Fire Vital: Seamless Real-Time Firefighter Health Monitoring and Command Center Collaboration

A PROJECT REPORT

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In partial fulfilment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

DEPARTMENT OF ELECTRONICS ENGINEERING MADRAS INSTITUTE OF TECHNOLOGY

ANNA UNIVERSITY: CHENNAI 600 044

DECEMBER 2023

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ACKNOWLEDGEMENT

We consider it as our privilege and our primary duty to express our gratitude and respect to all those who guided, helped and inspired us in the successful completion of the project.

We owe solemn gratitude to **Dr. J. PRAKASH,** Dean, Madras Institute of Technology, for having given consent to carry out the project work at MIT Campus, Anna University.

We wish to express our sincere gratitude to **Dr. P. INDUMATHI,** Professor and Head of the Department of Electronics Engineering, who has encouraged and motivated us in our endeavors.

We are extremely grateful to our project guide **Dr. K. MARIAMMAL,** Associate Professor, Department of Electronics Engineering, for her timely and thoughtful guidance and encouragement for the completion of the project.

We wish to extend our sincere thanks to the review panel faculty members **Dr. S. Vallisree** and **Dr. O. Vignesh** for their valuable suggestions during all the reviews which took our project to greater heights. We would like to thank our project coordinator **Mrs. M. S. Vinotheni**, all the teaching and non-teaching staff members of Department of Electronics Engineering, for their support in all the aspects.

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ABSTRACT

"Fire Vital" is a game-changing system that makes real-time health monitoring and command center collaboration effortless, revolutionizing firefighter safety. The system combines an Arduino board with a MAX30102 sensor and uses a piezoelectric generator as a sustainable power source to record vital health metrics like blood oxygen saturation (SpO2) levels, temperature, and pressure in real time. The gathered data is safely sent to The Things Network (TTN) by utilizing LoRa communication via a LoRa shield and gateway. Live health data can be transmitted to a user-created website via the TTN integration, which makes cloud connectivity via MQTT possible. This website serves as a central location for thorough analysis of firefighter health, offering an intuitive interface with dynamic graphs. Incident commanders and medical personnel gain immediate insights into the physiological conditions of the firefighting team, facilitating timely decision-making and resource allocation. "Fire Vital" represents a pivotal advancement in firefighting technology, offering a holistic solution that combines advanced sensor capabilities, robust communication protocols, and an intuitive web interface to enhance real-time health monitoring and command coordination during operations.

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LIST OF ABBREVIATIONS

TERM	ABBREVIATION
LoRaWAN	Long Range Wide Area Network
MQTT	Message Queuing Telemetry Transport
LOS	Line of Sight
TTN	The Things Network
ADHOC	Ad hoc on Demand Distance Vector
IOT	Internet of Things
IOT-FFM	Internet of Things (IoT) based firing zone monitoring and firefighter surveillance system
HRV	Heart rate variability
API	Application Programming Interface
RFID	Radiofrequency Identification
ML	Machine Learning
GSR	Galvanic Skin Response
EWS	Early Warning Score
3G	3rd Generation

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The "Fire Vital" project aims to utilize the MAX30102 sensor to track a firefighter's heart rate, oxygen saturation, and temperature in real time. In order to provide effective communication, the system seeks to send sensor data to the cloud via the Long-Range Wide Area Network (LoRaWAN) protocol. Additionally, it aims to create an easily navigable webpage that displays mission personnel details retrieved from the cloud using the Message Queuing Telemetry Transport (MQTT) protocol. By adding an appropriate piezoelectric generator to the system, the project also aims to achieve energy efficiency.

1.2 WORK FLOW

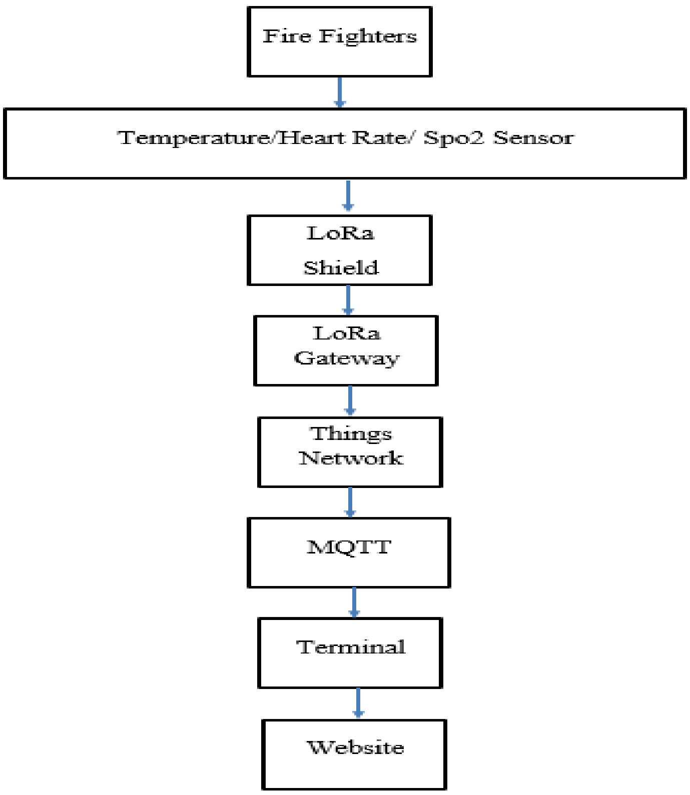

Figure 1.1 Proposed Work Flow of Fire Vital

The work flow of the "Fire Vital" system is been depicted in Figure 1.1. The flow starts from the initiation of data acquisition by monitoring Temperature, Oxygen Saturation, and Heart Rate through the MAX30102 sensor. The collected data is then wirelessly transmitted to the cloud using the LoRaWAN protocol, establishing efficient long-range communication. Subsequently, a user-friendly webpage is designed to extract and display mission personnel details, utilizing the MQTT protocol for real-time data retrieval from the cloud. To ensure sustainability and energy efficiency, the system incorporates a suitable piezoelectric generator. This integrated approach ensures seamless real-time health monitoring and command coordination for firefighters during critical missions.

1.3 FIRE FIGHTER’S CHALLENGES

As first responders to emergencies, firefighters face both psychological and physical difficulties. Because of the hard nature of their work, which increases the risk of accidents, they must navigate dangerous environments, carry heavy equipment, and fight fatigue. Traumatic event exposure increases mental stress, making priority mental health care necessary. Advanced technologies are essential in smoke-filled scenarios as visibility is compromised, hindering communication and search operations. Structural instability is a persistent threat that requires careful consideration. Hazardous chemical exposure increases complexity and necessitates strict safety precautions. Dedicated and tough firefighters go through extensive training in spite of these difficulties. Continuous technological development reflects a dedication to overcoming challenges and guaranteeing efficient emergency response. Its goal is to improve safety.

1.4 LoRaWAN

LoRaWAN (Long Range Wide Area Network) is a wireless communication protocol designed for long-range, low-power IoT (Internet of Things) applications. Operating on unlicensed radio bands, LoRaWAN facilitates efficient communication between low-power devices and gateways. In this network, devices, such as sensors or actuators, can transmit small amounts of data over extensive distances to a gateway. The gateway then forwards the data to a network server, and the information is ultimately sent to the application server. What distinguishes LoRaWAN is its ability to enable battery-operated devices to communicate over several kilometers while conserving energy. The protocol employs a star-of-stars topology, ensuring scalability and flexibility. LoRaWAN supports various data rates, adapting to different use cases and environments. It finds applications in smart cities, agriculture, industrial IoT, and more, offering a cost-effective and accessible solution for connecting a network of devices and sensors, particularly in scenarios where long-range communication and extended battery life are paramount. The openness, combined with a robust security model, contributes to its widespread adoption and its position as a prominent player in the evolving landscape of IoT connectivity.

1.5 MQTT

MQTT (Message Queuing Telemetry Transport) is a lightweight protocol designed for efficient communication in networks with low bandwidth, high latency, or unreliability. Employing a client-server architecture and a publish-subscribe model, MQTT enables devices to act as publishers, subscribers, or both. Topics, serving as communication channels, facilitate flexible communication in distributed systems. Devices publish messages to specific topics, with MQTT supporting various quality of service levels based on application reliability needs. Subscribers register with an MQTT broker, managing message distribution and enhancing scalability. Subscribers receive asynchronous messages based on topic subscriptions, enabling real-time communication crucial for applications like industrial automation and smart home systems. MQTT's lightweight nature is conducive to resource-constrained environments, minimizing overhead for devices with limited processing power. Operating on the principle of keeping connections open, MQTT reduces latency for message delivery, supporting low-power states for devices until needed. In summary, MQTT's publish-subscribe model, coupled with topic-based communication, offers an effective and scalable solution for distributed communication in IoT and diverse networked applications, providing flexibility, reliability, and support for low-power devices across industries.

1.6 **THE THINGS NETWORK**

The Things Network (TTN) stands as a global, community-driven Internet of Things (IoT) network, embodying principles of openness, decentralization, and collaboration. Operating on the LoRaWAN protocol, TTN facilitates low-power, long-range communication, relying on a decentralized architecture with deployed gateways acting as bridges between devices and the network server. TTN's ecosystem thrives on contributions from individuals and organizations deploying LoRaWAN gateways globally, creating an expansive network across urban and rural landscapes. Notably, TTN's commitment to openness allows free access to developers, fostering innovation in various IoT applications, from smart agriculture to industrial automation. The community-driven ethos extends to developer tools, including an API for seamless integration of IoT devices. TTN prioritizes security, implementing robust communication protocols and encryption mechanisms within its decentralized framework, mitigating risks associated with single points of failure. In essence, The Things Network emerges as a prominent, collaborative force in the global IoT landscape, championing accessibility, openness, and security to drive innovation and widespread adoption across diverse applications.

1.7 LITERATURE SURVEY

This study [1] discusses the Ad hoc On Demand Distance Vector (AODV) routing protocol and Internet of Things (IoT) based firing zone monitoring and firefighter surveillance system (IoT-FFM). Using the suggested IoT-FFM wireless communication system, frameworks like fire ground coordinates, fire temperature, and gas type in the environment are gathered, and monitoring devices that include the respiration rate, heart rate, and pulse oximeter of the firefighter as well as the nearest firefighter number are gathered. The collected data are recorded in an InfluxDB database using the Node-RED programming tool, and the Grafana monitoring system at the remote-control center allows for real-time data monitoring. When assessing the IoT-FFM's performance, end-to-end latency, throughput, and energy consumption metrics are taken into account. In conclusion, the Nakagami channel model has been used in a more accurate wireless setting and contrasted with the Free Path Loss model.

The subject of this study [2] is wireless network-based health monitoring systems. It is becoming a recurring worry in many different areas, including medical plans among others. It is required to gather bio signal data from field teams, such as fire departments, rescue squads, and emergency medical services, particularly in places with poor communication infrastructure. Three tiers make up the system structure. The wearable data gathering subsystem on the observed individual represents Level 1. The Level 2 protocol facilitates the transfer of data from the acquisition subsystem to the distant processing server and monitoring server. The server at level 3 is in charge of centralizing and processing the data so that the subject's health is continuously monitored There is greater flexibility in gathering and sending this data thanks to mobile wearable sensors. This article introduces a ZigBee-based health monitoring system that can be applied in a variety of settings.

The goal of this study, [3], is to develop a unique device that can monitor and report back on the firefighter's complete physiological status as well as any threats they may have experienced. The device, which resembles a Band-Aid, would be affixed to the firefighter's upper arm flesh. The physiological conditions of the firefighter, such as heart rate, blood oxygen saturation, carboxyhemoglobin levels, and hyperthermia, would be monitored by this apparatus. In addition to tracking the firefighter's physiological condition, the device will measure and relay the suits inside temperature and humidity. Additionally, it will keep an eye on any object contact or collision.

The availability of affordable consumer wearables that track vital signs and provide access to stress detection methods is the main focus of this study [4]. In order to accurately assess stress levels, wearable device data was used to calculate heart rate variability (HRV), a crucial indicator connected to stress. Labelled heart rate variability (HRV) data is gathered in controlled settings where participants were exposed to physical, psychological, and combination stress in order to develop and train a deployable stress detector. In order to distinguish and recognize the various stress types and comprehend how they relate to HRV data, machine learning is applied. The stress type can be determined by the resulting C5 decision tree model. Building an integrated system to gather expert classifications from firemen in real-time while they practice in a rescue maze could enhance the model. This research could be expanded upon to include the application of the algorithms to general monitoring and coaching systems for high-risk professionals, thereby lowering their risk in the workplace and enhancing their stress resilience during training.

This research, [5] talks about technology for soldiers useful to monitor their health on war zones. The device will measure temperature of body,oxygen level,Gps Live location, Heart rate.Using IOT the live exact locations are sent.The information which are collected will be transmitted through MANET system and LORA to base

Campsite using IOT in encrypted format.With these, basecamp can provide medical facility to soldiers if needed in urgent.

This paper, [6] is about safety measure for fire fighter. It predicts the fall detection for fire fighters using Machine learning (ML) . A wearable device is proposed,to improve the real time performance and accuracy. The information is transmitted using LORA gateway and stored in cloud platform, which is then sent to the computer in command center.

This paper, [7] a device is made which monitors environmental factors such as temperature, humidity, air pressure, position, geographic location and health parameters, blood oxygen level. Even the camera and microphone are attached to monitor the real time information for soldiers.All these sensors are mounted on raspberry pi controller.The information are transmitted using WSN(wireless sensor network).Even Lora is used to reduce battery consumption.

This paper [8] describes an Arduino Uno Myosignals shield-based Internet of Things health monitoring system. Additionally, it assesses how well wireless devices and sensors perform. Myosignals makes it possible to retrieve physical data from a variety of sensors, including temperature, pulse rate, oxygen saturation, and ECG. To design a flexible IoT-based health monitoring system, it is necessary to take into account the constant presence of healthcare professionals and staff, as well as the provision of adequate facilities in remote locations during emergency situations.

This research, [9] uses the lora and mqtt protocols to build smart farms for increased efficiency. In accordance with the parameters they wish to monitor, they have used a variety of sensors, and they have used the lorawan protocol to communicate the data they have collected to the cloud application of the Things

Network (TTN). The publish/subscribe Mqtt protocol enables message transfer in real-time for IoT applications. The irrigation node, gateway, and a user-friendly web application are the subscribers in this project's use of the TTN as a mqtt broker for collecting and publishing sensor data. The irrigation node will receive data from the TTN over the MQTT protocol and take specific action in response to the data. The web application displays all the necessary details needed for the remote monitoring process of the farm in an user friendly manner. The future improvision on this project will be implementing even more advanced and precise sensors which will perform efficiently even in adverse conditions.

In this publication, [10] an experimental investigation that was conducted as part of a Compartment Fire Behaviour Training is described. To measure the temperatures of the firefighters' garment layers, they employed wireless thermometers based on Radiofrequency Identification (RFID) technology. These UHF RFID-compliant gadgets can be applied straight to the skin like a plaster. They were able to collect multiple data from 10 firefighters during their training due to how easily sensors could be activated and data downloaded. These statistics provide a general notion of the thermal burden that firefighters encounter while carrying out their tasks.

This study, [11] describes a wearable Internet of Things sensor network that uses a wireless Lora network to detect hazardous environmental conditions for safety purposes. The recommended sensor node, known as the WE-Safe node, is built on a specialized sensor node that can accommodate a variety of environmental sensors and is self-powered and low-power. A distant cloud server receives real-time environmental data from the sensor node, which also monitors it. Users may see the data using a web-based application on the cloud server, and the device can notify users of emergency situations through a mobile application. The experimental findings show that energy harvesting ensures the reliability of the safety monitoring network that is currently being used.

This study's [12] goal is to talk about how to create and put into practice a stress monitoring system that firemen can use while on a fire rescue mission. In order to quantify stress levels, this work aims to develop a prototype wireless sensor node that can be fastened to firefighter gloves and uses heart rate and Galvanic Skin Response (GSR) sensors. A rechargeable, long-lasting power source, a ZigBee communication module for data transmission, and a microprocessor for data processing are also included. In order to store and analyze the data that the fire engine uses to see the alerts, the system uses Message Queuing Telemetry Transport (MQTT) as the Internet of Things message protocol. Adafruit IO serves as both the MQTT broker and the analytics platform. The short-range ZigBee communication technique was utilized in this work. LoRaWAN, an LPWAN protocol, is more appropriate for these kinds of applications and offers greater efficiency in terms of power consumption and communication to the center..

The goal of this research is to develop a smart textile-based protective system that will boost the safety of firefighters in high-risk circumstances [13]. A system that monitors heart rate, detects movements of the firefighters, and recognizes flammable and dangerous compounds in the surrounding air can all be integrated into a firefighter's protective gear. It can also assess internal and external temperature and relative humidity. Wide area network, commander control unit, suit control unit, body area network, and specially designed integrated sensor modules are all part of the protection system. A component of the defense system are the indoor and outside localization units. When there is no GPS connection, the indoor localization device with inertial sensors—which is mounted on a protective boot—is designed to allow firemen to follow their whereabouts remotely. Increasing firefighter safety is the primary objective of this method.

