SMART SAFETY DEVICE FOR WOMEN USING IOT

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A REPORT

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ABSTRACT

Women's safety remains a pressing concern worldwide, particularly in public and semi-public spaces where immediate assistance is not always accessible. Current IoT-based wearable safety devices offer a degree of protection but suffer from critical limitations, especially in terms of battery reliability and real-time responsiveness. This project proposes a station-based IoT safety system that eliminates dependency on wearable devices and ensures uninterrupted operation. The system comprises a fixed emergency station equipped with an alarm, visual indicators, and a portable GPS-enabled tracker, all integrated through real-time communication using Raspberry Pi, TTGO T-Beam and Telebot. By addressing key drawbacks in existing solutions, such as battery constraints, sensor reliability, and usability, this device offers a more dependable and accessible form of safety support. Strategic placement in high-risk areas like universities and office campuses ensures that women can quickly seek help in emergencies without relying on personal gadgets. The outcome is a sustainable and scalable infrastructure that strengthens public safety measures for women through the effective application of embedded systems and IoT technologies.

Area of Study: Internet of Things, Embedded Systems

Keywords: Women's Safety using IOT, Raspberry Pi, GPS Tracker, Station-Based Alert System, Real-Time Monitoring

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LIST OF ABBREVIATIONS

IOT	Internet of Things
GPS	Global Positioning System
GSM	Global System for Mobile Communication
MQTT	Message Queuing Telemetry Transport
UI	User Interface
LED	Light Emitting Diode
TTGO	Tiny Technical Global Open
ESP32	Espressif System 32-bit Microcontroller
CPU	Central Processing Unit
RAM	Random Access Memory
USB	Universal Serial Bus
GPIO	General Purpose Input/Output
RSSI	Received Signal Strength Indicator

Chapter 1
Introduction

1.1 Introduction

Recently, the issue of women's safety has become a global focus, encompassing issues such as harassment, violence, and human trafficking. To maintain sufficient economic resources, women need to go out to work or engage in other activities; however, safety becomes an obstacle to their daily lives. When women's safety is not guaranteed, they will reduce their participation in education, employment, and other activities. This not only brings negative costs to women but also places a burden and creates fear on society as a whole.

1.2 Problem Statement and Motivation

Concerns about women's safety also existed in Malaysia. A woman was harassed and followed while shopping in a mall in 2024.[11] The woman soon gained public notoriety after posting the footage she had recorded on social media as a result of the media's coverage. Using the video's popularity to pressure the government has already resulted in government action.

In 2025, there was also a similar case of sexual harassment of a college student on a long-distance bus from Kuala Lumpur to Malacca.[12] Concerns regarding women's increasing safety in daily activities were once again raised by this case. There is still a chance of sexual harassment in public settings. The event further demonstrated how urgently women need dependable safety measures and emergency support systems.

The real-life examples above clearly demonstrate the profound concern regarding women's public safety. Due to its unpredictable and sudden nature, governments struggle to provide constant assistance to every woman. However, electronic devices can offer some help, and a high-quality support system can assist them in emergency situations, particularly in sparsely populated public places. Women's extreme vulnerability in these situations underscores the necessity of developing affordable and effective solutions.

Personal electronic devices are currently the most widely used technology solution for women's safety. However, women may encounter difficulties in accessing and carrying these devices, and many devices are limited by their high price or limited functionality. For example, some devices may only be activated by a button if there is a lack of application/network integration [5][9]. On the other hand, devices that rely on sensor activation [2][4][6] may face more challenges, such as limited battery life, unstable connections, and accidental activation; these factors together make it difficult for many women to obtain and effectively use these devices when they need them most.

Both societal demands and technical opportunities are driving the urgent need to address women's safety. The increasing prevalence of harassment and violence against women calls for quick, reliable, and user-friendly solutions that are not limited by battery life, network connectivity, or the need for user activation. IoT and smart city technological advancements present an opportunity to establish a safety solution that can be used by anybody, anywhere. Our project aims to provide a wearable, accessible, and easy-to-use solution. By overcoming the current limitations of safety equipment, we can ensure that women feel safer and more comfortable in public spaces, allowing them to stroll freely without fear.

1.3 Objectives

This project aims to create an IoT-based emergency response system with stationary emergency response units at predetermined locations, which women can use in the event of an emergency. This system will provide women with access to emergency assistance through a mobile app instead of traditional, portable emergency devices that depend on battery life and may not work in a real-world emergency. The project's primary goals include:

1. To create an emergency station with user-friendly alert and activation functions.
2. To utilize IoT technologies like GPS to establish real-time communication and location tracking.
3. To incorporate a mobile platform-based remote SOS request option for increased accessibility.
4. To assess system performance in a realistic setting using usability testing and simulations.

1.4 Project Scope

This project will develop a reliable and practical safety system for women, providing them with more protection options. This system is suitable for high-risk locations such as university campuses and office buildings, places where women frequently visit, and areas requiring timely assistance. This solution is an IoT-based site-based security system designed to provide a rapid and reliable response to emergencies.

A stationary emergency call station has an activation button and an audible/visual alarm. This enables the person to trigger the alarm during an emergency and alert those nearby who may be responsible for providing support (such as security personnel) to the emergency. The fixed emergency call also includes a portable GPS tracking device that continuously sends out location information (including the GPS coordinates and RSSI signals) to assist security personnel in monitoring the emergency in real time without manually activating the emergency call.

The wearable tech used has been primarily dependent on battery life, which may run out at a time when it can be truly needed, whereas the design of the stations will create a much more stable and consistent platform. This is further enhanced by the strategic placement of these stations within the various campus and building environments, which will ensure users are close to an SOS station and still receive adequate coverage.

The other major part of the system is the SOS application available on a user's smartphone, which allows them to send an SOS alert directly from their phone. This will help cover situations when an individual cannot access a physical station and will help improve the accessibility of the system while increasing the flexibility of response.

