Design and analysis of energy efficient IoT system for health monitoring

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***Abstract*- Internet of things (IoT) has grown so much that it also finds its application in the design and development of smart health monitoring systems. With the help of IoT, one can design its own setup for health monitoring that can regularly help us to check the health of a patient such as its body temperature, SpO2 level and heart rate and can give emergency medical attention to the patient on time. In this paper, smart health monitoring system setup is designed for measuring the health parameters of a person. The system is capable of measuring body temperature, SpO2 level and heart rate of the patients. With the help of ESP8266 Wi-Fi module, the data is sent to the cloud i.e., Thing Speak Channel. The use of lora (Ra02) module makes the setup energy efficient as compared to Wi-Fi module. Then, the data sets are analyzed for different classes such as body temperature, SpO2 and heart rate. The system allows us to monitor the patient remotely all the time even if there is no physician or doctor nearby for the diagnosis.**

***Index Terms*- Internet of things (IoT), Barometric pressure, Oxygen saturation (SpO2), Lora, heart rate, beats per minute (bpm)**

I. INTRODUCTION

With the recent advancements in technology and with 6G under development, IoT plays a major role in almost every domain of life. If we talk about telecommunication, Banking sector, healthcare and even agriculture and Robotics. It has made our life easier and convenient. Sensors are now being used almost everywhere such as in automobiles, home automation, health bands and watches. Internet of Things (IoT) is now a reliable technological standard and a heavily research field. Sensors are being used almost everywhere in the present time, from everyday products to industrial monitoring systems [1]. One of the major applications of IoT is smart health monitoring systems where it is used to track the health of patient 24*7 and can give him emergency medical attention if needed. According to the most recent data, China spent over 4634 billion yuan in 2016, accounting for around 6.36 percent of total GDP, and 7231 billion yuan in 2021, accounting for 7.1 percent of total GDP [2]. Devices such as fit bits, smartwatches and smart bands are used to record the heartbeat of a patient and its oxygen level, which is very important for good health and can also save a person's life if timely steps are not taken. Parameters such as oxygen saturation and heartbeat are very vital for good health. Recent advancement in Wireless sensing technology has led to the emergence of a broad range of applications in different domains such as medical, sports, social networking [8]. The heart in normal resting conditions is between 60-100 bpm and can change upon varying conditions. Thus, IoT helps to give timely alarms when the patient requires medical attention. With modern technologies communication has also become fast and thus monitoring has also become very fast. Lo-Ra has also increased the communication levels and being energy efficient.

Nowadays, with the increasing workload and busy life, one of the major aspects of life is getting deprived, i.e., good health. Smart monitoring plays a major role in proper health monitoring of a patient. Smart technology has revolutionized the method of health monitoring very much. Smart health bands are a way to keep a record of a person's health and send an emergency signal in case of any criticism. The IoT-based smart healthcare system is a real-time patient monitoring system, which has significantly aided the healthcare industry [3] In such areas where the epidemic is spread, it is always a better idea to monitor these patients using remote health monitoring technology. So, Internet of Things (IoT) based health monitoring system is the current solution for it [4]. In recent years, the healthcare industry has shown rapid growth and has been a major contributor to revenue and employment.[5]

There are various devices that are used to monitor the health of patients remotely and can send the data directly to the clinical centers or hospitals that makes it easy for clinicians to monitor the patient and send regular updates. On the other hand, previously there were devices that didn't allow patients to leave the hospital because the technology was not that much advanced.

II. PROPOSED HARDWARE SETUP

It is a three-layered hardware device used for health monitoring of a patient and it can also be used as a wearable technology to monitor the health of infected people in real time. In case of any emergency or alert, this device tells us about the patient's health and informs us about the affected or contaminated patients. Shown in the above figure, the device architecture and all the essential components it includes.

Wearable IoT devices

This layer is the layer responsible for the collection of data from the patient for real time monitoring purposes. It collects GPS sensor data and the medical data needed for the evaluation of patients' health. All the sensors that are met with the Arduino collect the data from the patient. A GPS sensor data helps us to locate the patient, it tells us about the geographical location of patient and then finally transmits the data on the cloud or the server available nearby.

