sent to the person's contact list detailing the emergency of the person's health. Also, it is possible to track and lock the location of the person through the GPS attached to the device. It will be very helpful for emergency rescue operations [24].

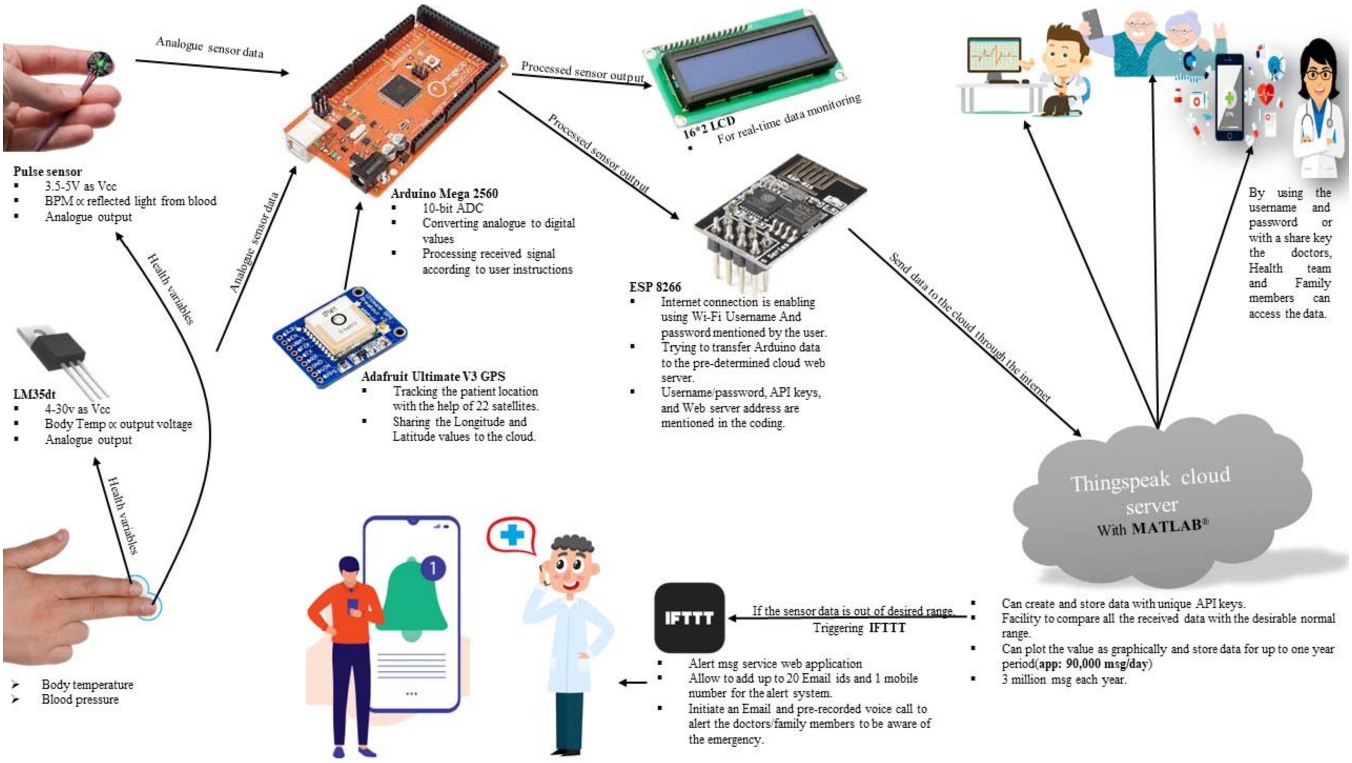

Fig. 1 Flow chart showing RHMS working diagram

A. Proposed Architecture

RHMS works in two phases: transmission phase and receiver phase. RHMS works through the following steps as suggested in Fig. 1.

Step1. Data are collected from sensors attached to the body and transferred to the microcontroller.

Step2. After the ADC convention, the processor processes and displays the data.

Step3. Processed data and GPS coordinates are transferred to the cloud via the internet with the help of ESP 8266.

Step4. The cloud displays the data in graphical/digital format in data presentation methods. Those who access the cloud using cloud credentials can read these data.

Step5. AI keeps monitoring the updated data. In the event of an emergency, the system will send an alert message to the patient's contact list.