A prototype of the system consisting of the fixed station, portable tracker, and mobile alert system shall have been built at the end of this project, and the entire system will then be tested via simulated real-world scenarios on sites such as college campuses and office buildings. The system performance will be determined through these types of evaluations. Upon completion of these evaluations, the ultimate goal is to achieve a reliable means of providing real-time location tracking and the capability to provide security personnel with immediate emergency notification so that they may respond on time to emergencies occurring in high-risk areas.

1.5 Contributions

This research helps to provide better systems for women's safety in locations such as schools and work environments, where there is a need for a timely response when there is an emergency. The system proposed by the authors utilizes an IoT-based station-based emergency system with fixed stations that provide more stable and continued support for users in need than traditional wearable devices that are limited by their battery longevity and could potentially fail in emergencies.

The use of IoT-based communications will enable users to communicate with system hardware and monitoring platforms through the use of IoT-based technology. This will allow for efficient transmission of data during emergency events, allowing security personnel to be aware of and respond more quickly to the event(s).

A significant contribution of this system is its dual-access emergency mechanism that allows users to activate an alert from either a physical station or via their mobile device, even when either option is inaccessible at the time of need (e.g., user at a great distance from the station). Therefore, emergency assistance may be provided and requested regardless of how far away that assistance may be from the user or how unable the user may be to access assistance through either method.

In addition, the system enhances the location uncertainty experienced using only either GPS tracking or signal-based positioning by providing location certainty through a hybrid tracking method incorporating both types of positioning technologies. As a result, the improved reliability of tracking users in varied environments (e.g., outdoor, where GPS is available, vs. indoor, where GPS is typically not available) offers enhanced location certainty at any time an emergency notification is provided.

In conclusion, the results of the experimental tests performed in realistic environments support the effectiveness of the current system as a feasible solution for improving personal safety by effectively providing timely (i.e., within necessary timeframes) and accurate location-specific emergency notifications to users.

1.6 Report Organization

Organised into several chapters, this report presents the complete development, implementation, and evaluation of the proposed women's safety system in a systematic way. Each chapter relates specifically to one stage of the project, starting with the initial background study through to the design of the system, development of the system, implementation, and then performance analysis of the completed system. The content structure allows the reader to easily follow the progression from the development of the concept through to the final evaluation of the project

Chapter 1 provides an overview of the project by giving background information, discussing the problem statement and motivation for developing the proposed system, outlining the project objectives, scope of the project, and key contributions to the proposed system. Additionally, Chapter 1 summarises the structure of the entire report and provides a roadmap to assist the reader.

The contents of Chapter 2 provide a comprehensive review of related studies and existing research into IoT-Based Safety Systems. The previous studies and their implementation are compared to establish their strengths and weaknesses, as well as their technological implementations. The review identifies areas of research that are currently unfilled, thus providing evidence to justify the development of the proposed system.

In Chapter 3, the methodology that was applied to this project will be explained. The first part of this chapter outlines the architecture of the whole system and the workflow process, as well as the major components of the system: fixed emergency station, portable tracking device, and mobile interface, with considerations for all design aspects that affect how the system will be developed.

Chapter 4 consists of the design of the actual system. This part covers the system block diagram, hardware specifications, circuit design, and each module’s interactions with each other. A description of what the fixed station, portable tracker, and mobile communication platform are and how they communicate will also be included.

The implementation phase for the System is covered in Chapter 5. This phase consists of assembling the hardware, writing the software, and configuring the system. This chapter explains how the system operates during normal usage and describes any difficulties that were faced while developing and merging each portion of the system into one.

The system's performance will be evaluated through testing and performance analysis in Chapter 6, which covers the various methods used to verify the system's accuracy, as well as a summary of the experimental results used to demonstrate that the system has met its design requirements. Results will also be analysed to determine the quality of the system, whether i.e. effective/reliable.

Chapter 7 will provide a summary of the project and highlight the major benefits obtained from the project, while providing suggestions for future improvements of the system and providing information on enhancements that could further improve the system.

Chapter 2
Literature Review

2.1 Previous Works on IOT

As embedded systems and Internet of Things technology have advanced, women's safety gadgets have also changed. While more recent gadgets include biometric and physiological sensors with app/web connectivity, earlier systems depended on straightforward activation mechanisms without smartphone integration. Every strategy has its own benefits, such as real-time monitoring, improved accuracy, or independence from smartphones. They do, however, also have some disadvantages in common, especially with regard to high battery consumption and dependability problems.

Products that are not connected to an app/Web will use simple ways to activate them by using either a panic button, an accelerometer, or via some type of GSM-based text messaging. An example of this is the devices designed by Dechamma et al. [5] and Kulkarni et al. [9], who both developed a GPS-based method for sending the user's location directly to their emergency contact. In addition, Kishore et al. [8] extended on this idea by introducing a heartbeat sensor as an option for detecting emergencies. The advantages of these types of devices are that they do not rely on wireless communications from a smartphone, so they will function if the user has no cell phone, it is turned off, or it is out of range. They also save battery because they do not require constant connectivity or high-power sensors. Therefore, these types of devices successfully solve the issue of users having no access to a cell phone in emergencies. The major negative aspect of these devices is that they are very limited in capabilities when compared to devices that are connected to an app/Web. Some of the limitations are no real-time tracking, no advanced location tracking, and no access to customer support via the cloud. Therefore, these devices may not be as useful in more complicated or prolonged emergencies.

Another group of safety devices utilizes both IoT connectivity and biometric authentication methods, like using fingerprint sensors. One example is the solution developed by Akram etal [1]. This system continually checks the user's fingerprint, and if there is no fingerprint is detected during a defined period, it will automatically trigger an alert. Singh etal [3] have created a GPS/ GSM safety system that can only be triggered by the owner of the system using their fingerprint; however, once the system has been triggered, it uses GPS, GSM, or an IoT Cloud Platform to provide real-time location and alert the authorities or next of kin of the emergency. A significant benefit of this type of system is that there is less chance of false activations because using biometric recognition will limit false SOS activations. Additionally, the user's security is increased because only one registered user can trigger an alert. Some systems will also prevent any user from cancelling an SOS once it has been activated, which prevents someone under duress from cancelling the activation. These different features help to eliminate false alarms and misuse of these systems. Although the main drawback to this type of system is the need for increased battery power due to the need for fingerprint scans and real-time connectivity to work properly, which makes them less able to be sustained in the long term.