For remote patient monitoring, the healthcare sector is using more and more wireless communication technologies, especially LoRa wireless technology. In order to avert irregularities, this work [14] suggests a low-power healthcare WBAN platform named HeaLoRa, which enables doctors to remotely monitor patients' blood pressure, heart rate, temperature, and oxygen saturation level. In order to minimize redundant data, power consumption optimization is used to govern data gathering and transmission. A fuzzy logic controller is used to dynamically modify the system configuration in response to changes in the Early Warning Score (EWS). An energy consumption analysis model for accepted LoRa transmission is introduced. In order to send data to a gateway and subsequently to the doctor using IP-based technology, the paper demonstrates a medical application of a wireless body area network system utilizing LoRa technology. The system uses three to ten times less energy than a reference system, according to simulation studies.

1.8 ORGANIZATION OF THE REPORT

The organization of the thesis is as follows. Chapter 1 presents the introduction of this thesis. Chapter 2 discusses the proposed architecture of Fire Vital system. It also deals with the design of individual blocks involved in this system. The results obtained from software and hardware implementation and analysis of the designed Fire Vital system is presented in Chapter 3. Finally, Chapter 4 presents conclusion and future works to be carried out in this system.

CHAPTER 2

Health Monitoring of Fire Fighters by Command Centre Collaboration

2.1 Fire Fighters Real Time Vital Levels

The Real time vital parameters of firefighters vary from person to person. However, the research findings shows that there is a common range for each of the vital parameter which is been shown in Table 2.1 for various situations.

Table 2.1: Common Range of Vital Parameters of Firefighters

	Temperature (in C^{0})	**Heart rate (in BPM)**	**SpO2 (In %)**
Normal	35-37	65-84	96-98
Mild	37-39	85-99	94-96
Severe	>39	>100	<94

2.2 Block Diagram

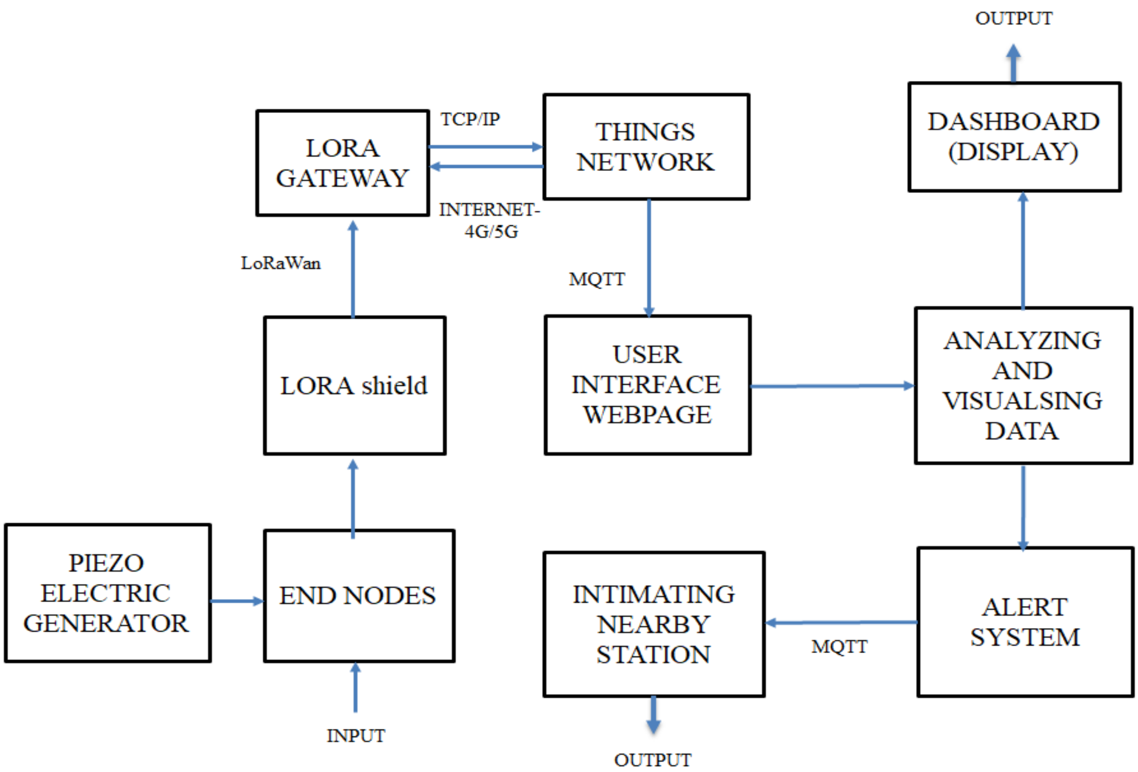

Figure 2.1: Block Diagram of FireVital

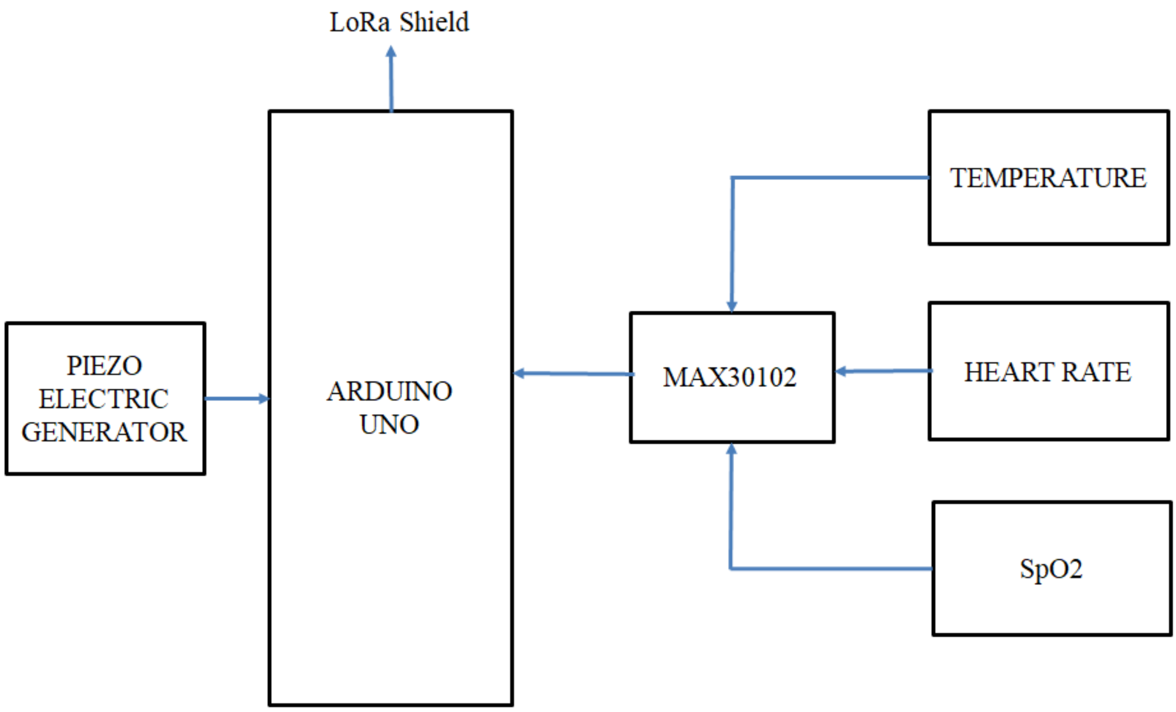

Figure 2.2: End Node of FireVital

The Figure 2.1 shows the functional blockages of the entire fireVital system .The Figure 2.2 depicts the End node the FireVital system which consist of MAX30102 sensor measuring temperature, spO2 and heart rate.

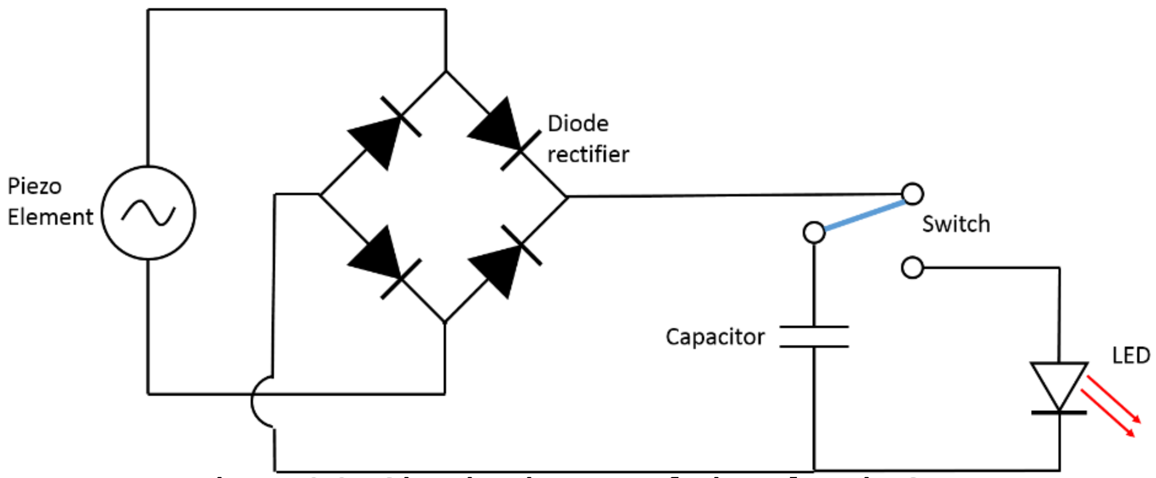

Figure 2.3: Circuit Diagram of Piezoelectric Generator

The Figure 2.3 depicts the circuit diagram of the Piezoelectric Generator used for the energy conservation of the FireVital system. This depicts the basic outline of the generator, for required power generation appropriate number of diodes and capacitors can be customized.

2.2.1 Piezoelectric generator

A piezoelectric generator transforms mechanical vibrations or deformations into electrical energy through the piezoelectric effect in materials like ceramics or quartz crystals. These materials generate an electric charge under mechanical stress. The generator comprises piezoelectric elements connected to a circuit, producing alternating current (AC) voltage when subjected to vibrations or pressure. A rectifier, often a diode bridge, converts AC to direct current (DC). The rectified output powers electronic devices directly or stores energy in batteries or capacitors. Piezoelectric generators are applied in diverse fields, powering small devices like Arduino Uno, wireless sensors, and wearable technologies that harness user movements. Their ability to capture energy from ambient mechanical sources makes them valuable for emerging technologies such as IoT sensors and energy harvesting solutions, offering a compact, durable, and sustainable energy source.

2.2.2 Arduino Uno

Prominent among open-source microcontroller boards, the Arduino Uno is praised for having shaped an extensive array of electronic projects. Created by the Arduino Company, it makes use of the flexible ATmega328P microcontroller and is becoming quite popular among makers. It is suitable for both novice and seasoned developers. The Uno easily integrates with a wide range of sensors and actuators thanks to its many digital and analogue input/output pins, and its USB interface makes programming and power supply easier. Even for nonprogrammers, accessibility for code development is ensured by the user-friendly Integrated Development Environment (IDE). Notably, users can personalize projects without getting bogged down in complex hardware details thanks to its compatibility with different shields. Supported by a vibrant community, abundant tutorials, and a vast library repository, the Arduino Uno has become a valuable tool for education and prototyping, appealing to makers, students, and professionals alike. Its affordability, adaptability, and user-friendly design make it a preferred choice, influencing the development of innovative technologies in diverse industries, from simple LED projects to complex IoT and robotics applications.

2.2.3 MAX 30102 Sensor

Figure 2.4: MAX 30102

The MAX30102 sensor is a flexible, all-in-one solution for tracking cardiac rate, blood oxygen saturation (SpO2), and temperature. Figure 2.4 illustrates this. This small sensor combines photoplethysmography (PPG) and temperature sensing capabilities, and it is widely used in wearable technology and healthcare settings. A photodetector for PPG, along with red and infrared LEDs, are used by the MAX30102 to extract vital signs such as blood oxygen levels and heart rate. Health monitoring is more comprehensive when integrated temperature sensing is used. The sensor combines digital signal processing and filtering mechanisms with advanced analogue front-end (AFE) and ambient light cancellation techniques to improve accuracy. I2C or SPI interfaces are standard and allow for seamless integration into a variety of applications. Notably, the MAX30102's low power consumption makes it suitable for battery-powered wearables, commonly found in fitness trackers and medical devices for continuous patient monitoring. While versatile, the sensor's accuracy may be affected by environmental factors and motion artifacts, necessitating proper sensor placement and occasional calibration against reference measurements. In summary, the MAX30102 sensor's integration of temperature, heart rate, and SpO2 monitoring, coupled with its compact design and low power consumption, positions it as a preferred choice for wearable health tech and medical device developers, with attention to environmental considerations crucial for accurate physiological data.

2.2.4 LoRa Shield

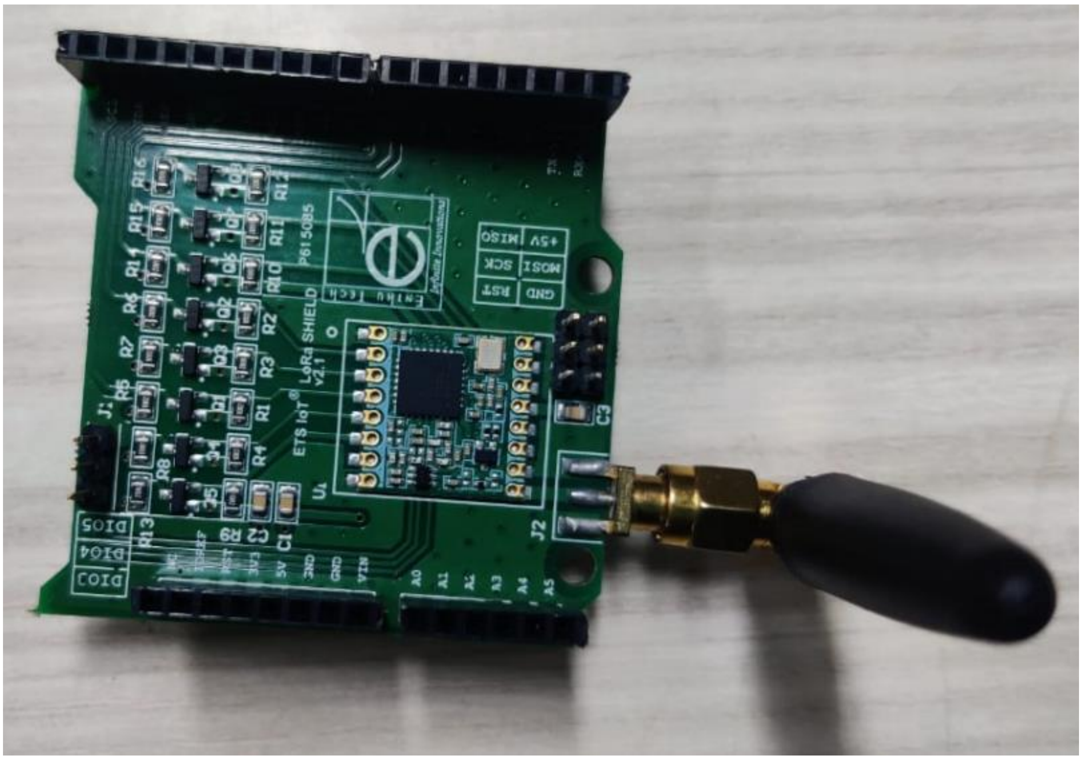

Figure 2.5 : Lora Shield

The Figure 2.5 depicts the LoRa (Long Range) Shield, is a specialized hardware module tailored for long-range wireless communication using LoRa technology, typically compatible with platforms like Arduino. Serving as an extension to microcontrollers, LoRa Shields empower devices with the capability to communicate over extensive distances, making them ideal for low-power, long-range applications in the Internet of Things (IoT). The standout feature of LoRa technology lies in its remarkable communication range, spanning several kilometers in rural settings and maintaining significant distances in urban environments. This versatility positions LoRa Shields as indispensable for diverse IoT applications, including smart agriculture, smart cities, industrial IoT, and environmental monitoring, connecting sensors and devices dispersed over vast geographic areas. Apart from its impressive range, LoRa technology is acclaimed for its low power consumption, crucial for IoT devices operating on battery power. The technology's low data rate optimization further supports scenarios where small data packets need intermittent transmission, conserving energy and extending the operational life of connected devices. Equipped with antennas, LoRa Shields ensure user-friendly integration into projects through common development platforms, providing developers with an accessible means to incorporate reliable and energy-efficient long-range wireless communication into IoT designs.

2.2.5 LoRa Gateway

A LoRa (Long Range) Gateway is a critical element in LoRaWAN (Long Range Wide Area Network) setups, acting as a crucial bridge between end-node devices and network servers. Operating as a conduit for long-range, low-power communication in Internet of Things (IoT) applications, these gateways receive data from LoRa-enabled devices and transmit it to a centralized network server, facilitating bidirectional communication. Key to their functionality is extending the communication range of LoRa-enabled devices, especially in sub-GHz frequency bands, making them ideal for expansive IoT applications like smart agriculture and industrial monitoring. Equipped with multiple channels and adaptable data rates, LoRa Gateways optimize network capacity and throughput, efficiently managing communication parameters for reliable data transfer. Strategically placed for optimal coverage, these gateways connect to the internet, forming a vital link in the end-to-end communication chain. They play a pivotal role in aggregating data from diverse sources, enabling centralized management, analysis, and application of insights in the IoT ecosystem. Overall, LoRa Gateways are indispensable in building scalable and resilient IoT solutions across industries, forming the backbone of LoRaWAN networks.