III. Implementation

The IoT system is a very powerful tool for remote monitoring techniques. For the IoT-based RHMS system, LM35 and Pulse's sensors are connected to analogue input pins A0 and A1 of the Arduino mega microcontroller board, respectively. GPS module access location through TX1 and RX1 interfaces.

LCD works through clock and data connectivity such as SCL and SDA. The ESP8266 communicates with the cloud via digital PWM pin 2 and pin 3. A 9V battery is connected as a power supply through a Vin connection. The data from the sensor are sent to the cloud via the ESP8266 microcontroller. Data can be stored and presented in different fields using a unique API key.

IV. Results and Analysis

Equipment used for health checks should always be calibrated and accurate. Even a small error in measurement times can lead to huge losses. Therefore, it is a very important stage to evaluate the performance of RHMS. For that, the result of the utility was compared with the result of medical types of equipment. A comparison was made by using V-600 to measure heart rate and a Welch Allyn temperature device to measure temperature. Table I adds the test results on five different patients [25].

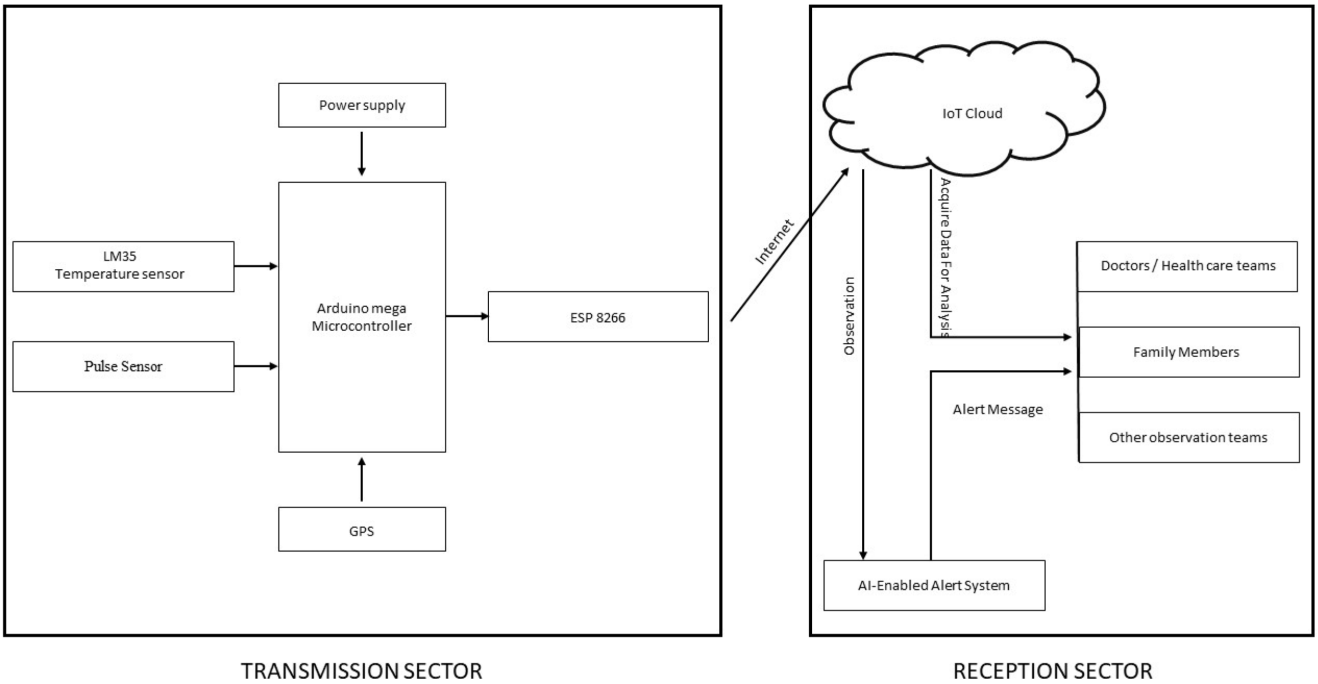