More sophisticated IoT safety devices make use of physiological sensors, such as heart rate monitors and temperature measurement devices, combined with an app or web interface. Harikiran et al. [4], Gantha et al. [2], and Palanisamy et al. [10] developed a system that constantly measures your heart rate to detect sudden increases indicating possible distress. More functions, including an accelerometer for detecting the occurrence of falls, were provided by Pratiksha et al. [6]. Mehtre and Kumar [7] demonstrated an IoT-based device using Raspberry Pi for heartbeat, temperature measuring, and video capture that generates an alert to emergency contacts/authorities. Detection of anomalies in vitals leads to alerts automatically sent with the location of the user to emergency responders. Total automation of alerting provides a major benefit to the user as it allows them to be alerted regardless of whether they are conscious or unable to activate the alert manually. Total automation of alerting solves the issue of delayed response to critical incidents due to the immediate dispatch of help. Continuous use of sensors and periodic transfer of data generate a continued drain on battery life and significantly reduce the practicality of using these solutions during emergencies.

In conclusion, gadgets without web or app connectivity save battery life and offer independence from smartphones, but they lack sophisticated features [5, 8, 9]. Due to biometric and communication modules, fingerprint-based devices increase accuracy and reduce false alarms, but they also use more battery life [1], [3]. Although they are extremely power-intensive, physiological sensor-based devices allow automated alarms in life-threatening conditions [2], [4], [6], [7], and [10]. Battery dependence, which compromises the dependability of wearable safety equipment, is a recurrent problem in all three categories.

2.2 Previous Works Summary

The author, title, methodology, benefits, and drawbacks of each item are highlighted in a table that summarizes the review of prior research on women's safety devices.

Table 2.1 Comparison of Previous Work

No	Author	Title	Method	Advantage	Limitation
[1]	Wasim Akram Mohit Jain C. Sweetlin Hemalatha	Design of a Smart Safety Device for Women using IoT (2019)	Microcontroller: 1. ATmega328 Communication: 1. Mobile App 2. GPS 3. GSM Function: 1. Fingerprint sensor 2. Shockwave generator 3. LCD screen	Automatically alerts police and family if a fingerprint is not detected Shockwave generator for self-defence Audio recording and map-based navigation to safe places	Require constant power and frequent charging May be bulky
[2]	Praveen Gaanth G Praveen V Vishnuvarathan A Balaji B	Design of a Smart Safety Device for Women Using IoT (2022)	Microcontroller: 1. Arduino Communication: 1. Web/App 2. GPS 3. GSM Function: 1. Accelerometer 2. Emergency button 3. Electric fencer 4. Heartbeat sensor 5. LCD screen	Multi-trigger system Sends location automatically to web/app and activates electric shock	Accidental triggers May be bulky Require constant power and frequent charging
[3]	Kamred Udham Singh Pushpendra Kumar	Integrating GPS and GSM Technologies for Enhanced Women's Safety: A	Microcontroller: 1. Raspberry Pi 3 Communication	Multi-trigger system Loud buzzer to get immediate help	Requires a continuous power supply May be bulky

	Varun Chaudhary Neeraj Varshney Pradeep Kumar Sharma Teekam Singh	Fingerprint-Activated Device Approach (2024)	1. No specific app/web 2. GPS 3. GSM Function 1. Fingerprint sensor 2. Buzzer 3. Emergency button		
[4]	G.C. Harikiran Karthik Menasinkai Suhas Shirol	Smart Security Solution for Women based on Internet of Things (IoT) (2016)	Microcontroller: 1. No specific Communication: 1. Mobile App 2. GPS 3. GSM Function: 1. Heartbeat Sensor 2. Temperature Sensor	Fully automatic detection using multiple sensors. Reduces size and power use by using the smartphone's capabilities.	Needs the smartphone nearby and connected Accidental triggers Require constant power and frequent charging
[5]	Dechamma A K Swathi Chaithali Harshitha K Prof. Yogesh N	Women Safety Device with GPS Tracking and Alerting System (2023)	Microcontroller: 1. AVR Communication: 1. Mobile phone SMS 2. GPS 3. GSM Function: 1. Emergency button 2. Shock generator	Electric shock for defence.	Relies on physical activation

[6]	Pratiksha S. Patil Swati B. Tamkhade Sakib S. Mulani Prof. P. B. Yadav Prof. S. R. Gore	A Review Paper on Women Safety Device with GPS Tracking and Alerting (2024)	Microcontroller 1. Arduino UNO Communication: 1. No specific Web/App 2. GSM 3. GPS Function: 1. Accelerometer 2. Heart Rate Sensor 3. Bend Sensor, 4. Buzzer	Fully automatic detection using multiple sensors. Loud buzzer to get immediate help.	Require constant power and frequent charging. Needs the smartphone nearby and connected.
[7]	Bhuvaneshwari Mehtre Prof. Prabhat Kumar Panda	A Raspberry Pi-based Safety System for Women Security using IoT (2020)	Microcontroller: 1. Raspberry Pi 3 Communication: 1. Mobile phone SMS 2. GSM 3. GPS Function: 1. Heartbeat sensor 2. Temperature sensor 3. Voice input 4. Emergency button 5. Camera	Works in 3 ways: auto-trigger from multiple sensors, manual panic button, and voice command Captures real-time data	Require constant power and frequent charging. May be bulky
[8]	K Hari Kishore	An Application on Women Safety Using Embedded Systems and IoT (2021)	Microcontroller: 1. Arduino Uno Communication: 1. GSM	Fully automatic detection using multiple sensors. Vibrates to confirm danger, avoids false triggers	Without a GPS, it is difficult to provide the fastest help.