Figure 2.6: LoRa Gateway

2.2.6 Things Network

The Internet of Things (IoT) can be made decentralised and community-driven with the help of the Things Network (TTN), which runs on the LoRaWAN protocol. Strategically positioned throughout the world, LoRaWAN gateways serve as a link between IoT devices and the network server. Because of its decentralised architecture, TTN can operate in a variety of environments and guarantees long-range, low-power communication. Developers are empowered by TTN's open-access model, which provides free platform access and a strong API for seamless device integration. Top priority is given to security, as evidenced by the use of strong encryption and communication protocols. TTN is a leading force in innovation and wide-spread adoption across a variety of IoT applications thanks to its collaborative ethos and dedication to accessibility. TTN places a high priority on security, and the platform is built with strict safeguards to protect communications and data. The decentralized framework incorporates robust protocols and encryption mechanisms to mitigate potential risks related to single points of failure. Because of its focus on security, TTN is able to continue serving as a reliable and strong solution for a wide variety of Internet of Things applications.

2.2.7 User Interface Webpage

The user-created webpage employs MQTT protocol to visualize data fetched from the cloud, ensuring real-time insights. Accessible through password-protected authorization, the webpage prioritizes security. Utilizing MQTT integration from the cloud adds a layer of efficiency, enabling seamless, secure data transmission to the webpage. This setup not only enhances user privacy but also facilitates a dynamic and interactive experience for users, allowing them to access and interpret live data with confidence and ease.

2.2.7.1 Analyzing and Visualizing data

The user-created webpage features an intuitive interface for analyzing and visualizing live data, employing dynamic line graphs. This interactive graphical representation enhances the user experience, providing real-time insights into changing trends and patterns. The line graphs dynamically respond to incoming data, offering a clear and concise presentation of information. Users can easily interpret fluctuations, observe trends, and make informed decisions, fostering a user-friendly environment for comprehensive data analysis on the webpage.

2.3 Summary

This Chapter explains each block involved in the Fire Vital system in detail. Overall working of this system is such that using the max 30102 sensor it obtains the temperature, heart rate and spO2 values from the fire fighter, strore those values in the the things network cloud platform and from there the live data is been pushed to our customized webpage using MQTT protocol inbuilt in the TTN. Subsequently, the obtained live data is been visualized graphically for better inference and monitoring. For system energy efficiency we have used a piezoelectric generator which generates electricity from mechanical stress generated.

Chapter 3

Results and Discussions

3.1 Implementation

The proposed system is been programmed using Arduino IDE and VS CODE, in C++ and python languages respectively. Further the complex command centre monitoring is been carried out using piezoelectric generator, MAX 30102 Sensor, Arduino Uno, Lora shield and gateway.

3.2 Results

The implementation results obtained for the proposed system is been discussed in this section.

3.2.1 Piezoelectric Generator

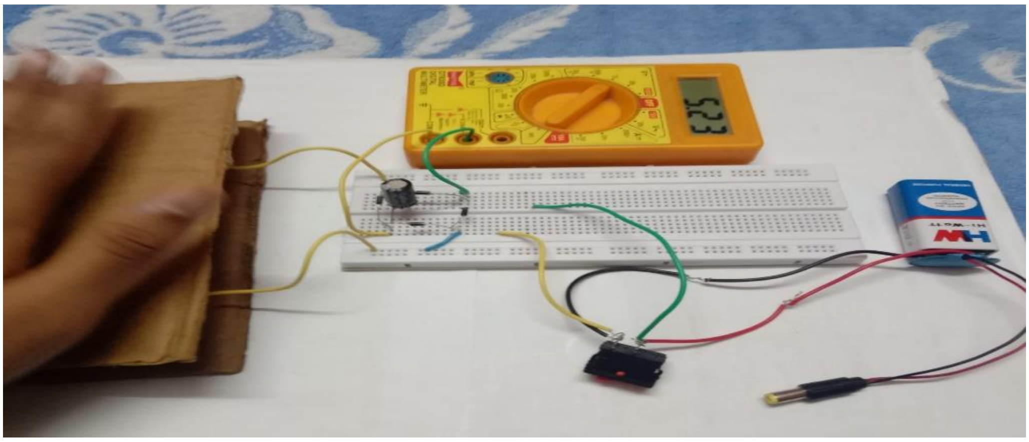

Figure 3.1: Voltage generated from the Generator

By continuous mechanical energy in form of tapping the constructed generator creates voltages of more than 5v as shown in the Figure 3.1 which can be stored in a battery for powering the Arduino Uno.

3.2.2 I2C Scanner

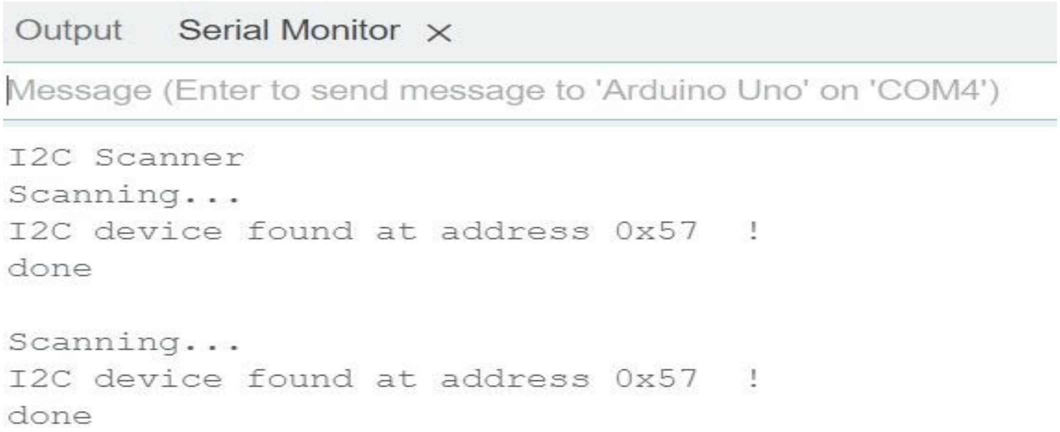

Figure 3.2: I2C scanner to check the sensor connectivity

The MAX30102 sensor is an analog sensor, it communicates with the Arduino uno using the I2C protocol and hence for checking the connectivity of the sensor this scanner code is programmed to check whether we are able to print the sensor address as shown in Figure 3.2 to ensure its proper establishment communication between the sensor and Uno.

3.2.3 MAX 30102 Sensor

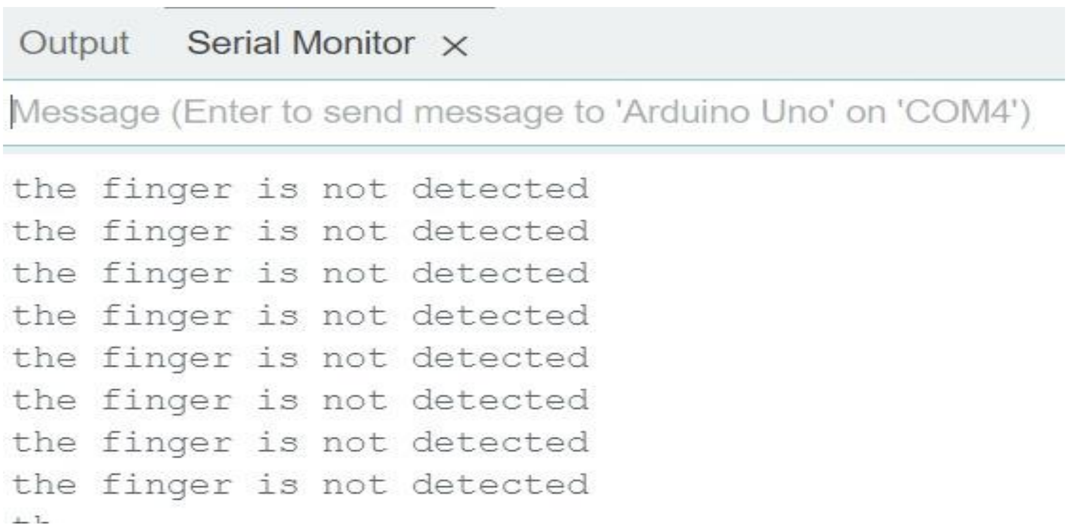

Figure 3.3: Output when the finger is not in contact

Figure 3.4: Vital values when finger is in contact

The Max30102 sensor is a pulse oximeter sensor which helps to compute the heart rate, spO2 and temperature with better accuracy compared to other sensors. When the finger is in contact with the ir emitter light, the values are computed using a photodiode beside it. Figure 3.3 shows when the finger is in not contact with the sensor and Figure 3.4 show the vitals values when finger is in contact.

3.2.4 Sending Data To TTN Using LoRa Shield

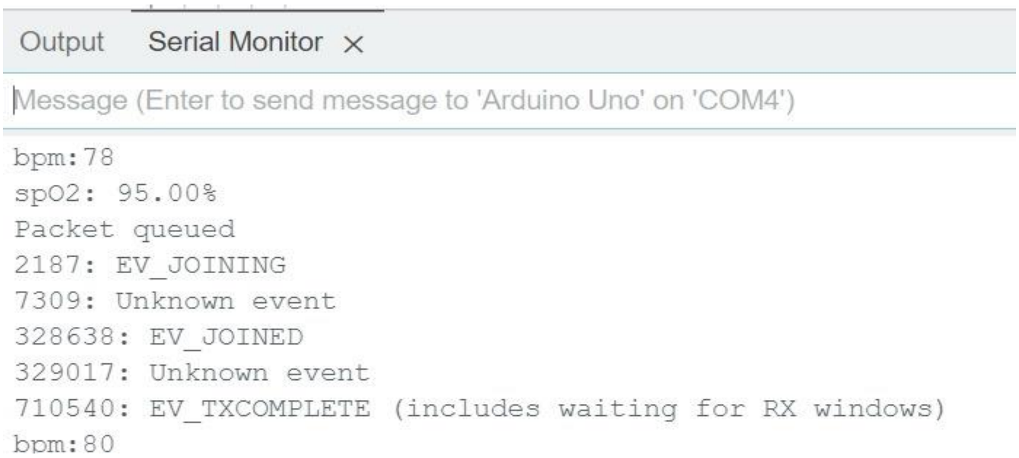

Figure 3.5 : Serial monitor during Lora Transmission

After collecting the data from the MAX30102 sensor, we transmit those values to the TTN using lora communication and Figure 3.5 shows the entire process seen at the transmitter side.

3.2.5 Receiving Data at the TTN

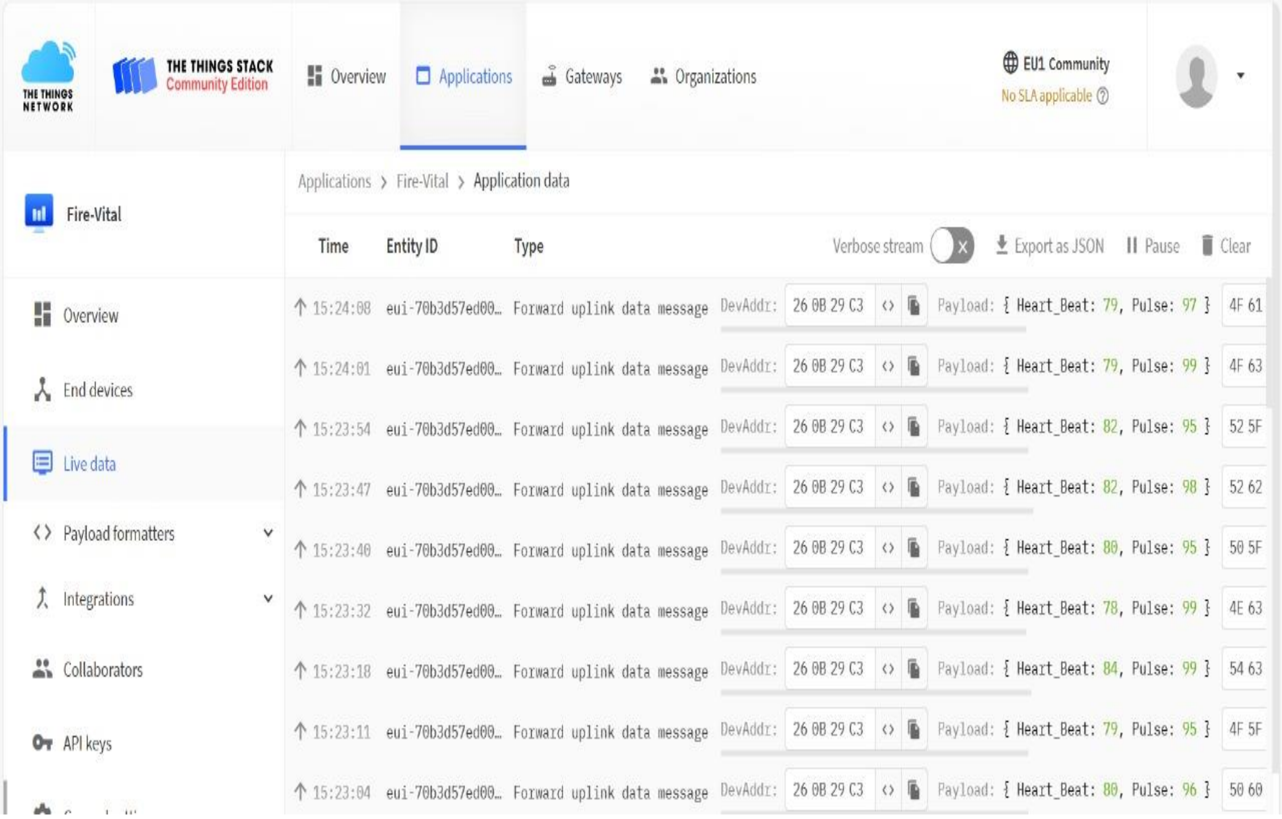

Figure 3.6: Data Receiving at the TTN Cloud

The live data transmitted by the shield is been received by the gateway and pushed to the cloud using the LAN OR 3G/4G. Fig 3.6 shows the data being received at the cloud side, the payload indicates the data transmitted.

3.2.6 MQTT Subscription in the TTN

After successful establishment of connection between the lora shield and gateway and proper arrival of live data we subscribe to the inbuilt mqtt integration present in the TTN as shown in Figure 3.7 to make it act as a broker to publish all the data to its subscribers.

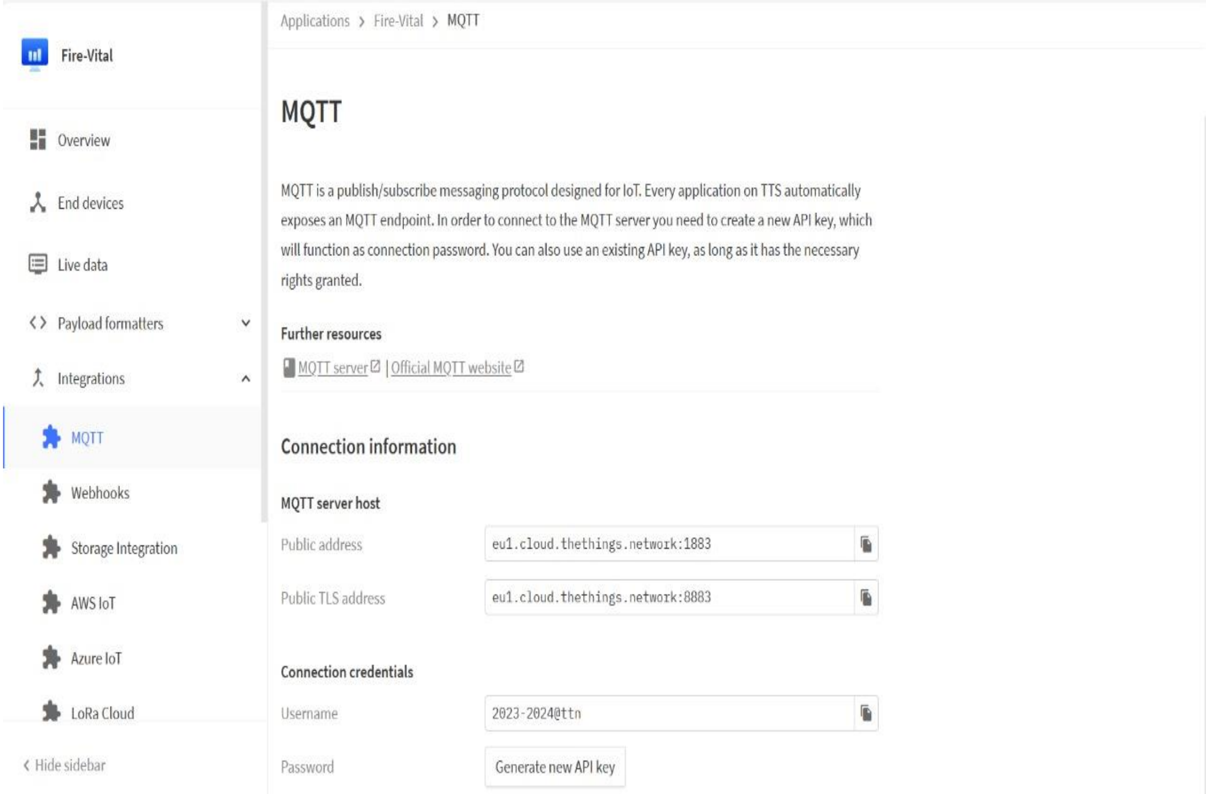

Figure 3.7: Configuring MQTT in the TTN Console

3.2.7 Connection Between MQTT Broker And Subscriber

Figure 3.8: Subscribing to the MQTT broker and receiving data

At the vs code, we have written program such that our local terminal is been subscribed to the mqtt broker available in the TTN as shown in Figure 3.8 and it starts receiving the live data with very little latency.