Fig. 2 IoT-Based Transmission and Reception Sections in RHMS

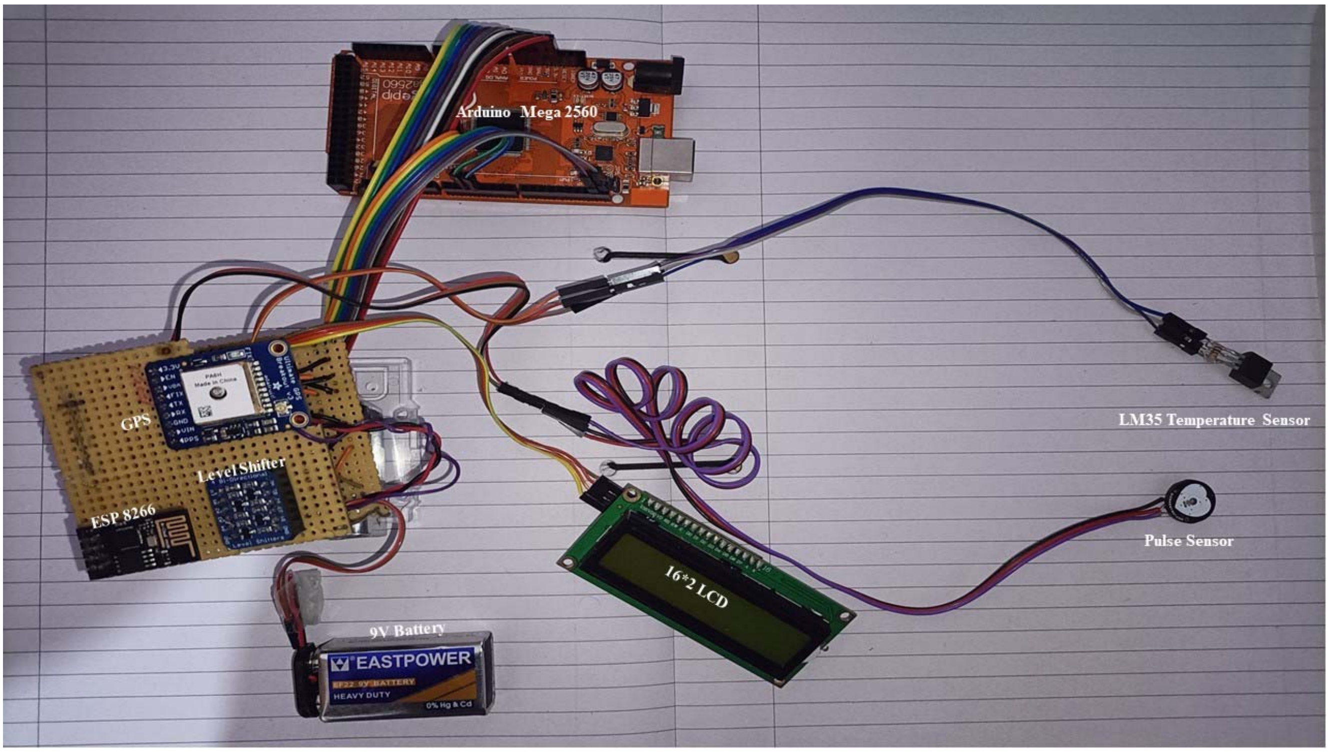

Fig. 3 Implementation of sensing module

According to the medical records, the health condition of the first three persons was normal, the fourth person suffered from fever and the fifth person suffered from heart disease. The information from the device supported the medical records; +/- 4 deflection pulse output and +/-2 point different temperatures and medical records showed differences also when tracking the location through a Google Map, the device shows only about 7.8 m actual location error. Hopefully, this error can be corrected with more precise sensors.

One of the key features of this project is data stored in the cloud. There are several user-friendly third-party cloud websites like Thingspeak and Blynk available for IoT-based projects. Thingspeak cloud website is used for this project which is based on MATLAB [26]. These are web applications based on the Play Store application that can be installed on a computer or smartphone. But Thingspeak is available as a website, so users can access these sites using Google Chrome or any other type of web browser [27]. Anyone can access the web page with the help of these URLs. At this stage, it will ask for credentials.