			Function: 1. Heart rate sensor 2. Vibration motor 3. Confirm button	No user interface needed.	
[9]	Manish Kulkarni	An Affordable, Portable Wearable Safety System for Real-Time Emergency Alerts and Location Tracking using Arduino, GPS, and GSM (2025)	Microcontroller: 1. Arduino Uno Communication: 1. GSM 2. GPS Function: 1. Emergency button	No user interface needed. Simple push-button triggers	Manual trigger only Limited features
[10]	Ms. Devi P Thaarini M Vansrani A Sreeja M	Smart Security Gadget for Women Using IoT (2021)	Microcontroller: 1. Arduino Uno Communication: 1. Blynk mobile app 2. GPS Function: 1. Heart rate sensor 2. Force sensor 3. Temperature sensor 4. MEMS sensor 5. Buzzer 6. Emergency button	Multi-trigger system	Requires continuous power supply or battery Needs internet access for IoT features to function May be bulky

Chapter 3
System Methodology

3.1 System Design Specification

Using an organized method, this initiative offers women a reliable, accessible means of protection or emergency response, emphasizing both offices and universities where the protection can be provided via a smart-based IoT station, including a real-time communication technology to ensure help when women need it the most.

3.1.1 System Architecture

The architecture of the system includes three components: a fixed station, a portable device, and a mobile app designed to provide users with security and allow the security back-end to respond to alerts, all linked through a central database. The portable device communicates from its location to the fixed station, where it continuously transmits GPS coordinates as well as resetting RSSI readings, which can also be accessed from the security app through a web-based front end. The fixed station functions as an interactive SOS or emergency signalling device; when users activate the SOS from the mobile application, the fixed station will also send real-time or live location data of the user to the Security Application via the central database; in so doing, enabling fast and reliable assistance to users. The security app performs two primary functions, responds to user SOS notification, activates the buzzer and LED on the fixed station, and provides access to the live location of the user via the portable device - thus allowing for fast and reliable assistance to users in their time of need.

Other than that, a portable tracker will be put together beside the fixed station, which allows the user to plug out during an emergency. This portable tracker will continuously provide the GPS location for the outdoor environment and RSSI-based location for the indoor environment. The security is able to access all the portable tracker's data using its IP address to monitor it, which provides an offline communication.

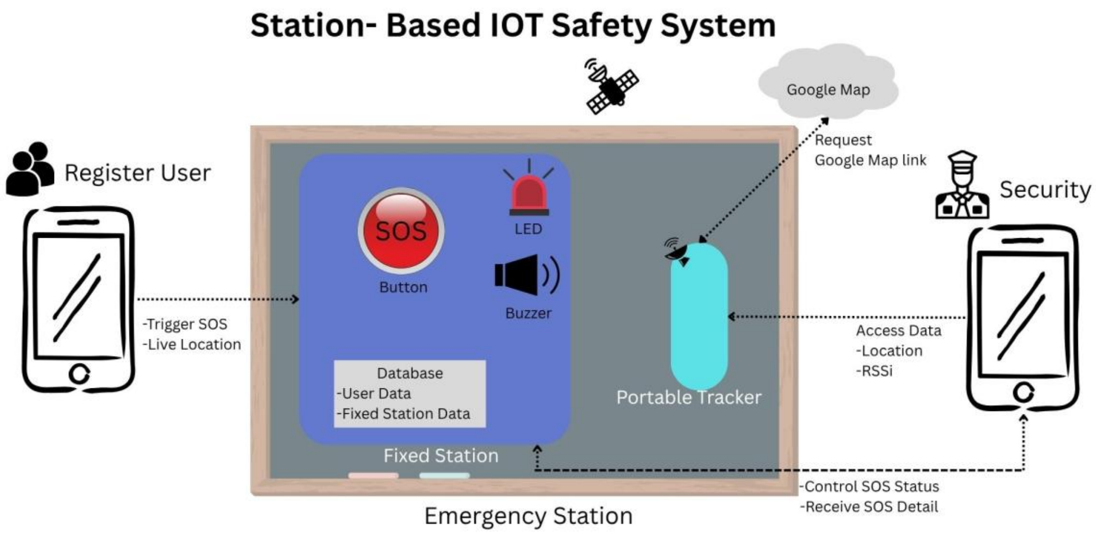

Figure 3.1 System Architecture Diagram

3.1.2 System Activity

The process to log into the mobile application starts with the registration of a user. By registering, users can now only send and receive SOS alerts through the application if they are considered authorized users. Simultaneously, the portable device sends out GPS data and RSSI data, which can be monitored via the web interface by security staff at any time, because the portable device sends out this information continuously.

The fixed station operates in a continuous monitoring state until an SOS alert is triggered. An emergency alert can be initiated either by the user or security personnel through the mobile application, or directly via the physical push button on the fixed station. Upon activation of an SOS event, the system immediately activates the buzzer and LED indicators on the fixed station while simultaneously transmitting the SOS alert, along with the user's details and real-time location, to the security personnel's mobile interface.

The portable tracker continuously scans latitude and longitude values to generate real-time Google Maps links for precise location visualization. At the same time, it also continuously performs RSSI scanning to estimate indoor room locations based on predefined signal strength mappings. To access all this data, security able get into the portable tracker web interface through its IP address. Through this platform, security personnel can monitor the current location of the device