Web Front-end layer

This layer manages the protection of information and the medical data when we extract it from the cloud while getting connected to a domain. The micro-controller plays a key role in receiving and analyzing information before sending or transmitting the data to the cloud for storing and extraction purposes. The data of patients is very important for analyzing and comparing with the data of an infected person. It may also help in knowing the differences between an infected person and a fit and thus we can take necessary or preventive measures to prevent the spread of that infection.

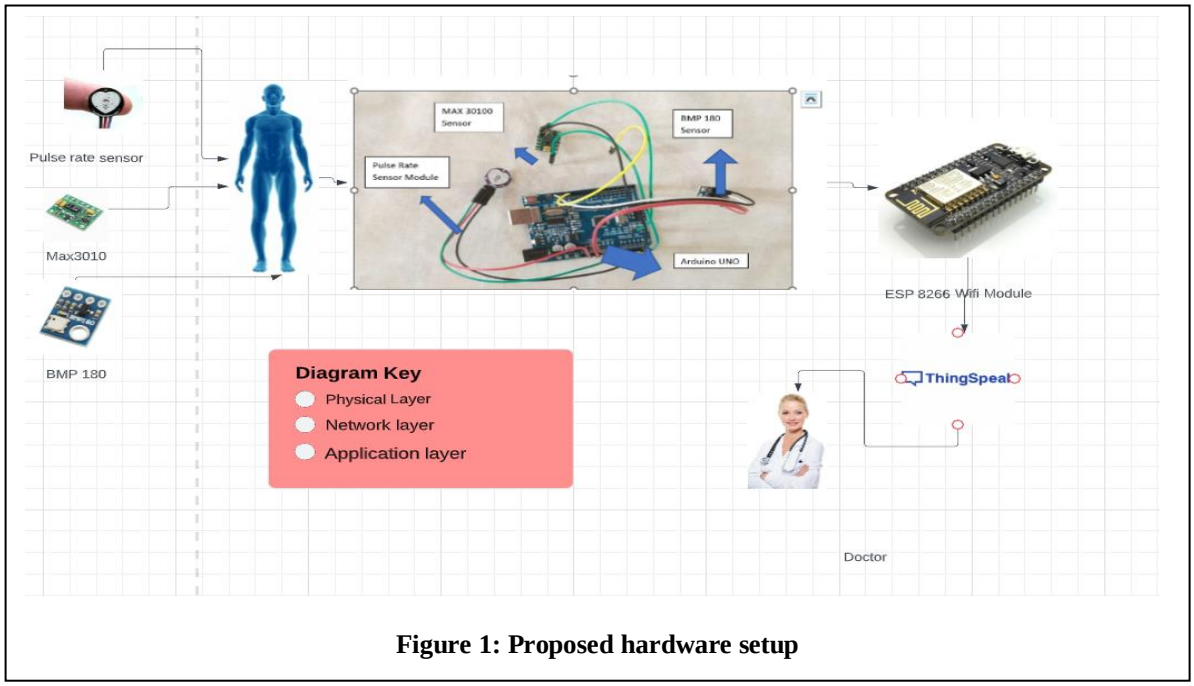

Figure 1: Proposed hardware setup

Cloud Layer

This layer is the software part responsible for storing the data for real time monitoring. Thing Speak cloud is a secure platform that provides data security, and no one can see or login to the data that we have stored. Thing Speak is a network architectural app and it is a team's platform as well as individual. It needs your google account to manage the data in the cloud as a free version is available only for a month. It enables the user to create a safe and internationally trusted network for the app. It saves all the information about its users that is kept private, and no one can see. It also shows the location and tells us about the recent changes or updates. One can thus see or monitor the data any time and get to know about the patient's health. It can also update his relatives or family in case of any emergency required for the treatment.

Lora

All the different layers have their specific task to perform, and each layer is interconnected with each other. If there is no physical layer, then it is not possible for us to extract the data and send it to the cloud layer for further processing. Hence, as IoT performs on the layered architecture, it tells us about the steps in which our hardware will work. Here, the lora module plays a key role and helps us in the fast transmission of data packets with increased range and lower energy consumption when compared to previous Wi-Fi ESP 8266 module.