TABLE I
DEVICE TESTING AND EVALUATION RESULT

Patient No.	Heartbeat/pulse (BPM) (From Fingertip)		Body Temperature (From Fingertip)		GPS Coordinates
	Measured value	Medical value	Measured value	Medical value	Measured location Vs. Actual location (m)
1	78	74	30.2	29.7	7
2	58	63	35.7	34.26	5
3	65	69	31.1	29.56	8
4	92	89	28.4	27.82	12
5	103	99	24.7	22.78	7

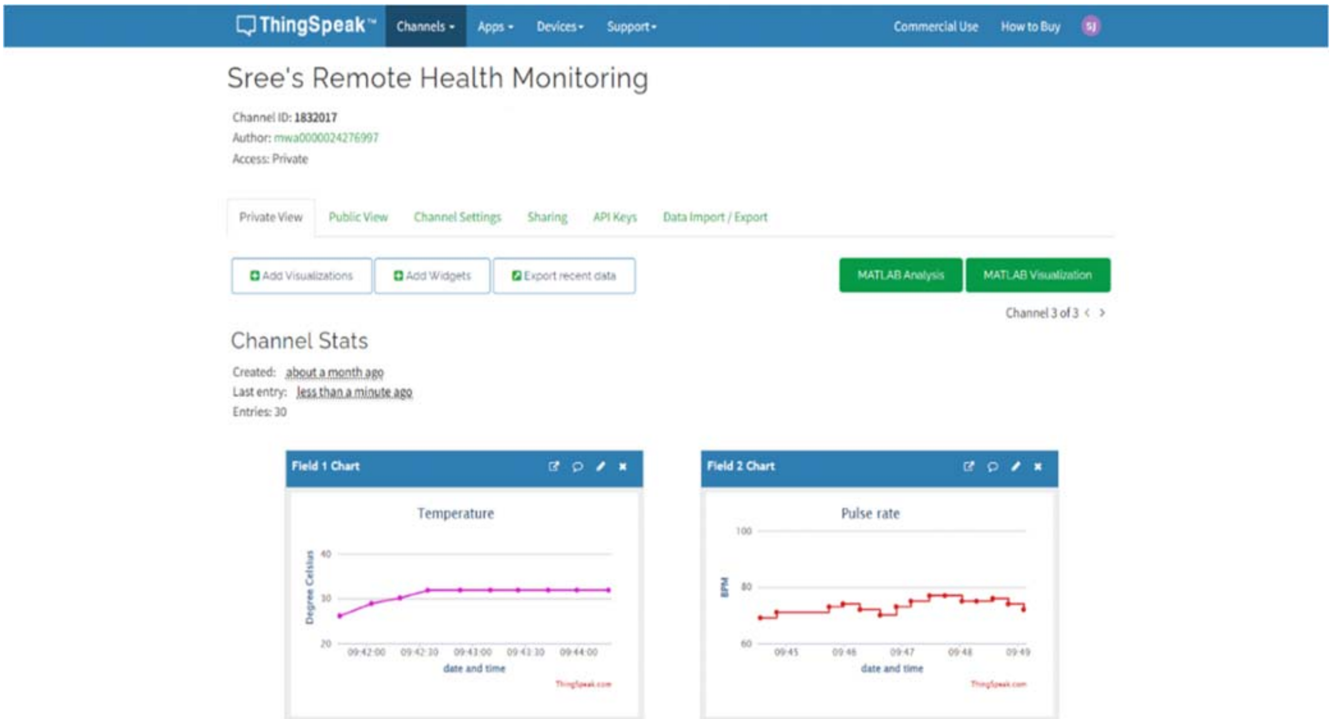

Fig. 4 Graphical representation of collected sensor data

The individual can log in to the page used for data storage with the correct username and password. Users can build a page using a unique API key mentioned in Arduino coding which helps to upload data to the page. On the page, user-collected data can be easily customized and displayed. The page includes settings to display data in graphical mode and digital counter mode with colours of your choice. Displayed data can also be sorted using the time/date they were uploaded. To know whether the received value is in the normal range, the user will keep comparing it with the previously set value range. The normal range of users can vary anytime based on the person being evaluated. The site is updated at 15 second intervals. ESP8266 will continuously send data to the cloud but only the data coming in this time frame will be updated. The data collected by the sensor are collected and presented in digital counter and graphical form as shown in Figs. 4 and 5. These data are updated at every 15-second interval and displayed on the cloud. These data are monitored and compared by the alert system [19], [28].