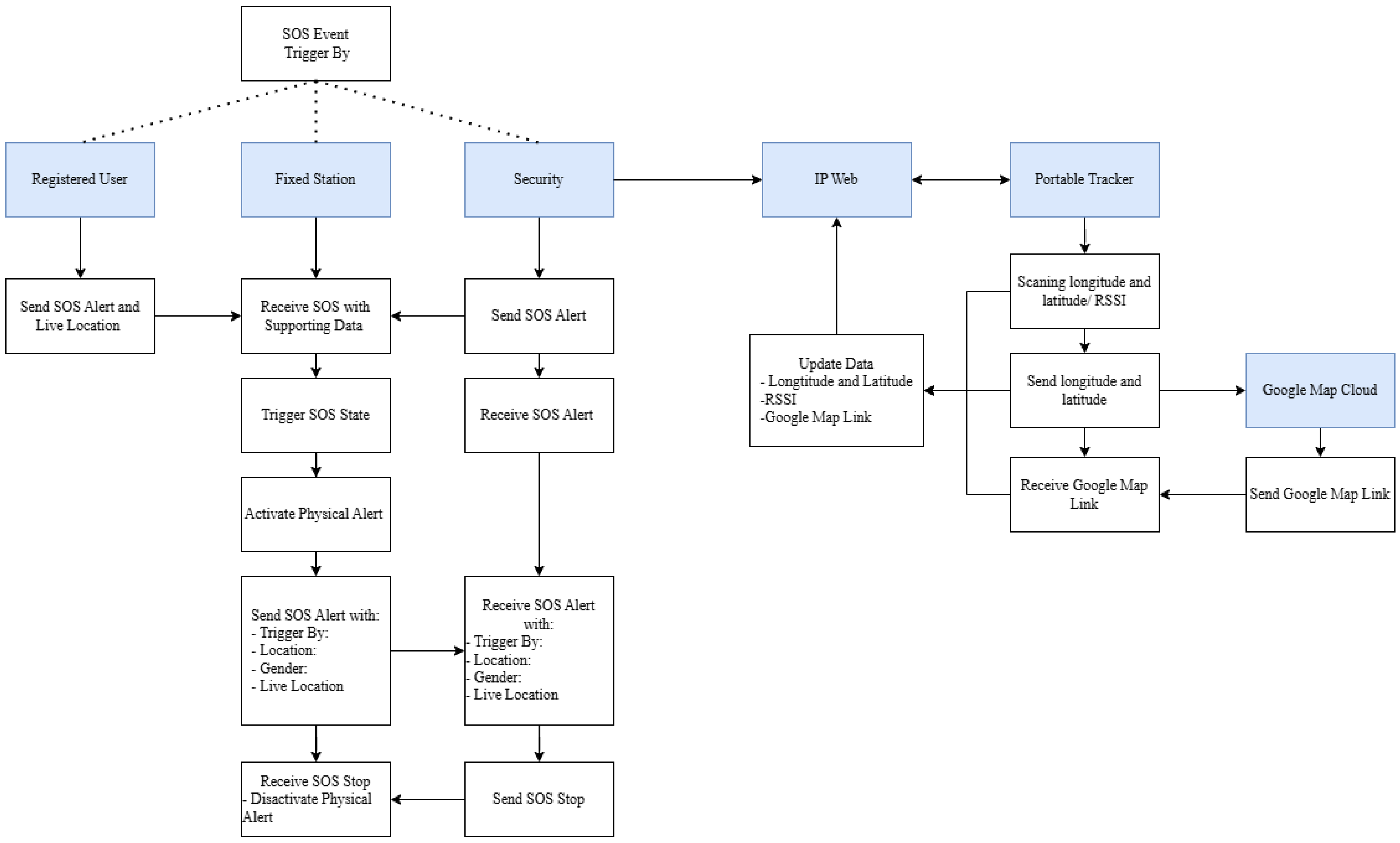

Figure 3.2 System Activity Diagram

3.2 System Elements Selection

The selection of appropriate elements is critical to ensure that the Internet of Things (IoT) Safety System functions at all times with dependable performance and efficiency. For this project, three distinct component types were identified as being the primary focus, which are the fixed station, portable tracker, and mobile application. The fixed station is responsible for managing SOS alert activation and managing the physical signals indicating your presence. The portable tracker will provide continuous real-time GPS and RSSI location information, while the mobile app will allow the user to send their location (SOS) alert on time, allowing persons in charge of security to monitor your location and to respond quickly. Choosing the right components carefully as part of this project will ensure that the result meets the specific functional requirements and is an effective monitoring tool for safety.

3.2.1 Fixed Station Component Selection

In order to operate effectively and reliably, a fixed station representing the main hub of the IoT safety system must satisfy many critical requirements. The first of these is sufficient processing power to carry out tasks simultaneously through monitoring SOS signals, processing the location of people needing assistance, and providing two-way communication between mobile applications and the fixed station. This allows alerts and location update data to be processed on time, without delays.

Reliable connectivity is the next goal because it allows data to be sent in real time between a stationary and a mobile device. The security team members will receive an SOS notification as well as be able to visually track their location from the fixed location and activity site via Wi-Fi or Ethernet, and remotely access and manage the stationary location.

The third requirement is sufficient general-purpose input-output (GPIO) connections to create an interface between physical objects (buttons and LED lights for visual alerts) and a fixed site that may be used locally to activate SOS, provide visual notification of SOS, or create audio notification of SOS & allow for future manual control of devices as needed.

A full operating system that supports multi-threading and an IoT networking structure is required for the fixed location. The presence of this operating system will allow the fixed location to process the data while sending a notification of the SOS and easily adding new sensors or modules at a later date. The last concern is the need for a stable source of operating power in order to prevent interruption of services, which is a key factor; however, it should be noted that all solutions for any location in the world should be cost-effective, long-lasting, and reliable.

Table 3.1 Comparison of Candidate Boards

	Arduino Uno	**ESP 32**	**Raspberry Pi 4**	**Notes**
Processing Power	Low (8-bit MCU)	Medium (32-bit MCU)	High (Quad-core ARM CPU)	Raspberry Pi can handle multiple tasks, including networking and SOS logic.
Connectivity	None / Optional Shield	Wi-Fi / Bluetooth	Wi-Fi / Ethernet / Bluetooth	ESP32 and Raspberry Pi support wireless, but Pi supports robust TCP/IP and database access.
GPIO Pins	14 digital, 6 analog	34 (digital & analog)	40 GPIO	All boards can handle buttons, LEDs, buzzers; Pi offers more pins and flexibility.
Operating System	None (bare-metal)	FreeRTOS / Arduino IDE	Linux-based OS	Pi supports multi-threading, libraries, database access, and web server hosting.
Power Supply	5V, low current	3.3–5V	5V, 3A	Raspberry Pi requires more power but can run continuously with a stable PSU.
Expandability	Limited	Medium	High	Pi can integrate cameras, sensors, and web-based dashboards easily.
Cost	Low	Low	Medium	Pi is slightly more expensive but provides high reliability and flexibility.