3.2.8 Connection of Local Host Website

```
PS C:\Users\heman\FLASK> python app.py
 * Serving Flask app 'app'
 * Debug mode: on
WARNING: This is a development server. Do not use it in a production deploym
ent. Use a production WSGI server instead.
 * Running on http://127.0.0.1:5000
Press CTRL+C to quit
 * Restarting with stat
 * Debugger is active!
 * Debugger PIN: 465-539-729
Connected To TTN MQTT Broker
Connected To TTN MQTT Broker
```

Figure 3.9: Local Host Web Server is Hosted and Connected to TTN MQTT Broker

We have created a website customized for easier analysis of the live data using graphs. Fig 3.9 shows the connection of our website with the subscriber in order to pull the live data to our website for analysis. The website is authorized with unique username and password for safer use of data.

3.2.9 Website Home Page

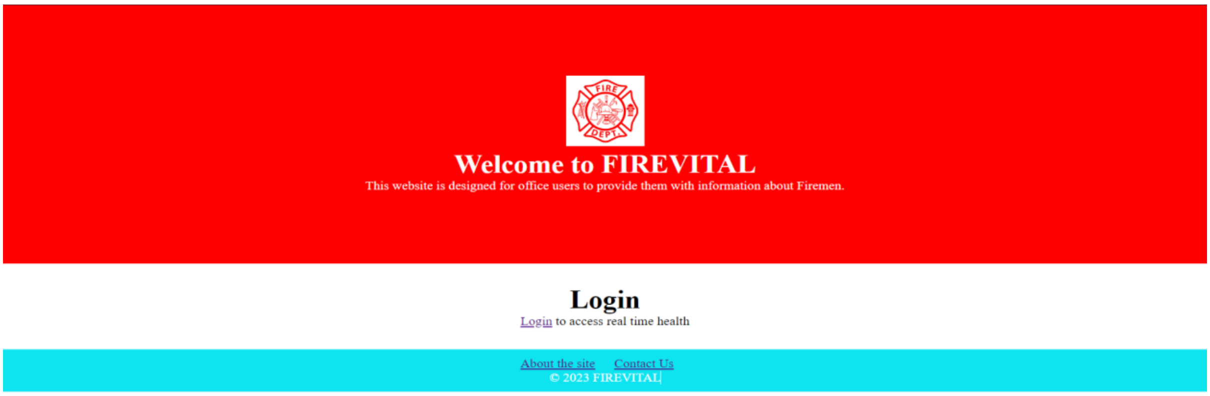

Figure 3.10: Website Main Page

The figure 3.10 depicts the website home page containing the welcome quotes and the navigation bar to the login page.

3.2.10 Other Pages in the Website

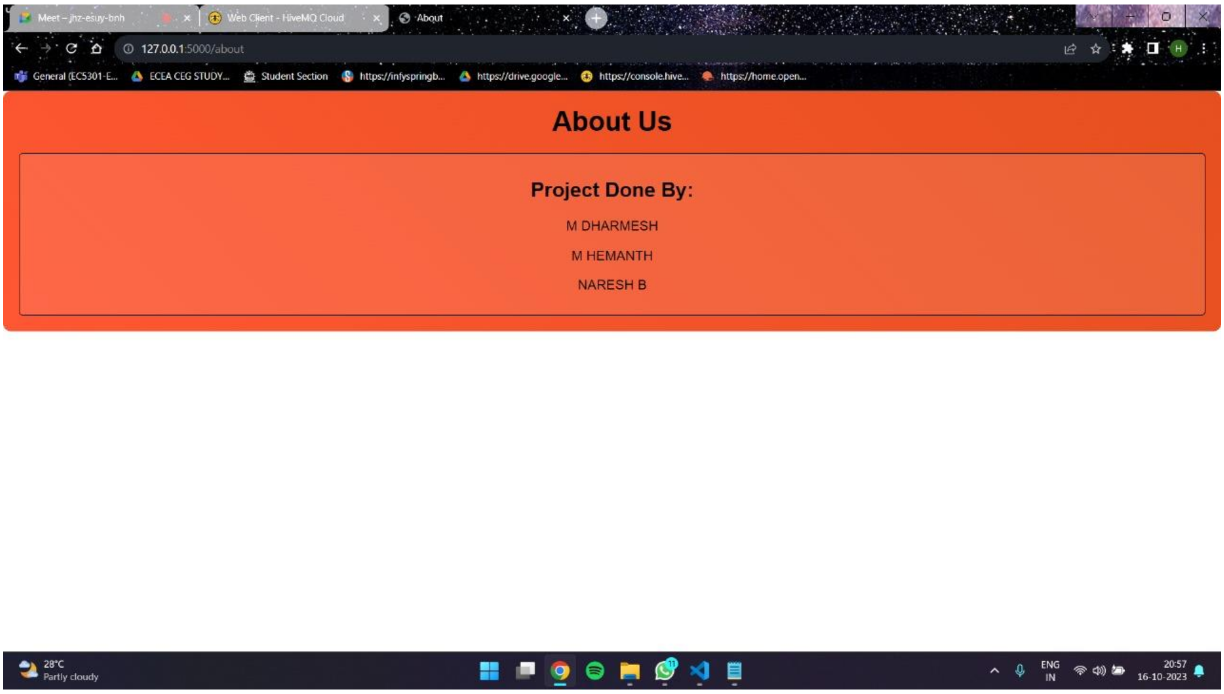

Figure 3.11: Website About Page

The figure 3.11 shows the website about page where it presents the names of the team members who have created this Fire Vital system.

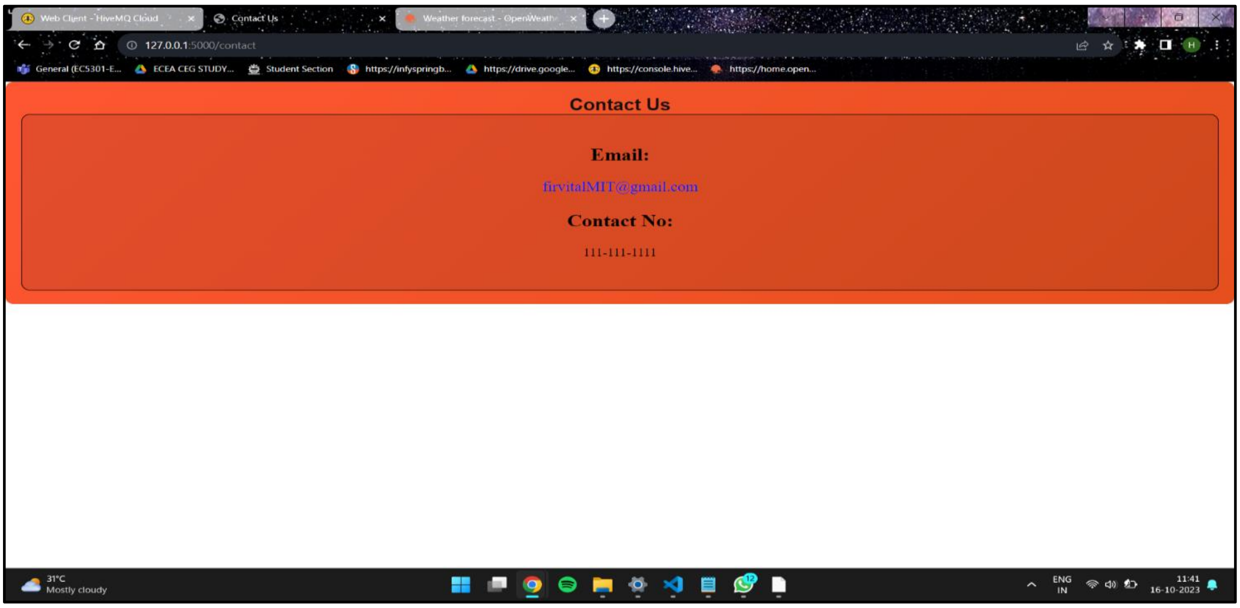

Figure 3.12: Website Contact Us

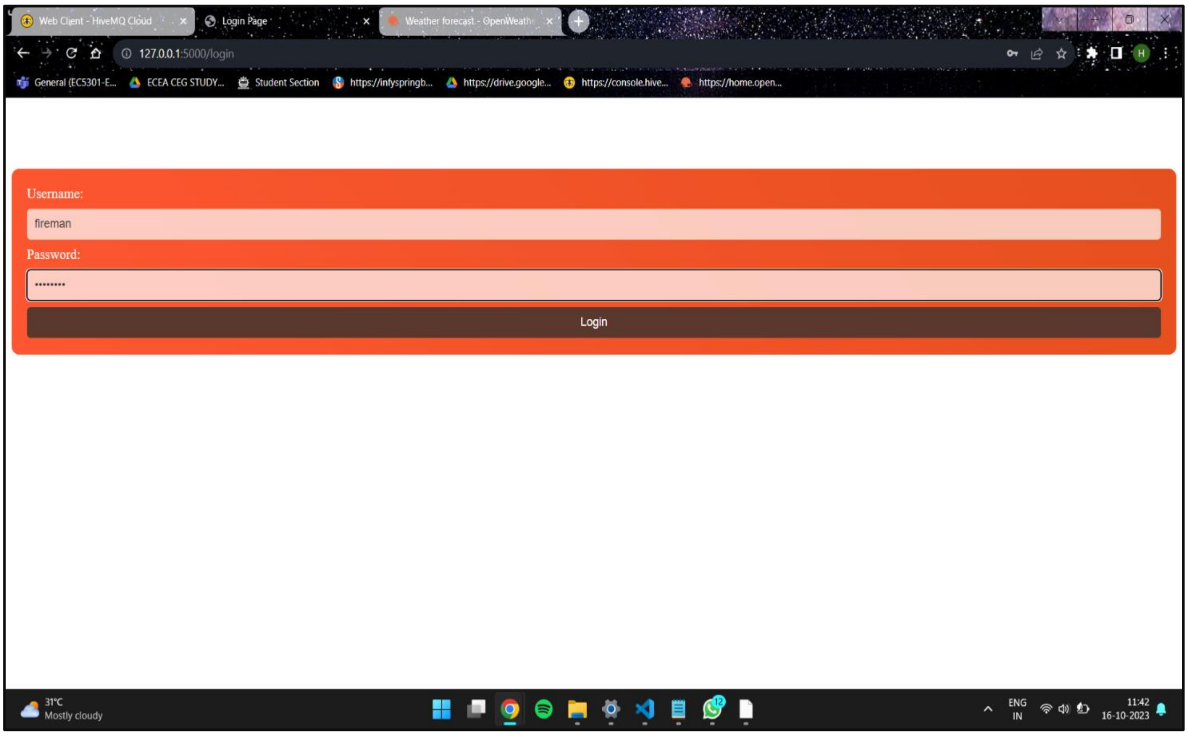

Figure 3.13: Website Login Page

The Website Login page is been depicted in the Figure 3.13 containing the spaces to enter the username and password given to only the authorized users for better safety of the data.

3.2.11 Visualization of Data Received

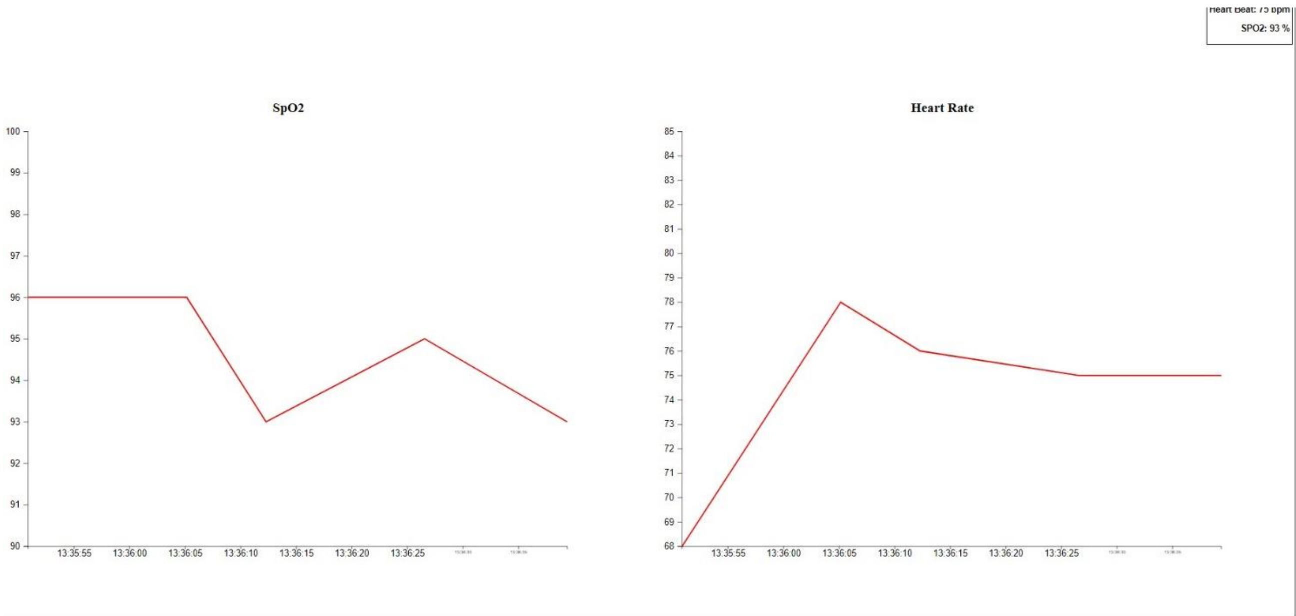

Figure 3.14: Visualization Of Heart Rate and SpO2

The figure 3.14 shows the visualization of the heart rate and spO2 data in a graphical representation with the timestamp of those data. The graph is been plotted dynamically as the data is been received at the cloud with minimum latency.

3.2.12 Fire Vital System

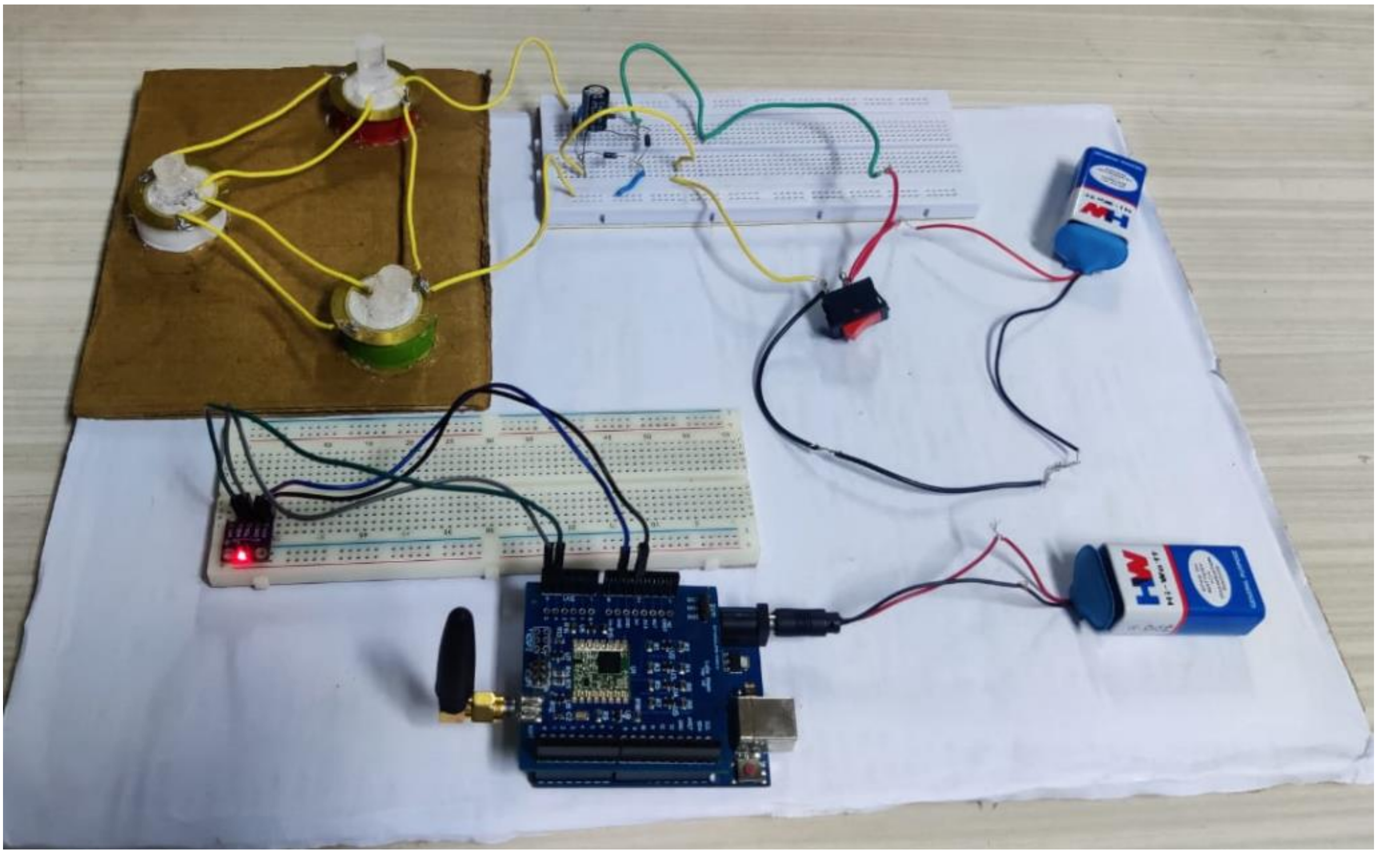

Figure 3.15: Complete FireVital System

Figure 3.15 depicts the complete FireVital System comprising of piezoelectric generator, MAX 30102 sensor, Arduino Uno, LoRa Shield, LoRa Gateway.