The devices able to sense human bio-signals are known as biomedical sensors. Their design has been guided by the need to make them lighter, less intrusive for human activity as well as able to provide value-added services to the user. These design criteria have helped to integrate them into the new wearables devices and to popularize them among citizens [6].

III. EXPERIMENTAL SETUP

In the hardware, authors have used microcontroller board (Arduino UNO), BMP 180 (Barometric pressure sensor) used to monitor the blood pressure with respect to the sea level or altitude, MAX 30100 Sensor (Pulse oximetry sensor) which is used to measure the SpO2 level or oxygen saturation level of the human body as well as the heartbeat and the Pulse rate sensor module used to monitor the heart beats.

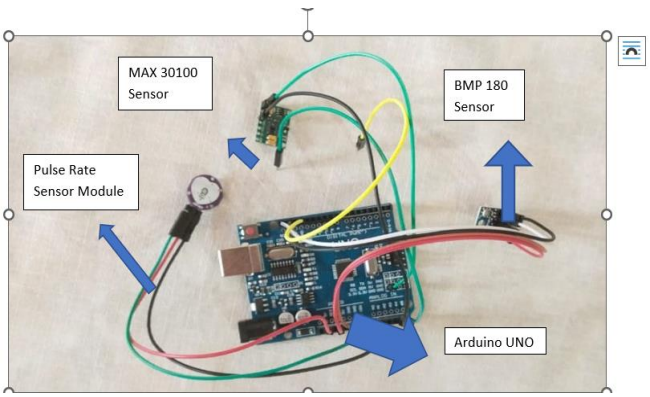

Figure 2: Experimental setup

The authors have also used ESP 8266 Wi-Fi module to send the data recorded to the Thing Speak IoT cloud. To send the data over the cloud using Wi-Fi we need to input our network Id and

password while coding the Wi-Fi module with Arduino. First, there is interfacing of all the sensors and the Wi-Fi module with Arduino by using jumper wires so that it can measure all the vitals (Blood pressure, SpO2 level and heartbeat monitoring)