Based on the system requirements, Raspberry Pi is the best option among fixed stations. The Raspberry Pi's ability to process data at a fast rate, support multiple concurrent tasks, offer extensive connectivity, and facilitate the integration of new technologies into existing solutions are other reasons it is a great platform for supporting real-time SOS monitoring, two-way communication, as well as interfacing with hardware components. While other platforms, such as Arduino and ESP32, are good for accomplishing basic tasks, their lack of processing power and network capability limits their ability to support this IoT Safety System.

3.2.2 Portable Tracker Component Selection

The portable device is an essential element of the IoT safety system, due to its provision of real-time location and signal strength information. The device is required to meet three distinct sets of specifications to allow the device to operate as intended. First, the device is required to incorporate an integrated GPS function to provide accurate location data when used in outdoor situations. The device must also have the capability for offline functionality, and therefore be able to connect directly from either a mobile or security application, even if there is no access to the Internet.

The second set of specifications is that it must enable wireless transmission of data in real-time to the network when connected. The device must also have ample processing power to support simultaneous GPS reading, RSSI scanning, and communicating.

Finally, expandability and the ability to be compatible with additional sensors or modules, as well as the ability to integrate directly with a fixed station and mobile application, are also essential parts of the specifications for this device.

Table 3.2 Comparison of Candidate Portable Tracker

	DIY Arduino	**DIY ESP32-**	**ESP32 TTGO T-Beam**	**Notes**
GPS Capability	Optional (need module)	Optional (need module)	Built-in GPS	TTGO T-Beam includes integrated GPS for convenience.
Wireless Communication	Need an additional module	Wi-Fi/ Bluetooth	LoRa /Wi-Fi /AP mode	TTGO T-Beam supports offline mode/access point for direct connection.

Offline/ AP Mode	Limited	Possible with extra coding	Built-in	TTGO T-Beam is ready for offline access without additional modules.
Processing Power	Low (8-bit MCU)	Medium (32-bit MCU)	Medium (32-bit MCU)	Should be adequate for GPS, RSSI, and SOS functionality.
Portability	Small battery required	Small battery required	Small, lightweight, battery-powered	TTGO T-Beam is designed for portable use.
Energy Efficiency	Limited	Moderate	Moderate	All ESP 32 Modules support continuous battery management
Cost	Low	Low	Medium	Lower cost for DIY tracker

The most practical and ready-to-use option for a portable device suitable for an IoT safety system, based on the system requirements, including GPS tracking, RSSI scanning, portability, and offline capability, is the TTGO T-Beam. It has built-in GPS, LoRa communications, and built-in access point mode, which enables it to continuously operate and be directly connected without using the internet, allowing for reliable monitoring in all location types. Although both DIY Arduino and ESP32 solutions may be lower cost, they require additional modules and programming to provide the same functionality as the TTGO T-Beam.

3.2.3 Mobile Application Component Selection

Users of the mobile application will use it to send SOS alerts, and security personnel will use it to monitor and respond to emergencies in real time. The mobile application must support real-time communications between mobile applications and fixed stations and provide real-time tracking of users' locations, to allow for prompt response by security personnel after triggering SOS alerts.

The mobile application must also be secure and have controlled access, with only registered users able to send alerts, and only authorized security personnel able to receive or deactivate SOS alerts. In addition, the mobile application must be cross-platform accessible, meaning that the system will work on both Android devices and iOS devices without the need for a custom mobile application to be developed.

Table 3.3 Comparison of Mobile App Options

	Custom Mobile App	**WhatsApp**	**Telegram Bot**	**Notes**
Real-Time Communication	Yes	Yes (limited APIs)	Yes	Custom app is flexible, but WhatsApp API is limited for automation; Telegram Bot delivers instant alerts reliably.
Live Location Tracking	Yes	Limited/ Manual	Yes	Telegram allows live location sharing via bot.
User Registration/ Authentication	Built-in	Limited	Supported via bot + database	Telegram ensures only registered users can send SOS, and only security receives it.
Cross-Platform Accessibility	Yes	Yes	Yes	Telegram works wherever the app is installed; no need for separate development.
Security/ Access Control	Customizable	Limited	Controlled via bot + database	Telegram allows secure access and prevents unauthorized access.
Cost	High	Low	Low/ Ready-to-use	Custom app requires long development; WhatsApp API limitations make automation harder; Telegram Bot is fast to deploy.

A custom mobile application provides the greatest flexibility, but requires significant development effort and time. While WhatsApp is widely used, it has limitations with its API that prevent automating SOS alerts, sharing live user locations, and providing secure user access control for SOS alerts. A Telegram Bot provides a ready-to-use solution.

Chapter 4

System Design

4.1 System Block Diagram

The system block diagram shows the interactions between the key components of the IoT safety system. Users can trigger SOS alerts through the mobile application and the fixed station button, which are sent to the fixed station and the security mobile app simultaneously. The fixed station, equipped with a button, LED, and buzzer, provides local notifications and communicates two-way with the security app. Meanwhile, the portable device continuously provides GPS and RSSI data for monitoring, and the database stores user registrations and location information to ensure secure and reliable operation.