3.3 Analysis of the System

This section shows the performance analysis of the system in various areas. The section 3.3.1 shows the analysis of the vital parameters of 5 citizens to check the efficiency of the sensor used.

3.3.1 Vital Trends of 5 Citizens

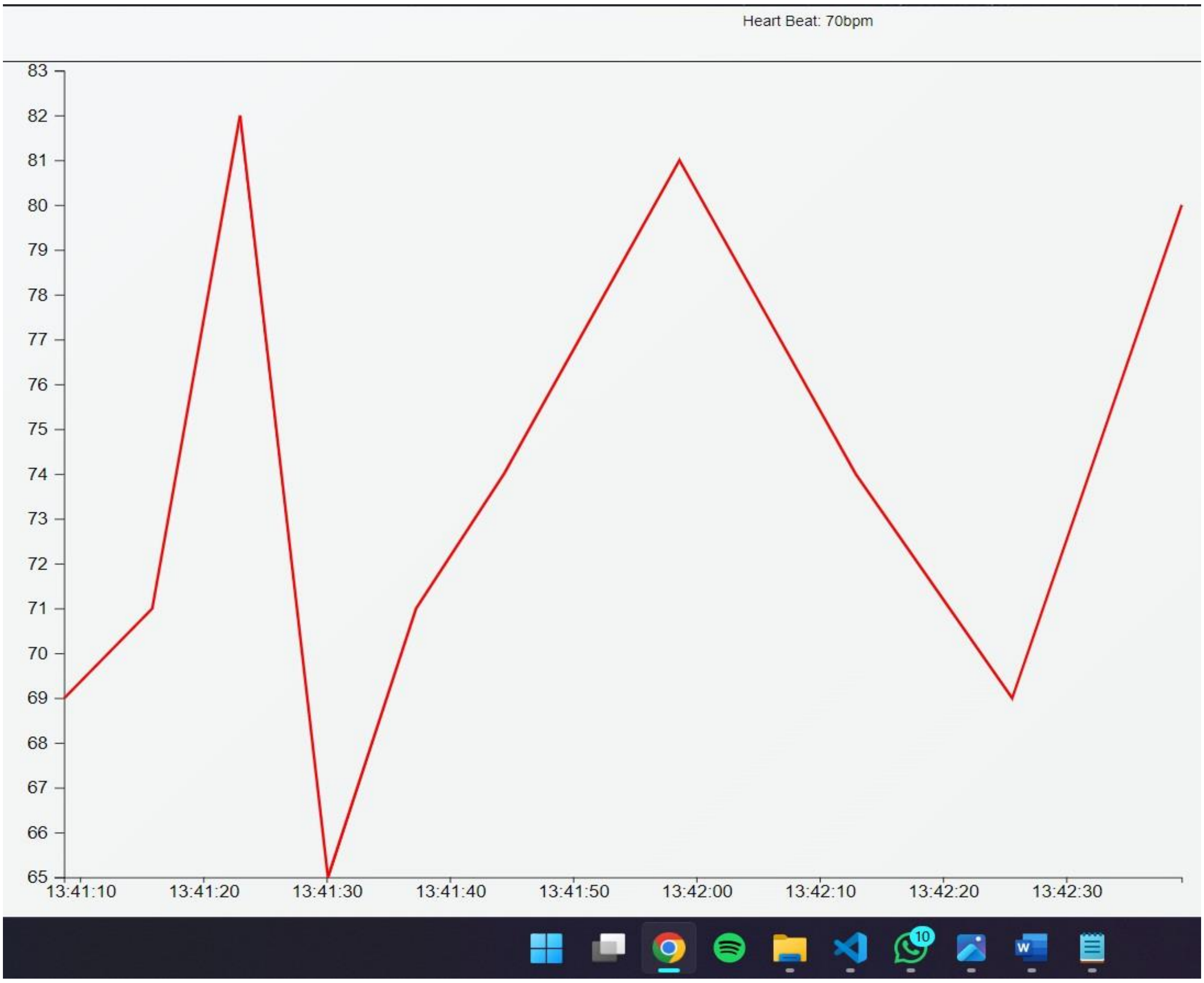

Figure 3.16: 1st Person Heart Rate

Table 3.1: 1st Person Heart Rate

S.no	Heart Rate(Bpm)	Time(HH:MM:SS)
1	69	13.41.10
2	82	13.41.20
3	65	13.41.30
4	72	13.41.40
5	82	13.42.00

Table 3.1 depicts the Heart Rate data obtained for the respective person observed over duration of time.

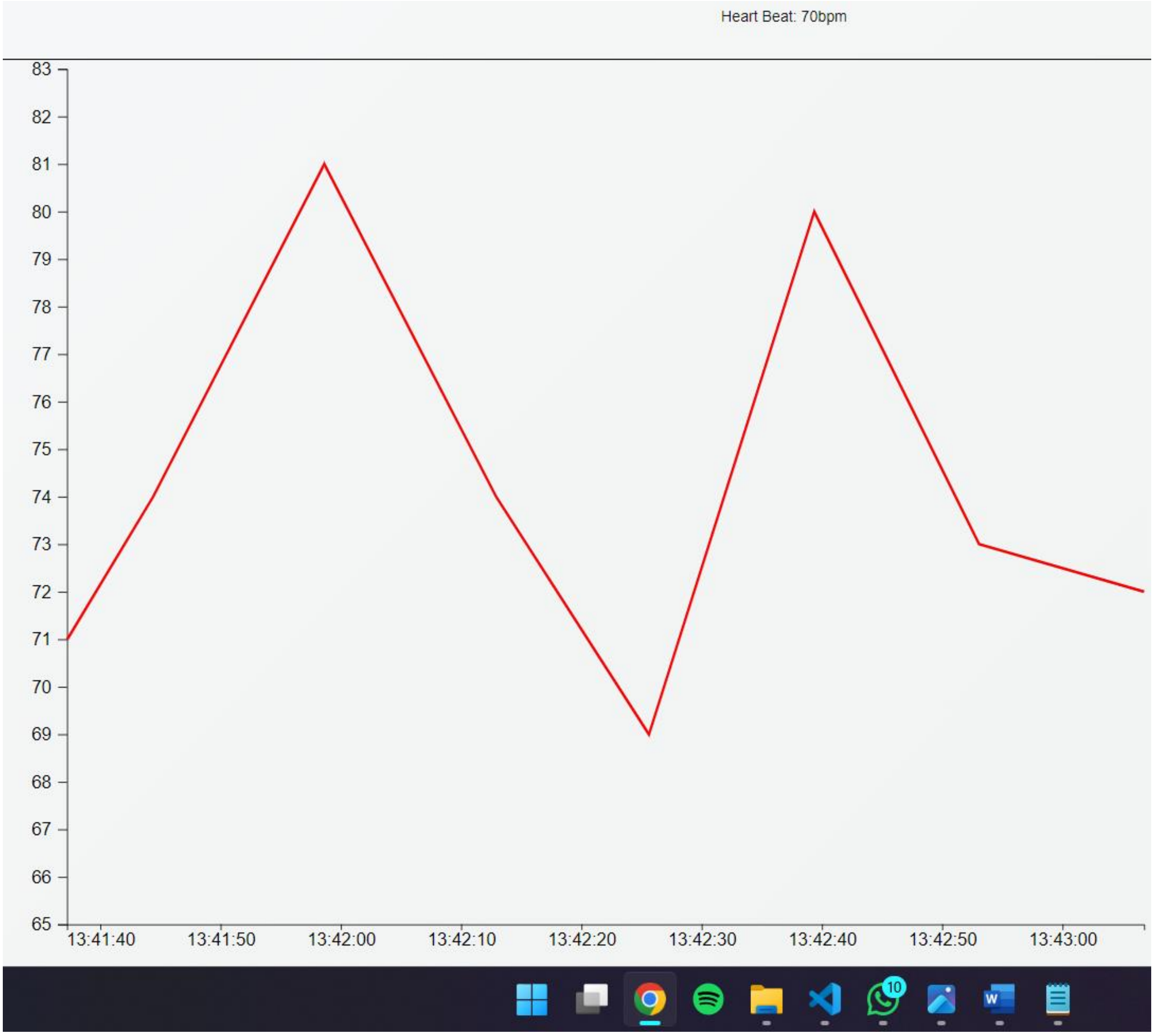

Figure 3.17: 2nd Person Heart Rate

Table 3.2: 2nd Person Heart Rate

S.no	Heart Rate(Bpm)	Time(HH:MM:SS)
1	74	13.42.10
2	70	13.42.20
3	69	13.42.30
4	80	13.42.40
5	74	13.42.50

Table 3.2 depicts the Heart Rate data obtained for the respective person observed over duration of time.

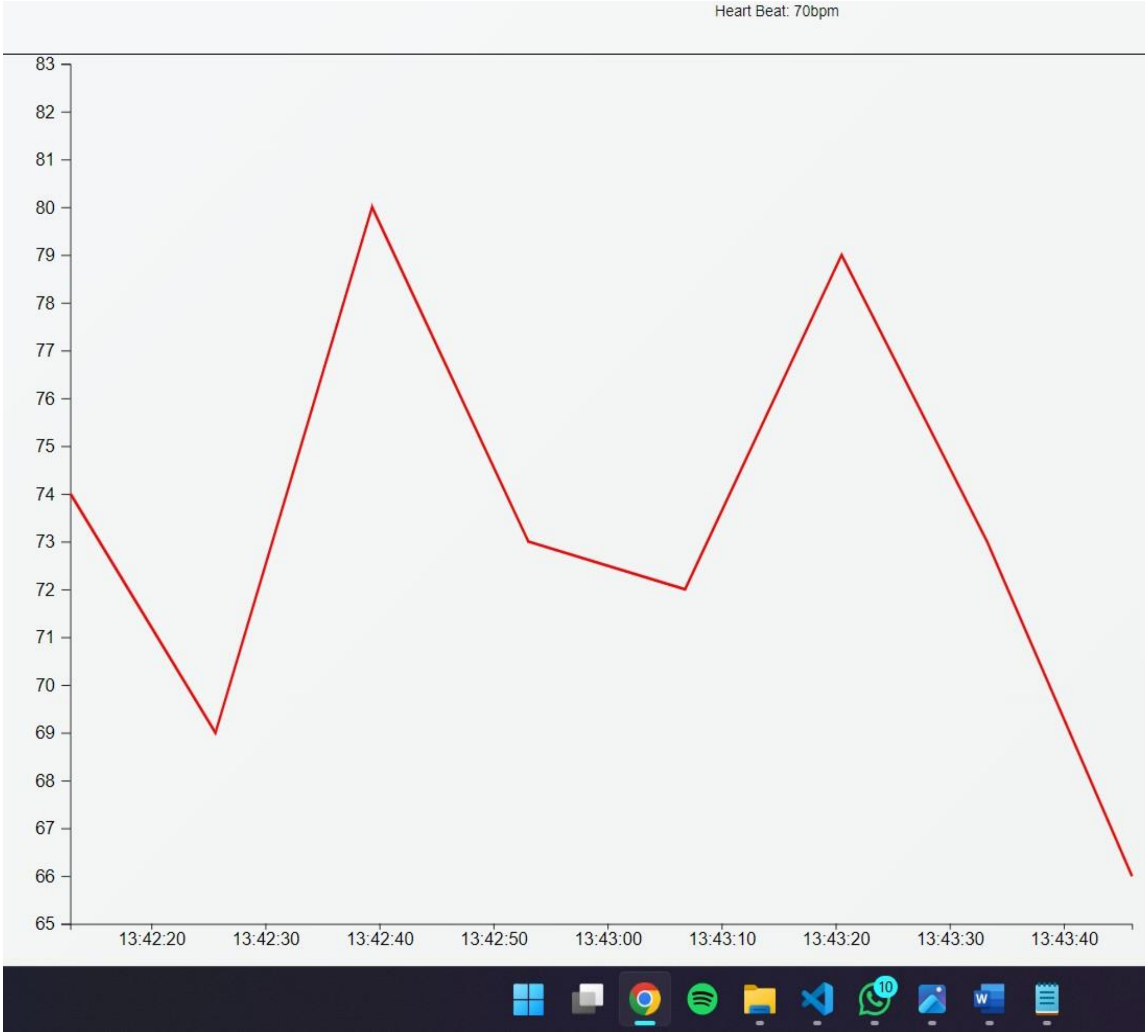

Figure 3.18: 3rd Person Heart Rate

Table 3.3: 3nd Person Heart Rate

S.no	Heart Rate(Bpm)	Time(HH:MM:SS)
1	73	13.43.00
2	72	13.43.10
3	79	13.43.20
4	74	13.43.30
5	70	13.43.40

Table 3.3 depicts the Heart Rate data obtained for the respective person observed over duration of time.

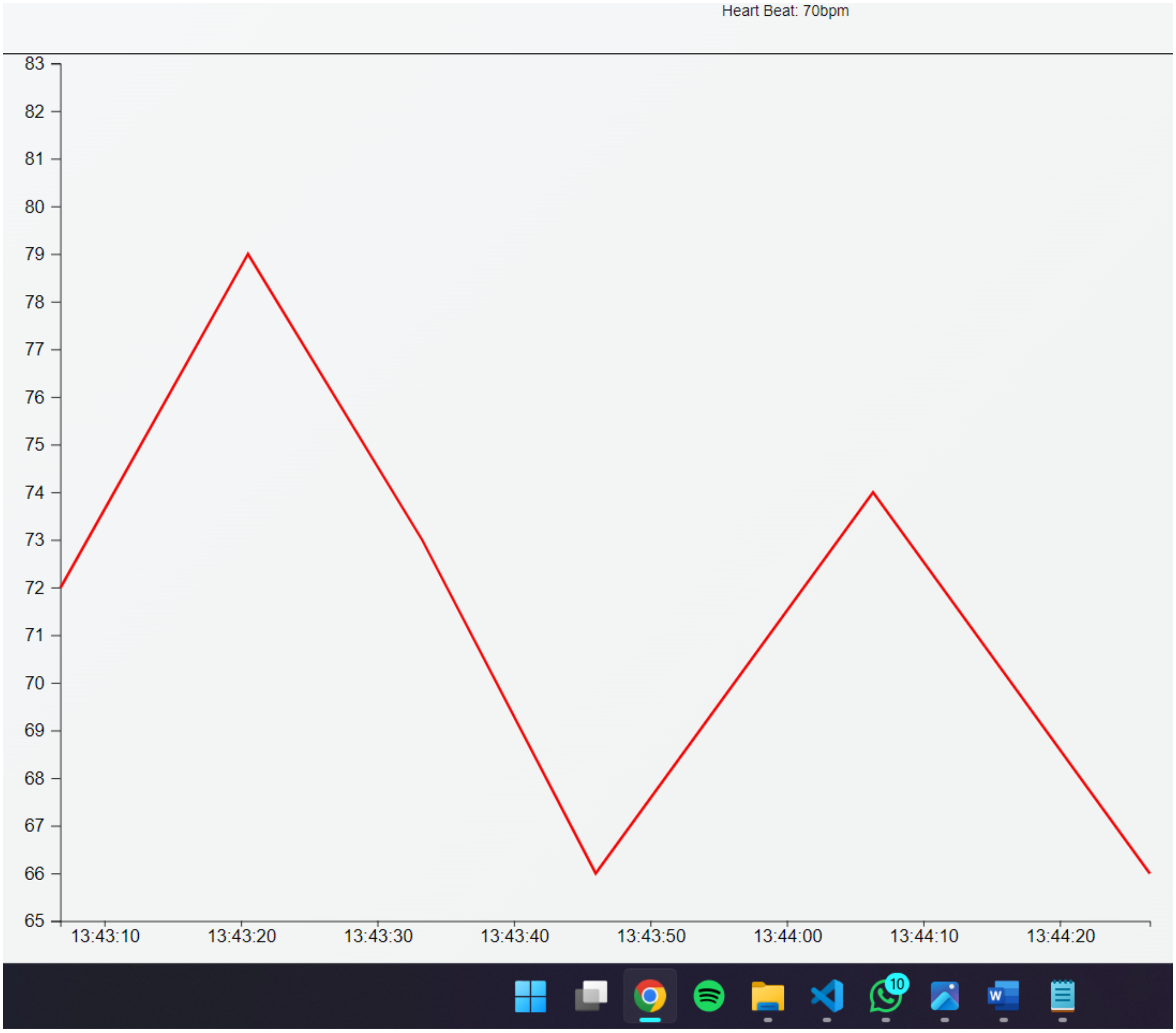

Figure 3.19: 4th Person Heart Rate

Table 3.4: 4th Person Heart Rate

S.no	Heart Rate(Bpm)	Time(HH:MM:SS)
1	66	13.43.45
2	71	13.44.00
3	73	13.44.10
4	68	13.44.20
5	66	13.44.25

Table 3.4 depicts the Heart Rate data obtained for the respective person observed over duration of time.