V. CONCLUSION

The construction phase of the project was very challenging. It was important to keep the project goals in mind when selecting sensors and accessories for the prototype. A lot of attention had to be paid to the price and size. Designed PCB boards that can be attached to the motherboard with minimal wiring helped reduce the project's overall size. RHMS is packed with accessories out of 10 parts so keeping the power consumption within the budget was a very difficult task. Accuracy in soldering and reduced leakage current helped power budgets. Since the measured current is 1.1 mA, power consumption is 9.9 mW (P=V*I = 9 * 1.1 = 9.9 mW). The design of the RHMS, which is not limited to patients, but is also useful to other populations, helps extend the application of the RHMS to other areas. RHMS is made of very lightweight parts; hence, the machine is very lightweight and compact. Every accessory has been selected after a lot of market study and price comparison. So, the device will be affordable in price and budget friendly. It has been possible to design a batteryoperated device that completely avoids AC voltage but includes a slot to use AC in emergencies. The device is powered by a 9V DC battery. Such batteries are easily available and any user can easily replace this battery. The battery box is fixed at the bottom of the machine. The software-controlled alert system works very efficiently. An example of this is when an alert system is activated when a patient is observed during testing. A GPS working without an external antenna is an example of a very successful tracking system that provides location coordinates within a radius of a very small tolerance value (+/-7M). The use of ESP8266, which can be connected to both mobile hotspots and Wi-Fi modems, is suitable to provide internet service to the monitored person in any situation and keeps the person always connected to the RHMS. This IoT-based miniature system 11 × 10 × 10 cm^3 with a low weight of 500 gr only consumes 10 mW. This smart monitoring system is manufactured for 100 GBP, and can facilitate the communication between patients and health systems.

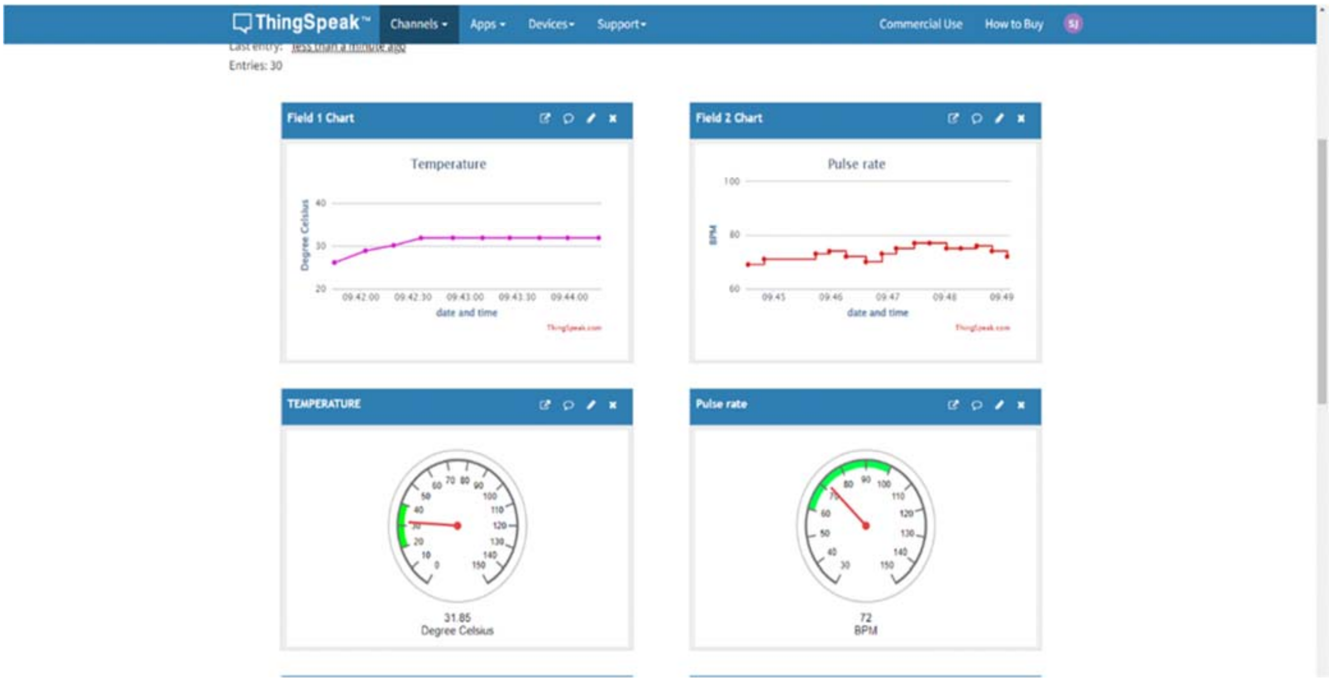

Fig. 5 Digital and graphical representation of collected sensor data

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