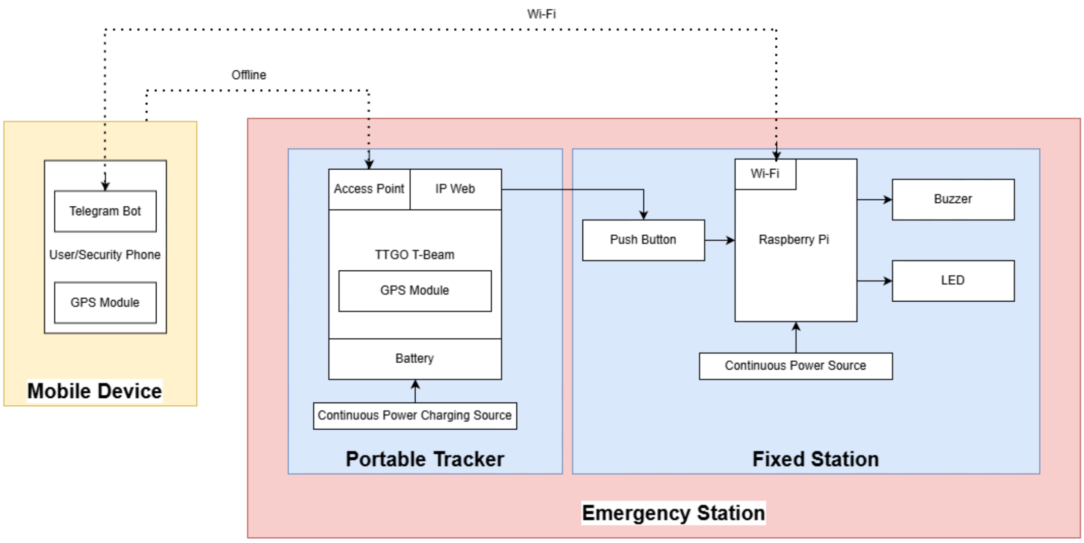

Figure 4.1 System Block Diagram

4.2 System Component Specification

The fixed station manages all SOS alerts, contains the components for controlling the buzzer, LED lights, and communicates with the security app using a Raspberry Pi with Python language. However, the TTGO T-Beam runs the portable device to track both GPS and RSSI data, and it is programmed in Arduino C/C++. The mobile application for the system is built using the Telegram API, which allows the alert that the user has sent out to be sent to the mobile application to allow the person in a position of providing security to monitor and respond.

4.2.1 Fixed Station

The Raspberry Pi serves as the main processing unit of the fixed station; it handles processing of SOS alerts and control of the buzzer and LED, as well as communication between the fixed station and the security app on the user's mobile phone. The fixed station's programming language is Python and allows for GPIO control, networking, and database integration.

Table 4.1 Specifications of Raspberry Pi 4

Description	Specifications
Model	Raspberry Pi 4 Model B
Processor	Quad-core Cortex-A72 (1.5GHz)
RAM	4GB
Connectivity	Wi-Fi, Bluetooth 5.1, Ethernet
USB Port	2 x USB 3.0, 2 x USB 2.0
GPIO Pins	40-pin header
Operating	Raspbian / Linux-based OS

4.2.2 Portable Tracker

The portable tracker is a TTGO T-Beam, which provides GPS tracking, RSSI scanning, and wirelessly communicates with the fixed station. The portable tracker's programming language is Arduino C/C++, allowing for efficient sensor reads, LoRa/Wi-Fi communication, and continuous operation.

Table 4.2 Specifications of TTGO T-Beam

Description	Specifications
Model	TTGO T-Beam
Processor	ESP32 Dual-core
RAM	8GB
Connectivity	Wi-Fi, LoRa
GPS Module	NEO-6M
Power	18650 Lithium Battery
Charging	Micro-USB / Charger Module

4.2.3 Telegram Mobile App

The security mobile app is based on the Telegram Bot API. Registered users of the app can send out SOS alerts, share their current location, and provide security personnel with immediate alerts and the ability to respond. The mobile app does not require custom development and will work on any platform.

4.2.4 Portable Tracker Web Interface

In addition to the mobile app, the portable tracker has a web interface where security personnel can access real-time GPS and RSSI data from the portable tracker. This provides continuous monitoring and situational awareness to security personnel, even when they do not have access to the mobile app.

4.3 Circuit and Component Design

A major aspect of the complete system is the design of the circuit and its parts. It will be critical to ensure that all hardware functions correctly together to promote dependable operation for all hardware components in the system. Proper design and setup will facilitate accurate signal transmission, a stable power supply, and the ability of all devices to communicate with one another efficiently and effectively.

An organized circuit and selection of the appropriate component type will enable maximum speed and efficiency in operating the entire system. These changes will result in improvements to the overall effectiveness of the safety systems as a whole and allow us to continue providing timely assistance to others who require help.

4.3.1 Raspberry Pi Wiring Design

Raspberry Pi's SOS button, buzzer, and light are all hardwired with the SOS button system from an electrical perspective and connect directly to the Raspberry Pi GPIO pins. The power supply to the Raspberry Pi is provided via a constant 5V DC using a wireless or Ethernet connection through the security mobile application.