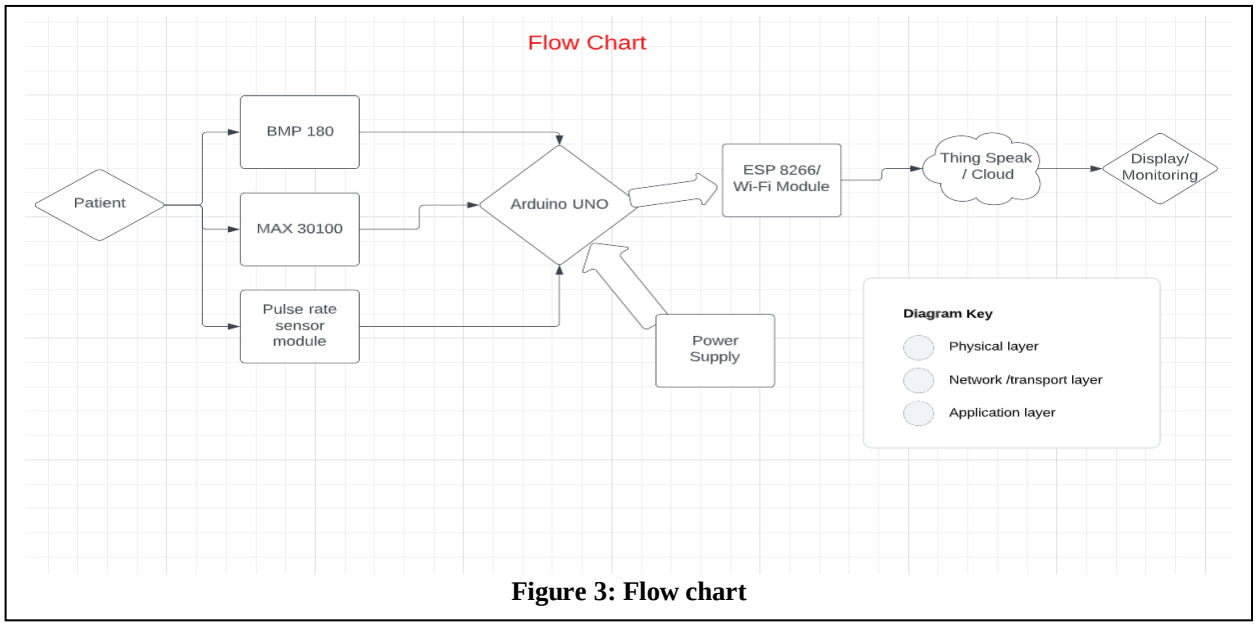

Figure 3: Flow chart

Software

After the hardware, comes the software that is very essential for the Real Time monitoring of the patient's health. By using the ESP 8266 Wi-Fi module we have transmitted the data over the Thing Speak IoT cloud and then we can monitor the data by creating a channel with the required API Keys. Here we can use different techniques over Thing Speak such as MATLAB analysis and visualizations. In this way, we first used all the sensors and using Arduino, we have interfaced these sensors. These sensors will be working after programming them with Arduino. For recording of the data from sensors, place the finger on them and open the monitor window of the Arduino. Initially, the screen appears with successful initialization of the sensors. Now the sensor starts recording the data from you (your vitals). All the readings of data can be monitored on the screen. The recording of the Pulse rate sensor can also be viewed. It shows a waveform for pulse. There is also an option of selecting the baud rate. Here the default baud rate is set to 9600 for our readings but can be changed too. After recording or watching the data, it finally needs to be transmitted on the cloud or server with the help of any gateway or technology. So, we have used the Wi-Fi module to send our data on the Thing Speak channel. This is ESP 8266 Wi-Fi module.

First, it is essential need to meet this Wi-Fi module with Arduino. For this, it is very important to turn on our hotspot and then need to enter the Network id and password which was decided prior to this. After adding network id and password, it finally sets up the connection and starts blinking. Now, the module is ready to send the data from Arduino to the cloud after setting up the connection. Now, open the Thing speak channel that we have created specifically for these types of readings. Copy the read and write channel IDs and paste it in the code. Finally run the code, we can see the data on our channel now as it has successfully transmitted from Arduino to the cloud. We can perform various analysis and visualization techniques to see the data in different forms. For example, we can perform a histogram, a correlated data plot and can even see the min max values of the curve.

Lo-Ra Ra02 module.

To make the system energy efficient, authors have used the LoRa module after ESP 8266 Wi-Fi module and send the data packets with the help of the lora module. As we know, lora is more energy efficient than other networks and has a longer range compared to Wi-Fi and Bluetooth. It is a radio communication technique that uses radio waves for communication. It is based on CSS (chirp spread spectrum technique). It is used for long range transmissions with low power consumption and increased data security and less interference. It consists of a transmitter and receiver with bi-directional communication whereas on the other hand Wi-Fi and Bluetooth are only unidirectional.

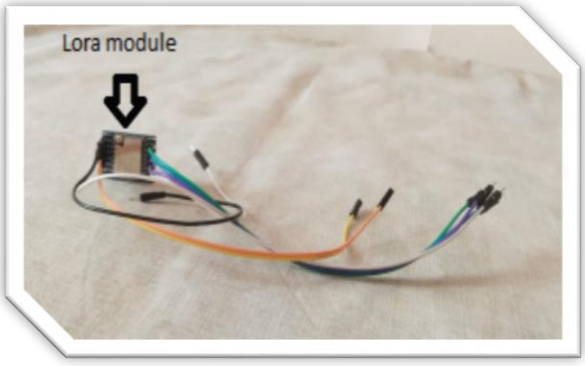

Figure 4: Lora Transmitter setup

In this project, data packets are transmitted with the help of the lora (Ra02) transmitter module and receiver module. Thus, authors have stored the data in a cloud and done data analysis and MATLAB visualizations. After taking the readings from our setup for Temperature and pressure, SpO2 saturation and heart rate we

have created data sets for body temperature, SpO2 and heart rate in csv format. Finally, after the hardware setup and data extraction, authors analyze the data by performing ML techniques with the help of Kaggle. We have given the input as our data set and analyzed the data. We can segregate our data sets into six different columns with body temperature, SpO2, heart rate, elevation, longitude, and latitude. The elevation we have taken here is 228 meters. Finally performing the health parameters showing the status of SpO2 whether it is normal or below the normal condition. SpO2 level between (95-100) % is found to be adequate and it is from 90-95 the person is below normal. But SpO2 level <90 % saturation is a critical condition, and, in that way, he needs emergency medical attention.