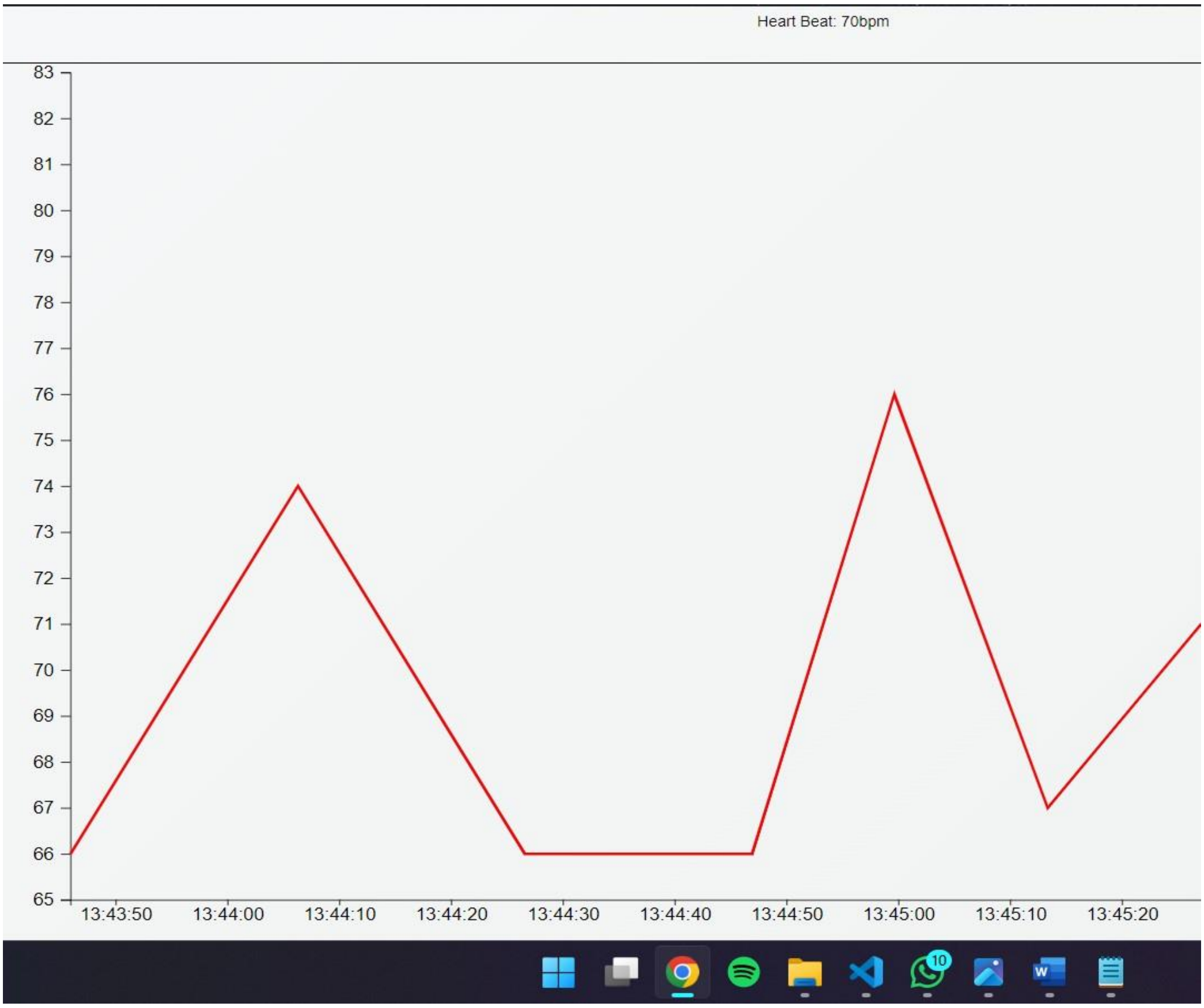

Figure 3.20: 5th Person Heart Rate

Table 3.5: 5th Person Heart Rate

S.no	Heart Rate(Bpm)	Time(HH:MM:SS)
1	66	13.44.30
2	66	13.44.40
3	68	13.44.50
4	76	13.45.00
5	71	13.45.10

Table 3.5depicts the Heart Rate data obtained for the respective person observed over duration of time.

Figures 3.16, 3.17, 3.18, 3.19, 3.20 represents the heart rate trends of 5 citizens over a duration of time along with their timestamps represented in the x axis. The range of values obtained were in the range of 65-83 BPM.

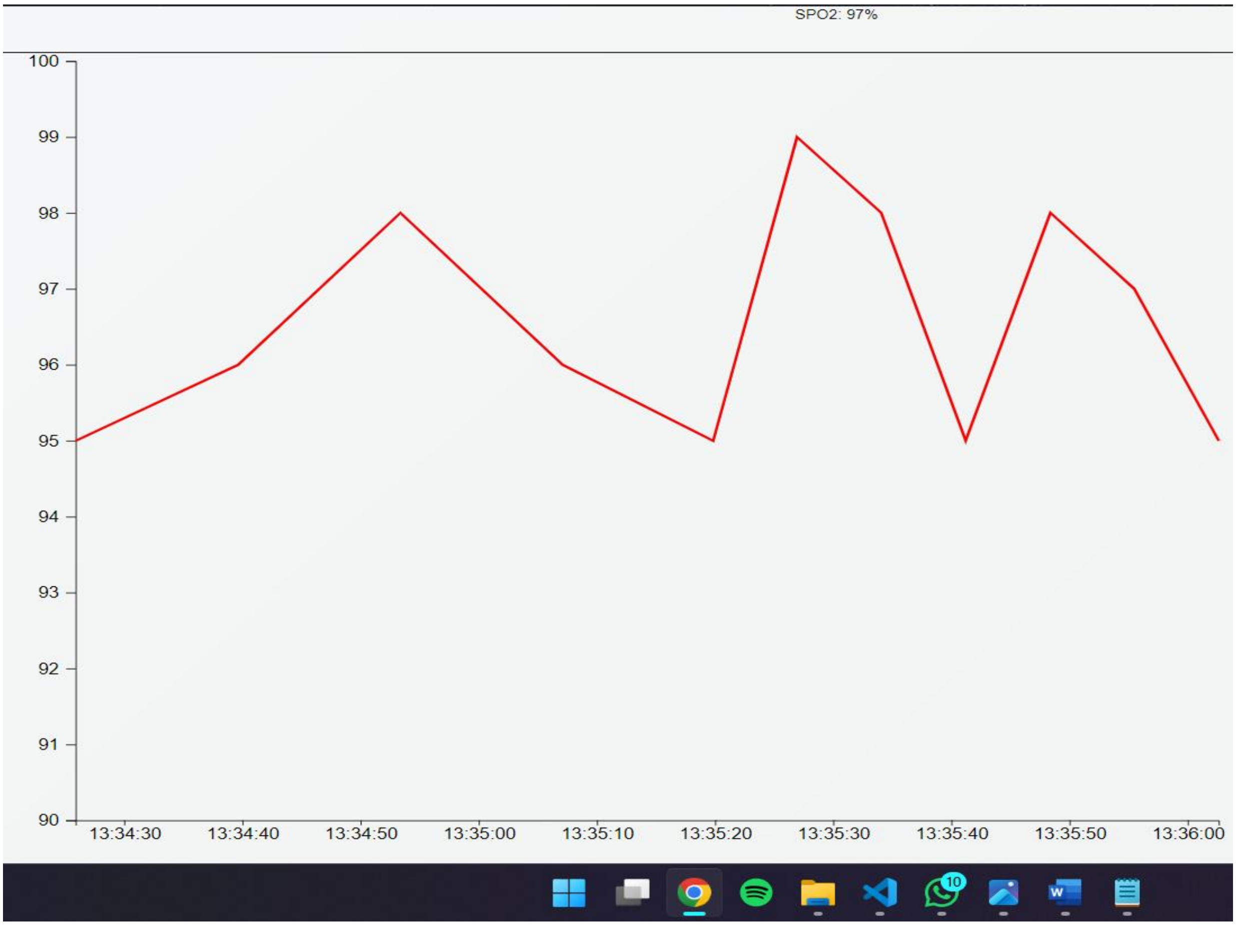

Figure 3.21: 1st Person SpO2

Table 3.6: 1st person spO2

S.no	SpO2(%)	Time(HH:MM:SS)
1	95	13.34.30
2	96	13.34.40
3	97	13.34.50
4	96	13.35.00
5	95	13.35.10

Table 3.6 depicts the SpO2 data obtained for the respective person observed over

duration of time.

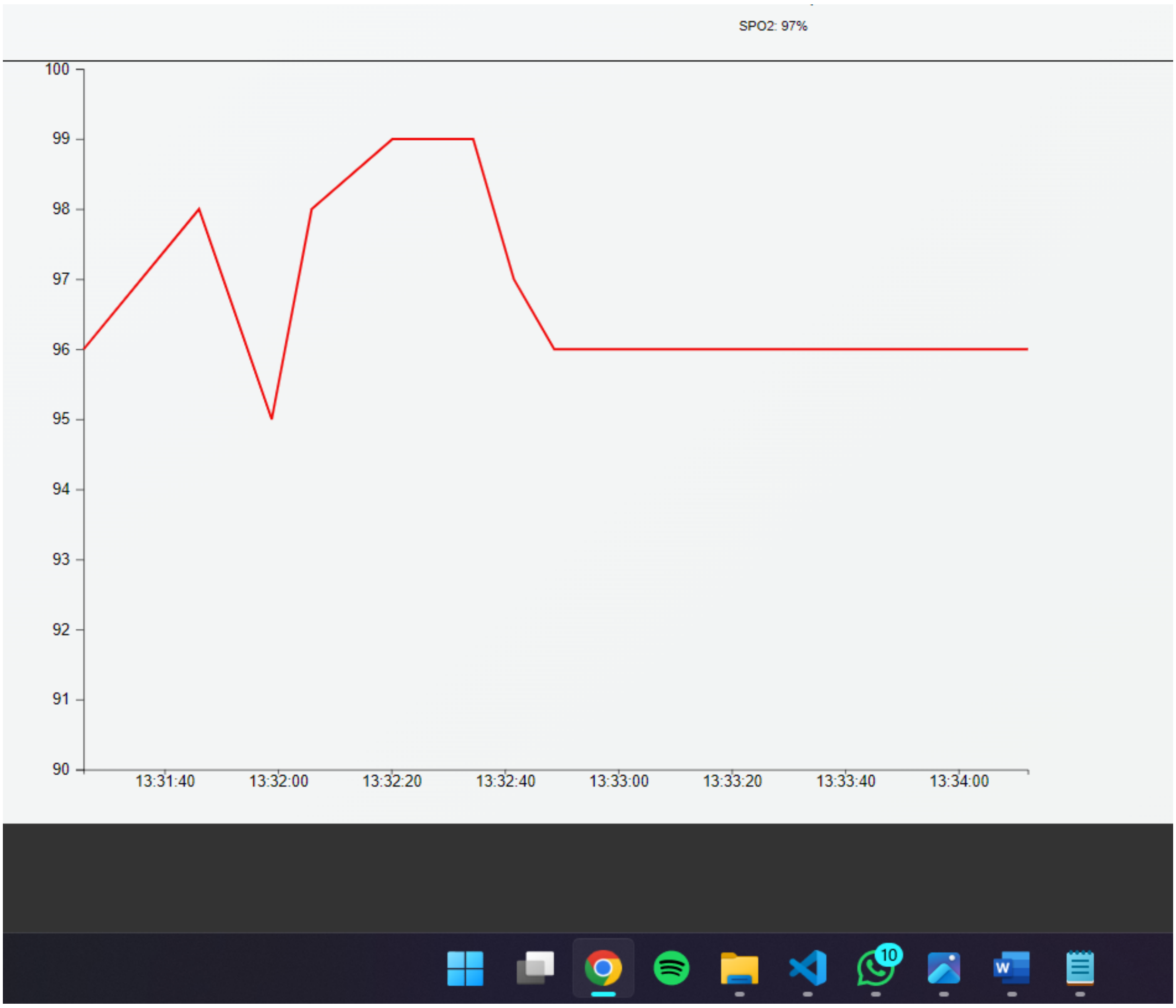

Figure 3.22: 2nd Person SpO2

Table 3.7: 2st person spO2

S.no	SpO2(%)	Time(HH:MM:SS)
1	96	13.31.40
2	95	13.32.00
3	98	13.32.20
4	97	13.32.40
5	96	13.33.00

Table 3.7 depicts the SpO2 data obtained for the respective person observed over duration of time.

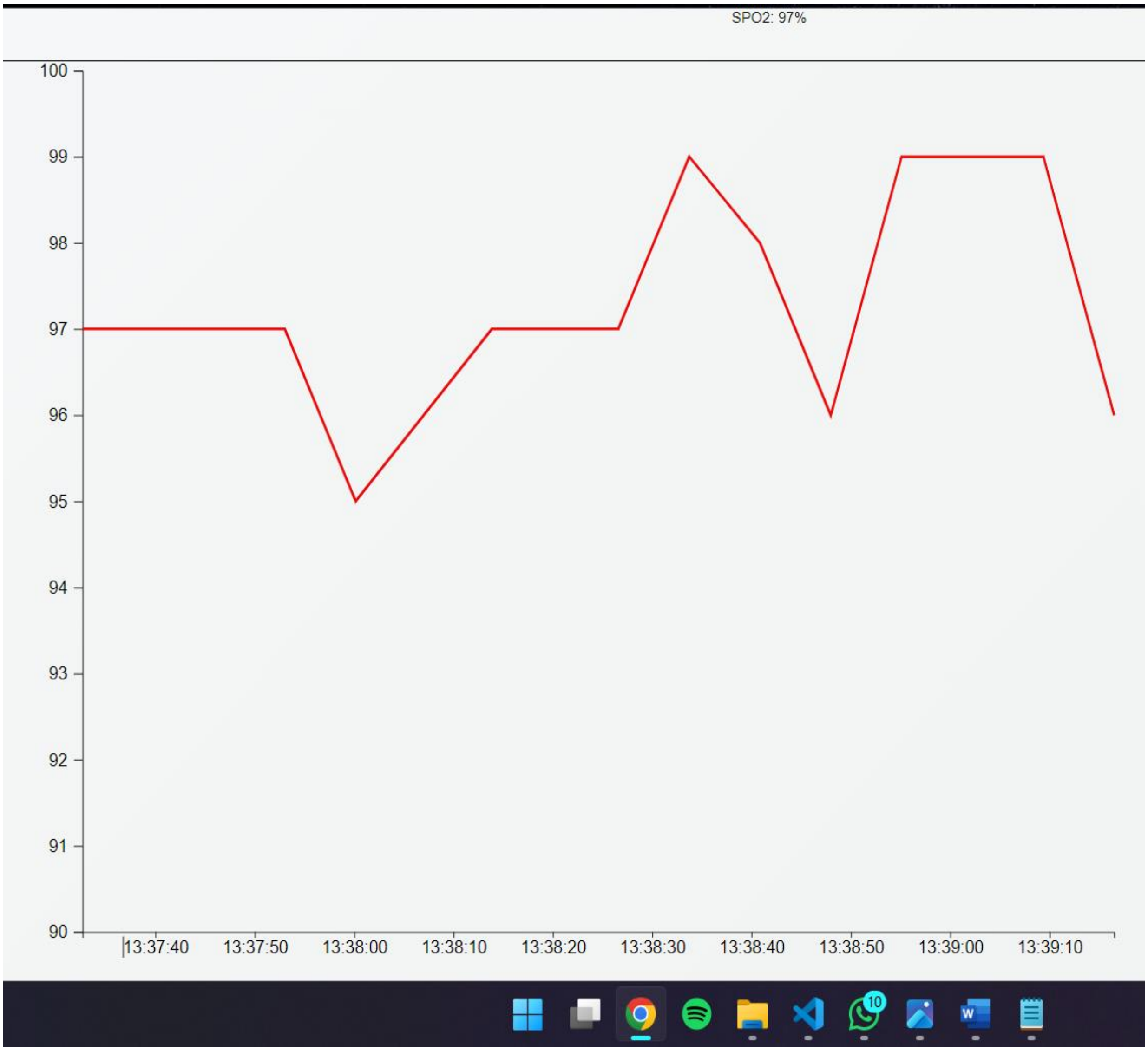

Figure 3.23: 3rd Person SpO2

Table 3.8: 3st person spO2

S.no	SpO2(%)	Time(HH:MM:SS)
1	95	13.38.00
2	97	13.38.10
3	97	13.38.20
4	97	13.38.30
5	99	13.38.40

Table 3.8 depicts the SpO2 data obtained for the respective person observed over

duration of time.

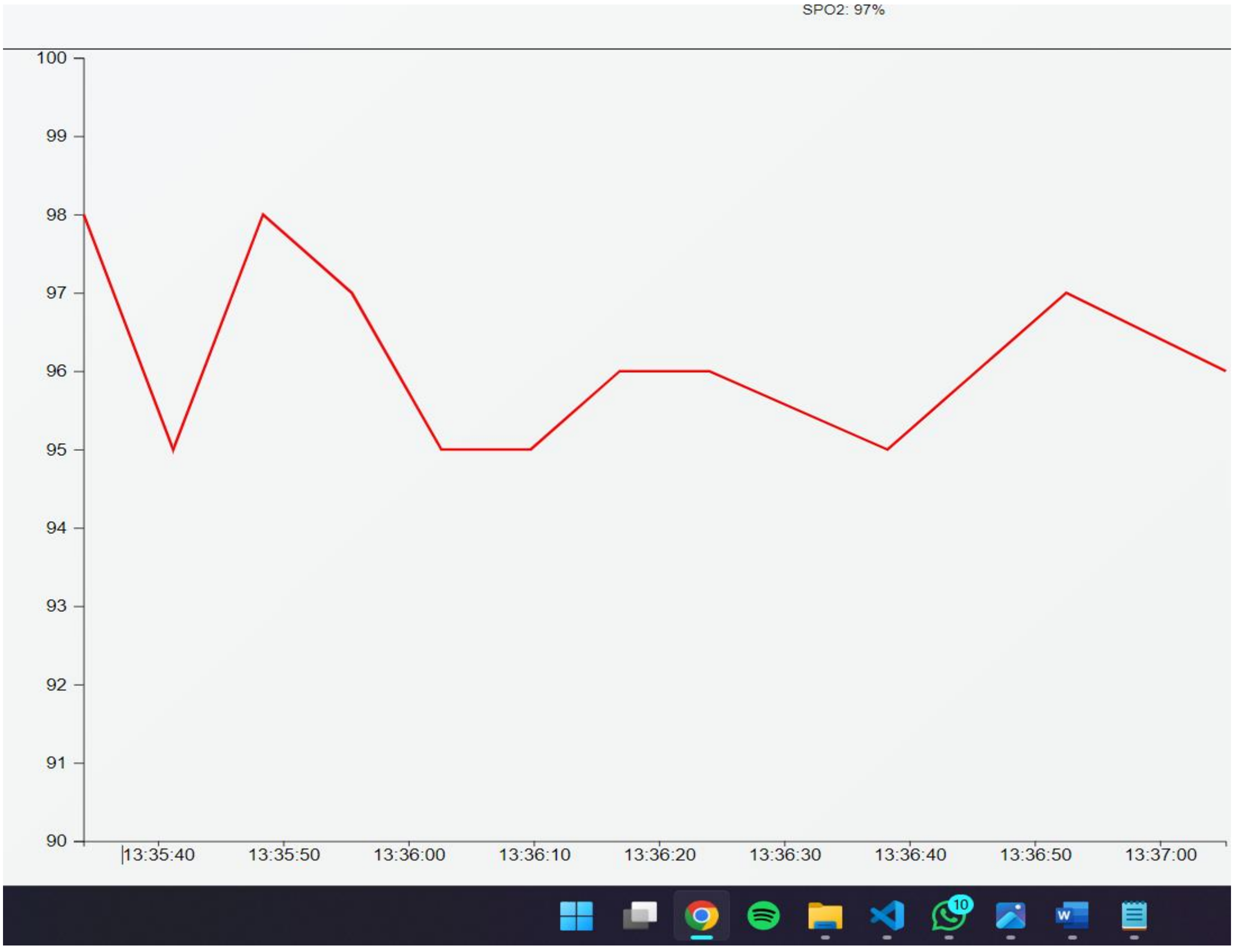

Figure 3.24:4th Person SpO2

Table 3.9: 4st person spO2

S.no	SpO2(%)	Time(HH:MM:SS)
1	95	13.35.40
2	98	13.35.50
3	95	13.36.00
4	95	13.36.10
5	96	13.36.20

Table 3.9 depicts the SpO2 data obtained for the respective person observed over duration of time.

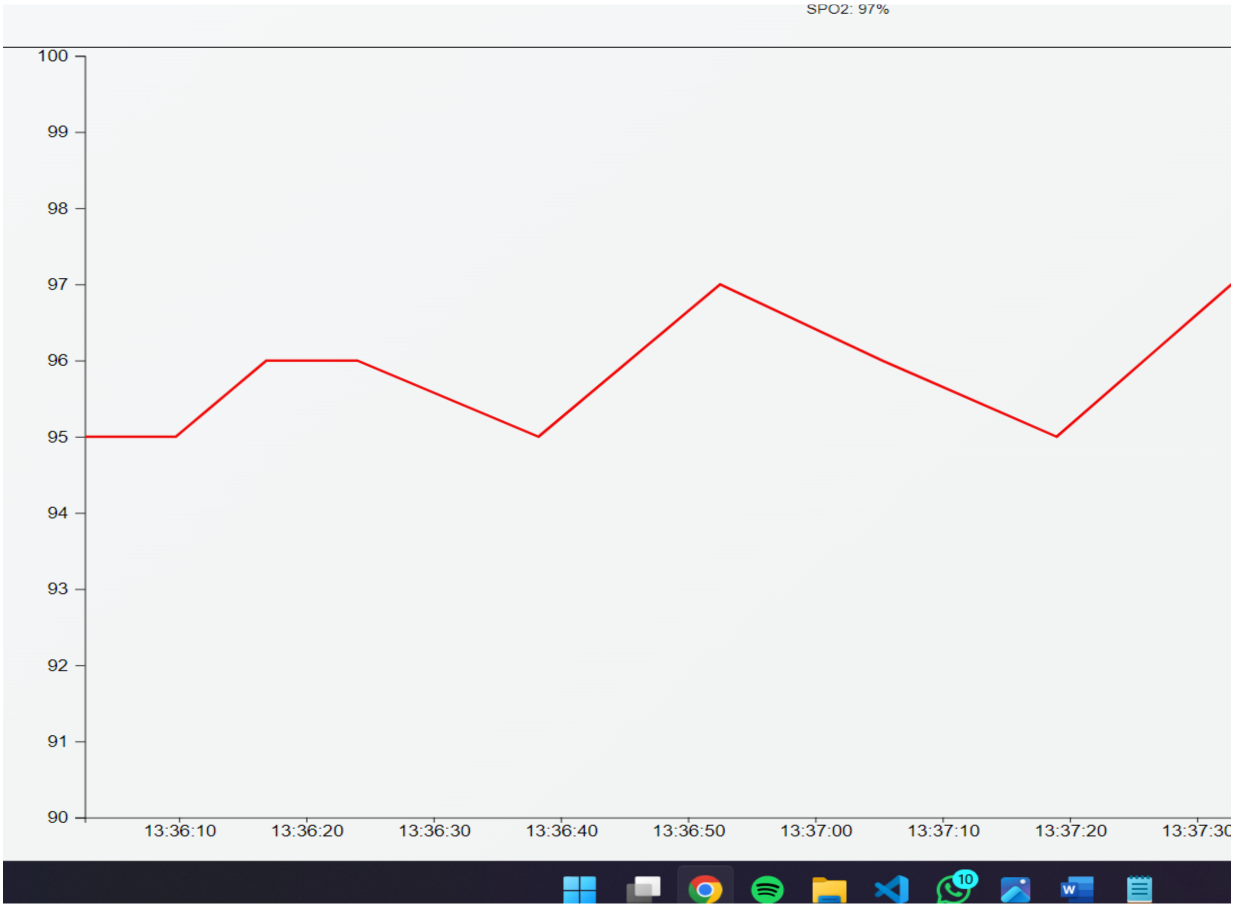

Figure 3.25: 5th Person SpO2

Table 3.10: 5st person spO2

S.no	SpO2(%)	Time(HH:MM:SS)
1	95	13.36.40
2	96	13.36.50
3	97	13.37.00
4	95	13.37.10
5	95	13.37.20

Table 3.10 depicts the SpO2 data obtained for the respective person observed over duration of time.

Figures 3.21, 3.22, 3.23, 3.24, 3.25 represents the SpO2 trends of 5 citizens over a duration of time. The observed analysis of the spO2 values of these 5 citizens shows a common range of 94-98%.

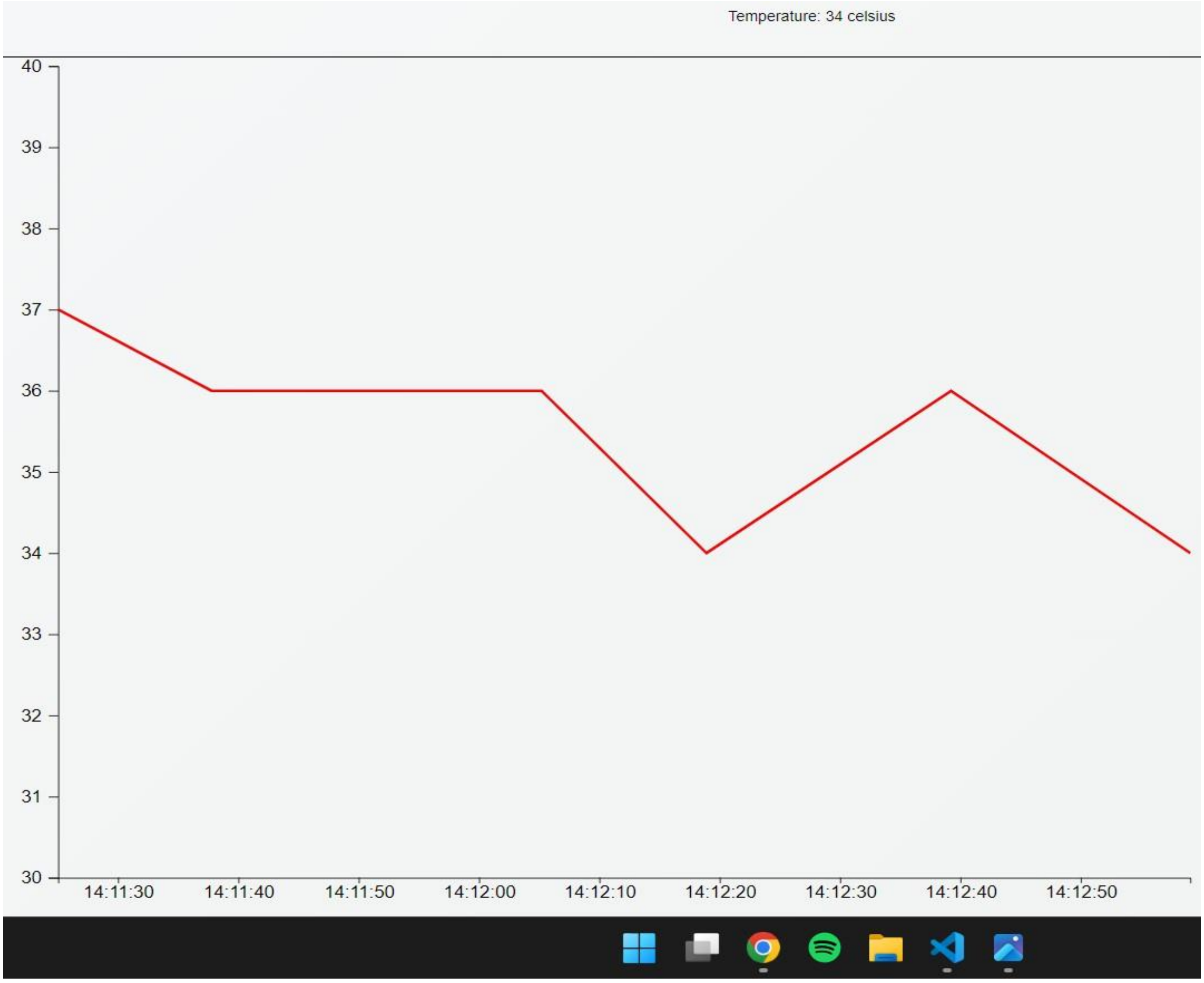

Figure 3.26: 1st Person Temperature

Table 3.11: 1st Person Temperature

S.no	Temperature(Celsius)	Time(HH:MM:SS)
1	36	14.12.00
2	35	14.12.10
3	34	14.12.20
4	35	14.12.30
5	36	14.12.40

Table 3.11 depicts the Temperature data obtained for the respective person observed over duration of time.

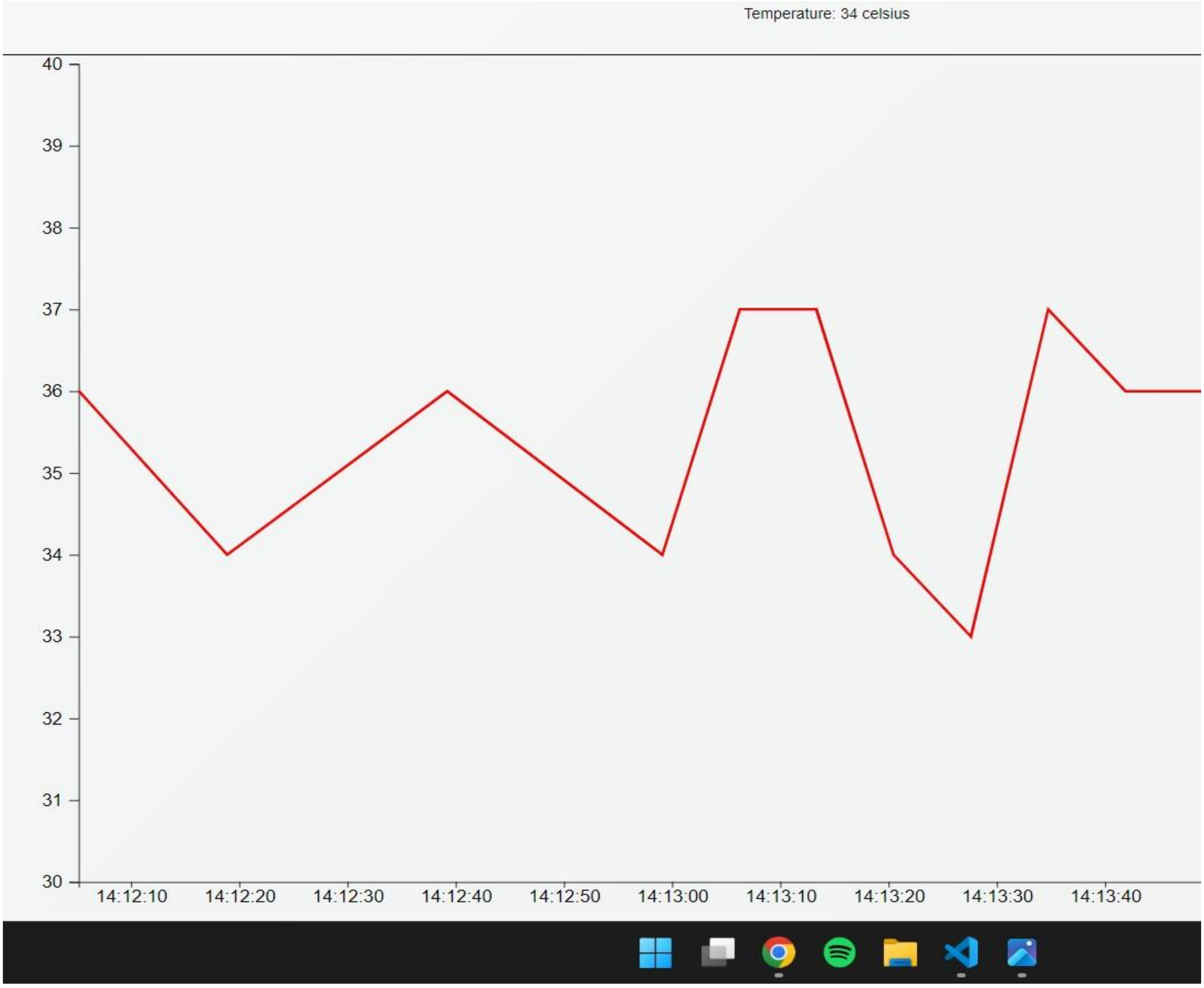

Figure 3.27: 2nd Person Temperature

Table 3.12: 2st Person Temperature

S.no	Temperature(Celsius)	Time(HH:MM:SS)
1	35	14.12.50
2	34	14.13.00
3	37	14.13.10
4	35	14.13.20
5	34	14.13.30

Table 3.12 depicts the Temperature data obtained for the respective person observed over duration of time.