Similarly, the analysis of heart rate can be done and it can be known if the patient has a good heart rate or if it is below the normal rate. SpO2 also plays a key role for good bpm. If a person has SpO2 level below the normal conditions, then he has a higher number of heart beats per minute. A normal heart rate in ideal resting conditions is from 50 to 70 beats per minute. If the heart rate is below 50 bpm, then the patient needs emergency medical treatment. We can study and check all the necessary health indicators for a patient that pertains to his good health. A good body temperature, adequate SpO2 saturation and good heart rate. We can also plot a correlation plot for all the data set that gives a brief comparison of the patients having ailment or the level.

Table 1: Sample sets

created at	entries	body temperature	Sp02	heart rate	elevation
2022-11-03T03:12:07+05:30	1	31	93 %	52	228
2022-11-03T03:13:00+05:30	2	34	94 %	59	228
2022-11-03T03:15:28+05:30	3	36	95 %	62	228
2022-11-03T03:19:27+05:30	4	35	93 %	63	228
2022-11-03T03:26:26+05:30	5	33	93 %	64	228
2022-11-03T03:27:47+05:30	6	32	94 %	65	228
2022-11-03T13:01:50+05:30	7	30	96 %	67	228
2022-11-03T13:02:06+05:30	8	34	96 %	68	228
2022-11-03T13:02:32+05:30	9	33	91 %	47	228
2022-11-03T13:03:09+05:30	10	30	93 %	73	228

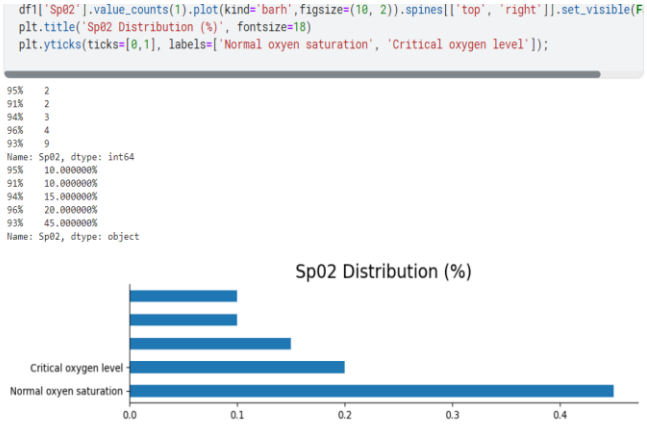

Figure 5: Analyzing the data sets for SpO2 distribution.

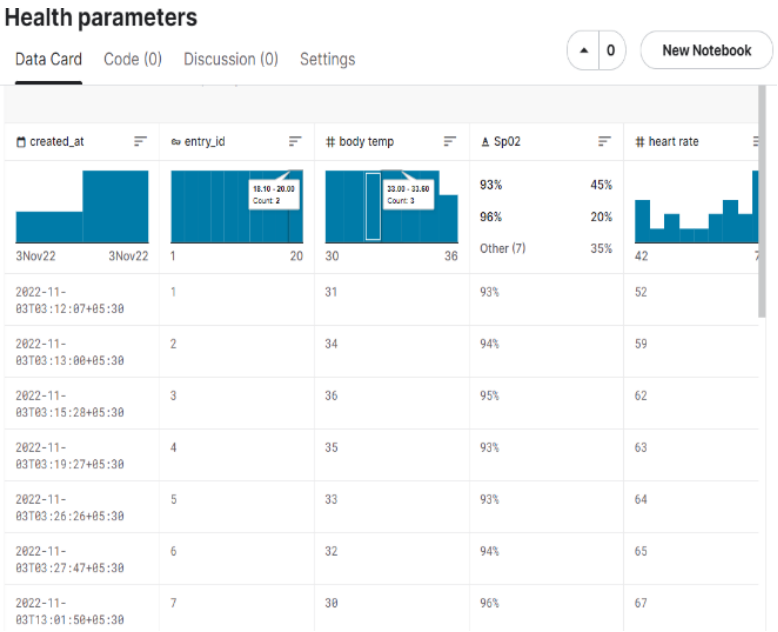

Figure 6: Distribution of data sets into different class

Similarly, different readings from BMP 180 for the body temperature and barometric pressure. From there, authors have measured the body temperature of the patients and can analyze whether the patient has a normal body temperature or not. Temperature from 35-37 degrees is normal and if the body temperature goes below 31 or 30 then the patient needs emergency medical attention.

IV. RESULTS AND DISCUSSION

A. Data stored on Things speak IoT cloud.

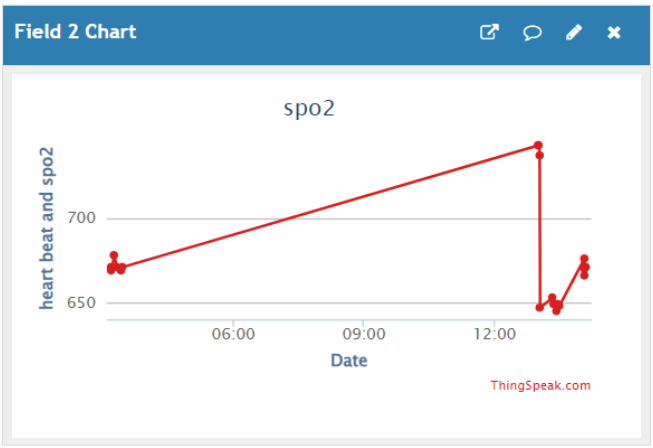

Figure 7: Heartbeat and SpO2 data plot by using MATLAB Visualizations

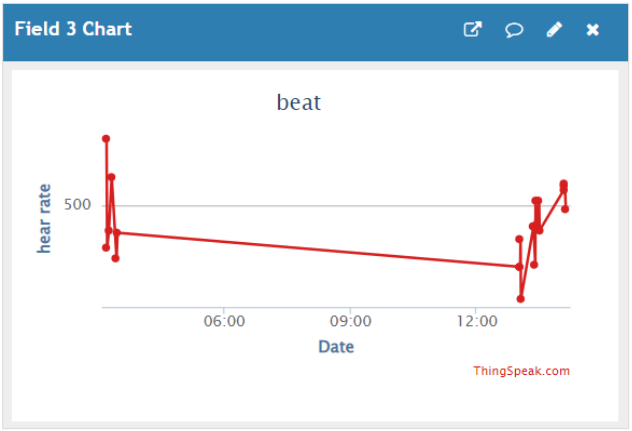

Figure 8: Heart rate data plot by using MATLAB Visualizations

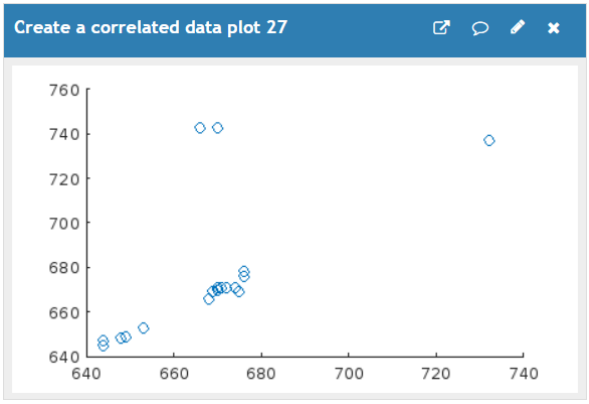

Figure 9: Correlated data plot for all the data sets using MATLAB Visualizations

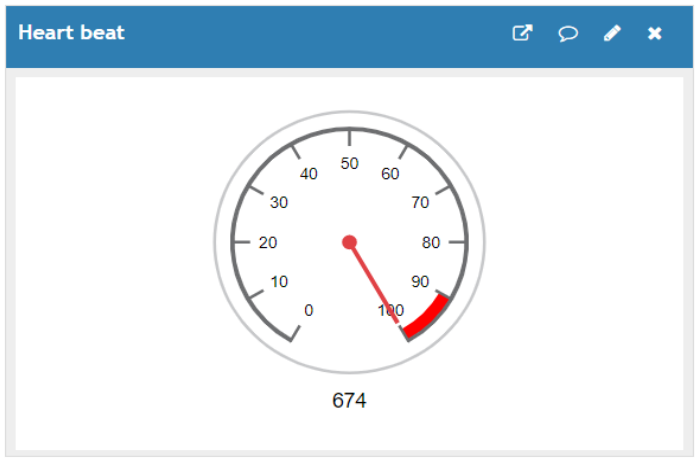

Figure 10: Gauge display for the data using widgets using MATLAB Visualization's

B. Data recording from the sensors

The IoT Based health monitoring system is now ready for data monitoring. It can now be used to measure blood pressure, blood SpO2 level and pulse monitoring. After all the sensors are met and programmed with the help of Arduino, we run the code and the screen appears successfully initialization of the sensor.