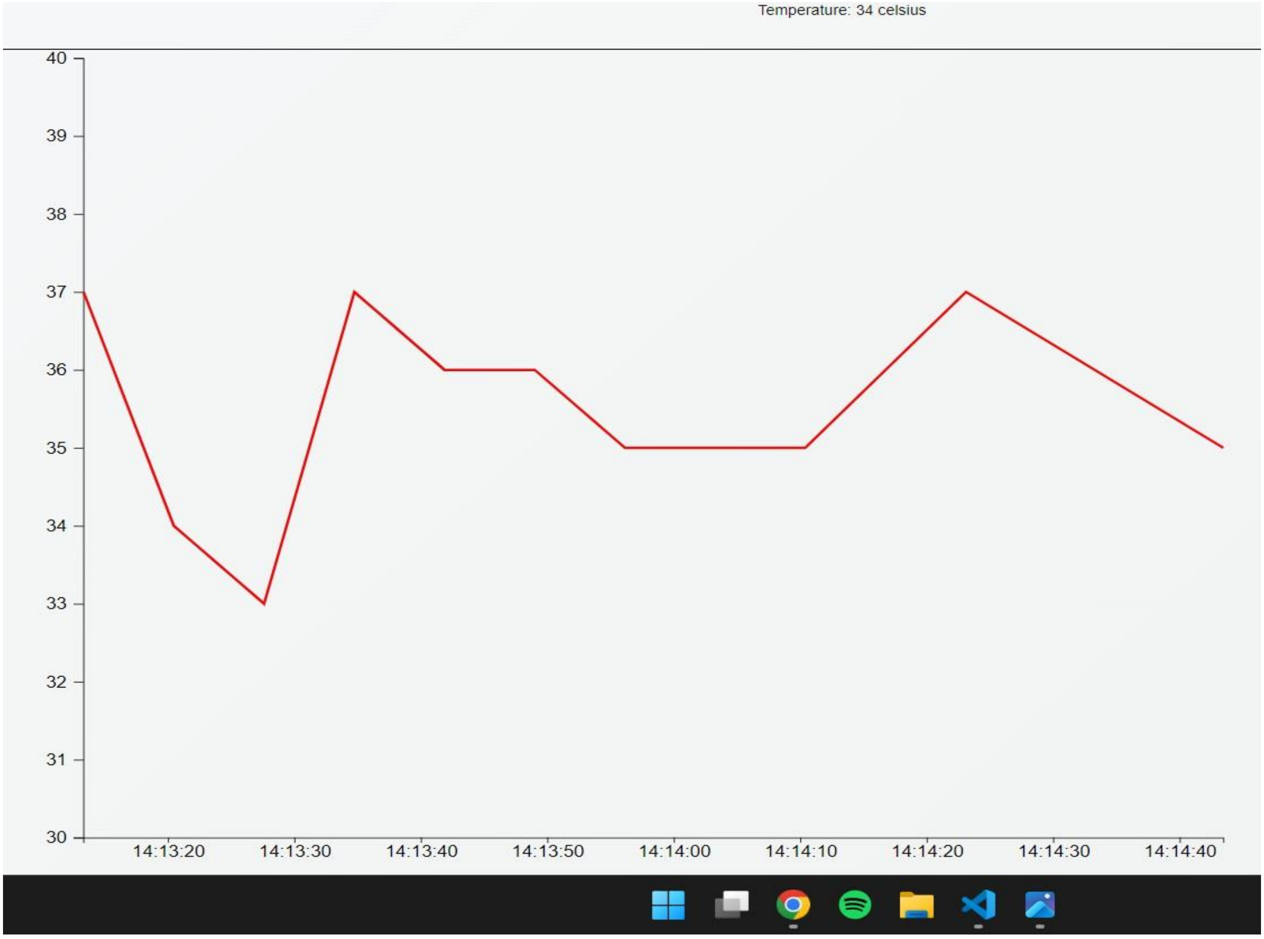

Figure 3.28: 3rd Person Temperature

Table 3.13: 3rd Person Temperature

S.no	Temperature(Celsius)	Time(HH:MM:SS)
1	36	14.13.50
2	35	14.14.00
3	35	14.14.10
4	36	14.14.20
5	37	14.14.30

Table 3.13 depicts the Temperature data obtained for the respective person observed over duration of time.

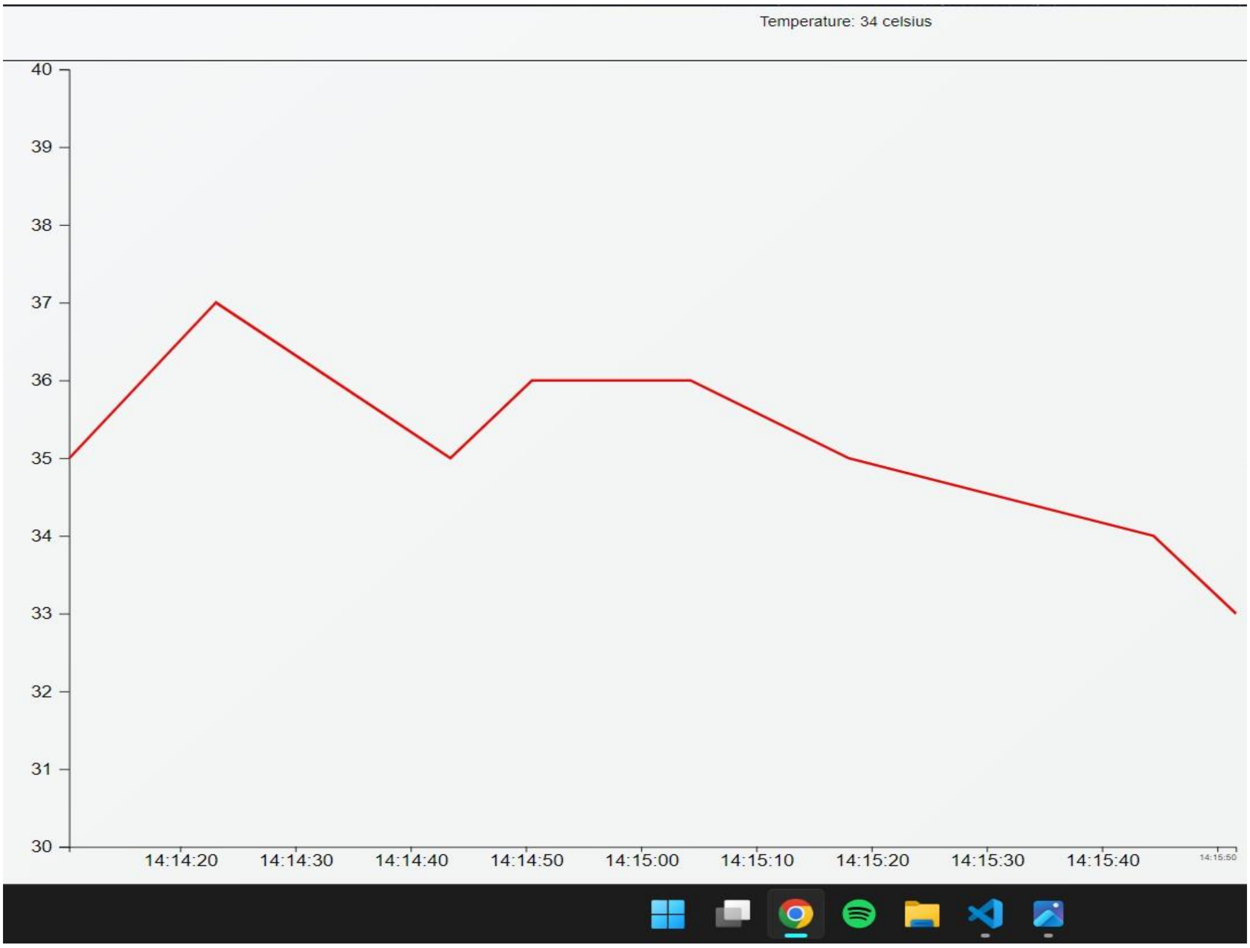

Figure 3.29: 4th Person Temperature

Table 3.14: 4st Person Temperature

S.no	Temperature(Celsius)	Time(HH:MM:SS)
1	36	14.14.50
2	36	14.15.00
3	35	14.15.10
4	35	14.15.20
5	34	14.15.30

Table 3.14 depicts the Temperature data obtained for the respective person observed over duration of time.

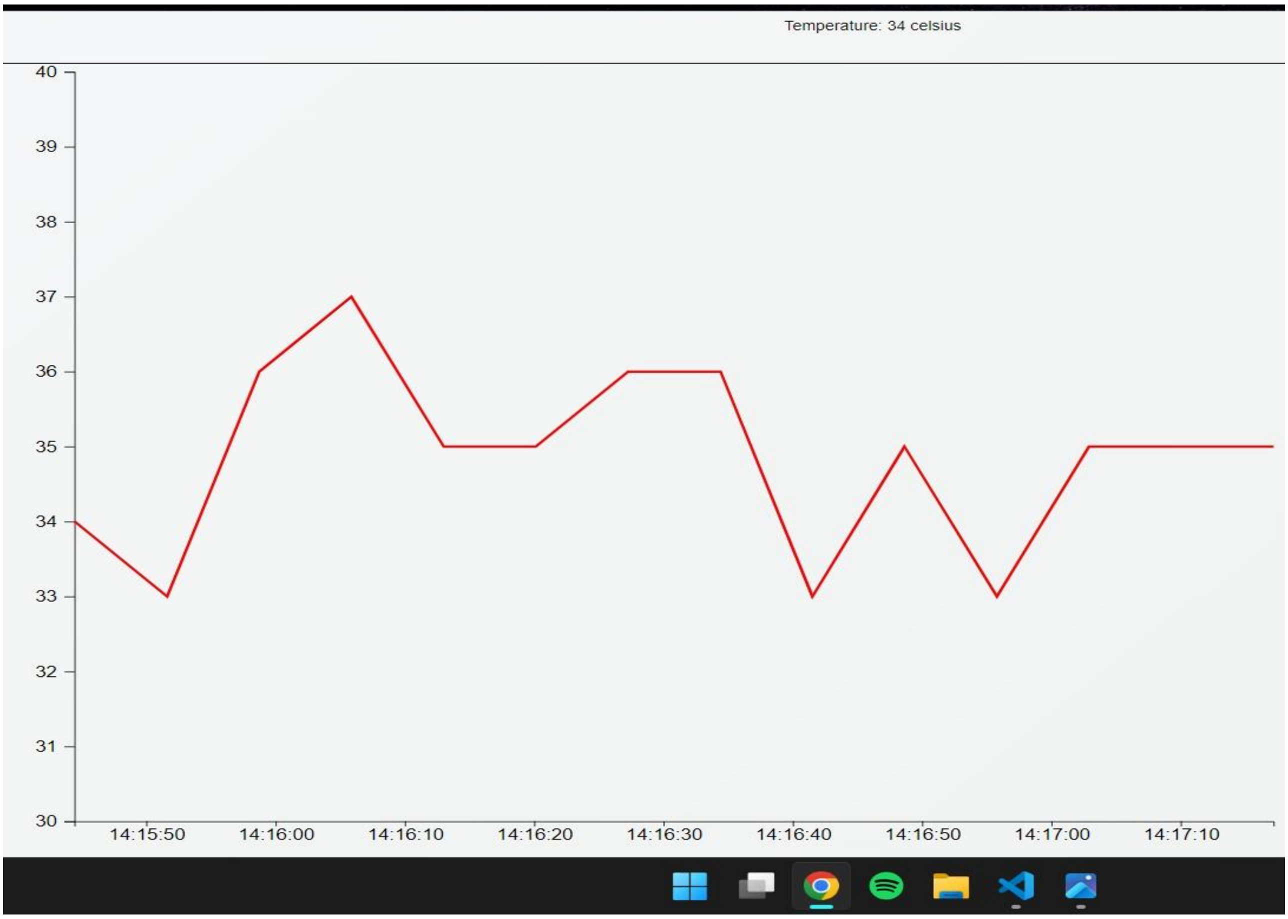

Figure 3.30: 5th Person Temperature

Table 3.15: 5st Person Temperature

S.no	Temperature(Celsius)	Time(HH:MM:SS)
1	33	14.15.50
2	35	14.16.00
3	35	14.16.10
4	35	14.16.20
5	36	14.16.30

Table 3.14 depicts the Temperature data obtained for the respective person observed over duration of time.

Figures 3.26, 3.27, 3.28, 3.29, 3.30 represent the temperature trends of 5 citizens over a duration of time. The range of values obtained were in the range of 33-37 Celsius.

3.3.2 PERFORMANCE ANALYSIS

The proposed Fire Vital system is been analyzed in real time by considering the reference point as the IOT building, MIT Campus, Anna University where the gateway is been stationed.

Table 3.16: Analysis of working range of the system

DISTANCE (LoRa Shield)	INDOOR	OUTDOOR
Lecture Hall Complex, MIT (200 meters)	YES	YES
Hangar 2 (500 meters)	YES	YES
MIT Hostel Gate (1 Kilometer)	YES	YES
Chrompet Railway Station (2 Kilometers)	NO	YES

Table 3.16 represents the operating range of the FireVital System. It can be inferred that when receiver is placed in the outdoor environment, the operating range exceeds 2 kilometers whereas incase of indoor placement the range does not exceed 2 kilometers.

With the given Line of Sight (LOS) between the transmitter and the receiver the range can be maximized up to a distance of 10 kilometers in urban areas and up to 15kms in rural areas. This is because it will offer less multipath fading and the signal will undergo less attenuation and loss compared to the non-LOS condition.

Table 3.17: Comparison of our FireVital with existing research

[11] F. Wu, etal	[14] H. Taleb,etal	FireVital: Seamless Real-Time Firefighter Health Monitoring and Command Center Collaboration
• Solar cells generate electricity when exposed to sunlight, causing power fluctuations and challenges for low-power devices, especially during cloudy or night time conditions. They also require a large surface area, which can be limited in small, portable devices due to space constraints. • Range for temperature is 34-37celsius. Range for SpO2 is 94-98%.Range for	• Fuzzy logic systems are complex due to their numerous variables and rules, requiring significant computational resources for low-power devices. They also require extensive training data to adapt to different operating conditions, which can be challenging to obtain. • Range for temperature is 33-38celsius, SpO2 is 92-99%, Heart rate is 65-75 bpm.	• Piezoelectric generators convert mechanical vibrations into electrical energy, making them ideal for low-power devices like wearables or sensors. They are small, lightweight, and have fewer moving parts, reducing maintenance requirements, making them ideal for compact applications like wearables or sensors. • Range for Temperature is 32-38 Celsius, spO2 is 92-100%,Heart rate is 65-83bpm.

heart rate is 70-80bpm.		

Table 3.17 shows the comparative analysis of the existing researches in this line of research. It can be inferred from the table that FireVital System is much efficient compared to the existing works in terms of power efficiency.

3.3.3 LATENCY ANALYSIS

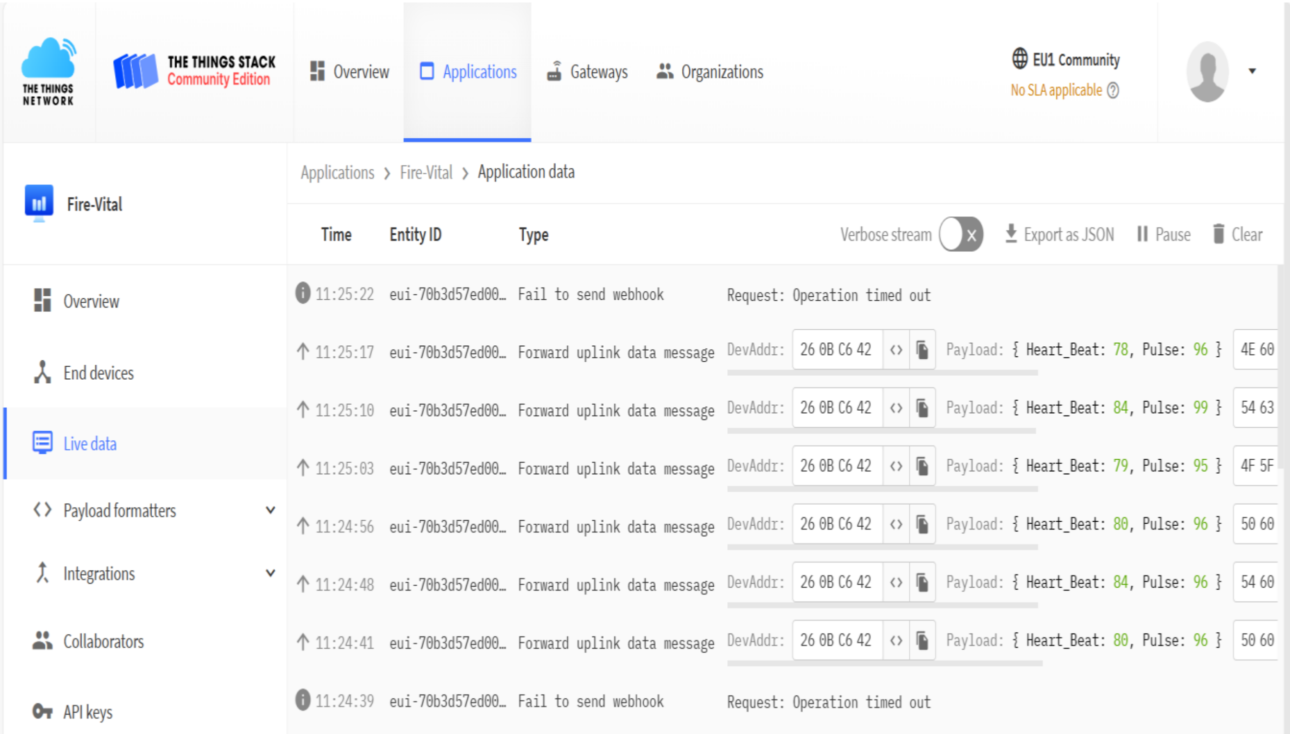

Figure 3.31: Visualization of data in Cloud Console

The above Figure 3.31 depicts that the transmitted data takes around 8-10 seconds to be received at the Gateway and get stored in the cloud for further processing.

3.4 SUMMARY

This Chapter discusses the results of each block involved in the Fire Vital system in detail. It also discusses the various analysis conducted to test the performance of the Fire Vital system.

CHAPTER 4

CONCLUSION AND FUTURE SCOPE

To sum up, the proposed system combines several sensors to monitor critical health parameters like heart rate, oxygen saturation, and body temperature. The data collected by these sensors is sent to the cloud via the LoRaWAN protocol, providing a low-power, long-range communication option. The Things Network (TTN), a cloud infrastructure, receives and stores the sensor payloads.

On the User interface front, a user-friendly webpage has been made to present the mission participant's current information. This data is retrieved from the cloud via the MQTT protocol, which ensures a stable and efficient connection between the cloud and the user interface.

This system's future scope involves studying wearable technology integration with your monitoring system. To make your monitoring system more accessible to users in a range of contexts, you may need to create a more compact, wearable version. Apply machine learning algorithms to the analysis of the collected data over time. Because of this, the system might be able to predict potential health issues by utilizing trends identified in earlier data.

For example, predicting the likelihood of a particular illness or sounding the alarm in the event of anomalies. Add more sensors to monitor health indicators like electrocardiograms, blood pressure, and glucose levels. This expansion might enhance the overall health monitoring capabilities of your system. Create a mobile app that communicates with the surveillance system.

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