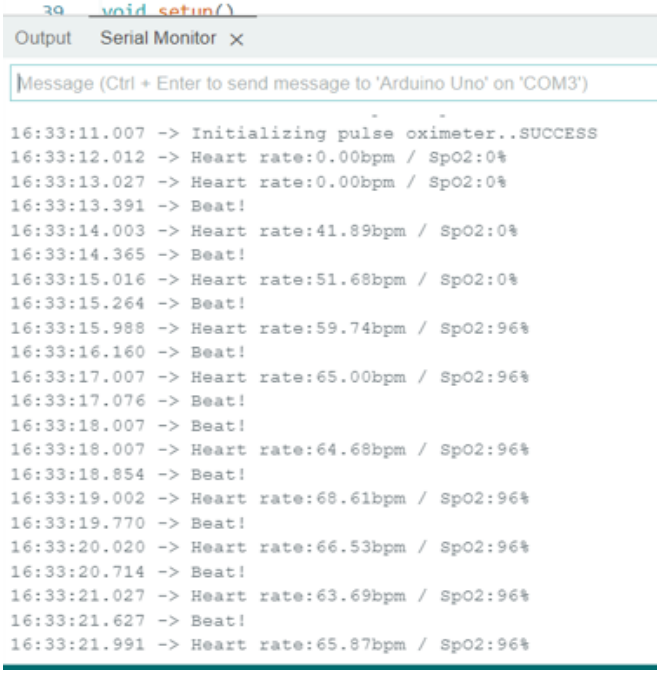

Fig.11 MAX 30100 readings

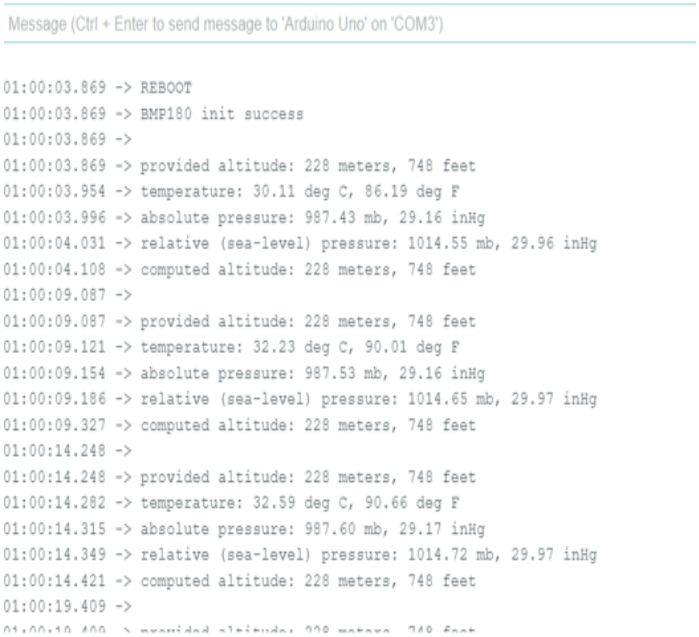

Figure 12: Readings from BMP 180 sensor

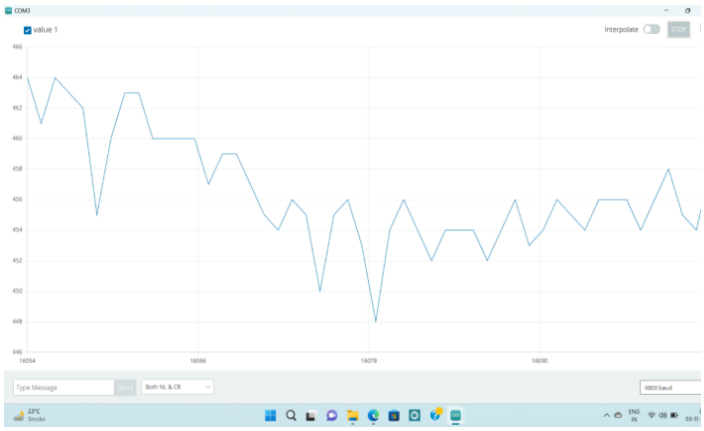

Figure 13: Real time pulse monitoring with pulse sensor module

V. CONCLUSION

Hence, the complete design and setup of an IoT based health monitoring setup that can measure the body temperature, SpO2 level and heartbeat of the patient and stored the data on Thing Speak cloud is successfully completed. One of the essential components of this health monitoring setup is that it is an energy efficient model created by using lora Ra02 module as compared to the Wi-fi module. Lora also has more range compared to other technologies that help us for long range monitoring of data The data is segregated into different classes such as body temperature, SpO2 level and heartbeat and mentioned the altitude. The authors have analyzed the data and plot the SpO2 distribution level for the patients have oxygen saturation in normal range and below the normal range as mentioned in Figure 5

VI. REFERENCES

[1] Rahman, A., Islam, M. M., Islam, M. R., Sadi, M. S., & Nooruddin, S. (2019). Developing IoT Based Smart Health Monitoring Systems: A Review. Rev. intelligence Arif., 33(6), 435-440.

[2] Subhan, Fazli, Alina Mirza, Maliha Bin Mohd Sa'd, Muhammad Mansoor Allam, Shibli Nisar, Usman Habib, and Muhammad Zubair Iqbal. "AI-Enabled Wearable Medical Internet of Things in Healthcare System: A Survey." Applied Sciences 13, no. 3 (2023): 1394.

[3] Khan, Mohammad Mirjana, et al. "IoT- based smart health monitoring system for COVID-19 patients." Computational and Mathematical Methods in Medicine 2021 (2021).

[4] Valsalva, Prasoon, Tariq Ahmed Barham Boamah, and Ali Hussain Omar Baboo. "IoT based health monitoring system." Journal of critical reviews 7.4 (2020):739-743.

[5] Pradhan, Bikash, Sauget Bhattacharyya, and Kunal Pal. "IoT-based applications in healthcare devices." Journal of healthcare engineering 2021 (2021): 1-18.

[6] Mora, Hagino, et al. "An IoT-based computational framework for healthcare monitoring in mobile environments." Sensors 17.10 (2017): 2302.

[7] BK, Bhoomika, and K. N. Muralidhar. "Secured smart healthcare monitoring system based on IoT." International Journal on Recent and Innovation Trends in Computing and Communication 3.7 (2015): 4958-4961.

[8] Rajput, D. S., & Gour, R. (2016). An IoT framework for healthcare monitoring systems. International Journal of Computer Science and Information Security, 14(5).

[9] Adere, Endale Mitiku. "Blockchain in healthcare and IoT: A systematic literature review." Array (2022): 100139.

[10] Mohammadi, Farid Ghareh, Farzan Shenavarmasouleh, and Hamid R. Arabnia. "Applications of machine learning in healthcare and internet of things (IOT): a comprehensive review." arXiv preprint arXiv:2202.02868 (2022).

[11] Bhatt, Vaidik, and Samyadip Chakraborty. "Improving service engagement in healthcare through internet of things-based healthcare systems." Journal of Science and Technology Policy Management 14, no. 1 (2023): 53-73.

[12] Mohamed, Rasha MK, Osama R. Shahin, Nadir O. Hamed, Heba Y. Zahran, and Magda H. Abdellattif. "Analyzing the patient behavior for improving the medical treatment using smart healthcare and IoT-based deep belief network." Journal of Healthcare Engineering 2022 (2022).

[13] Belfiore, Alessandra, Corrado Cuccurullo, and Massimo Aria. "IoT in healthcare: A scientometric analysis." Technological Forecasting and Social Change 184 (2022): 122001.