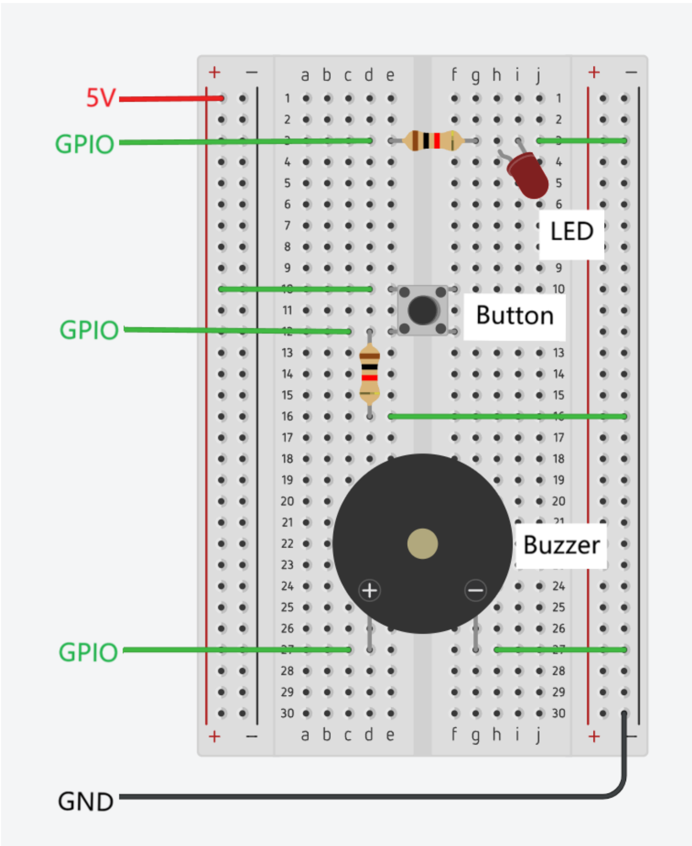

Figure 4.2 Raspberry Pi Breadboard Wiring Design

4.3.2 Telegram Bot Interface Design

The Telegram Interface provides an overview of how the software will flow for registered users and security personnel. Registered users can send SOS messages and share their current location with other registered users by using the Telegram Bot. Security personnel will receive the SOS message, be able to see the user's location on a Map, and have the capability to turn on the buzzer and lights of the fixed station, if needed.

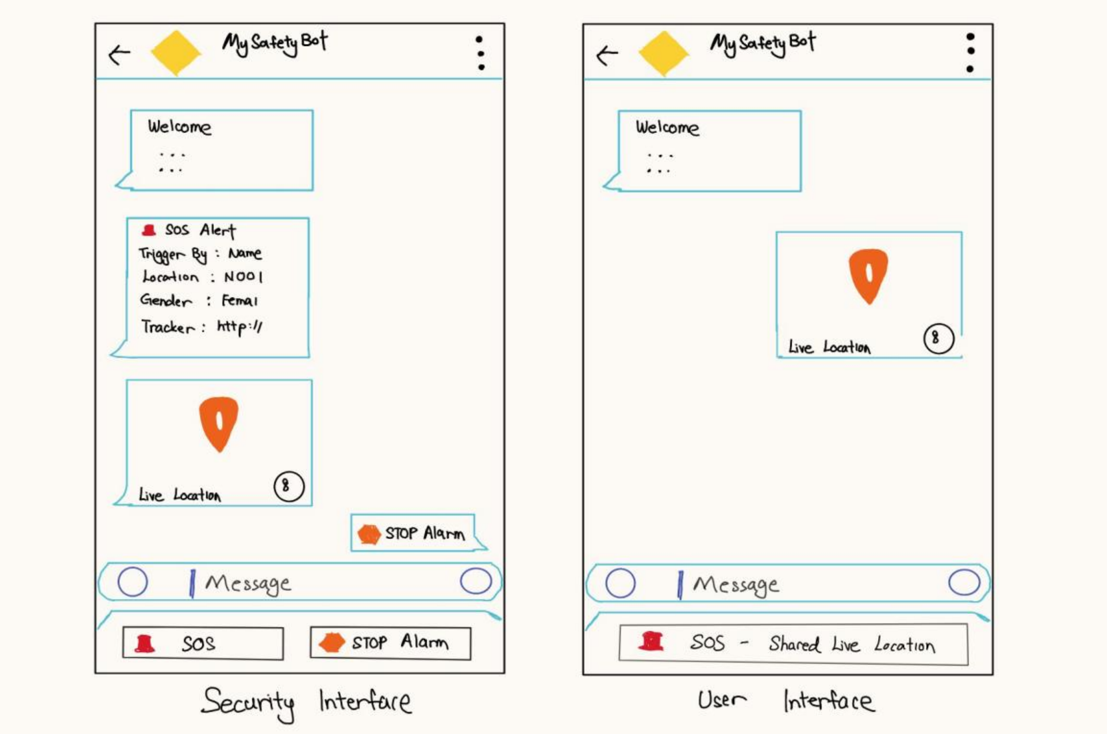

Figure 4.3 Telegram Bot Interface Design

4.3.2 TTGO T-beam Web Interface Design

This portable location tracker will use the onboard GPS module in the TTGO T-Beam for acquiring the user's location. The tracker has a built-in rechargeable battery that can be charged through a permanent base station. The device's IP address can be accessed through any web interface, allowing security personnel to view the device's current GPS and RSSI (Received Signal Strength Indicator) levels without having to rely on mobile applications

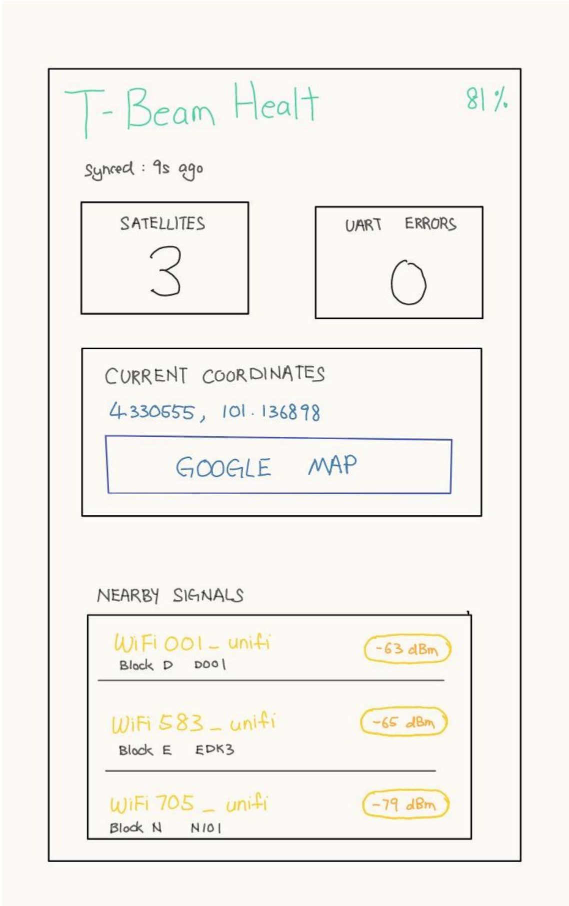

Figure 4.4 Web Interface Design

Chapter 5
System Implementation

5.1 Hardware Setup

The hardware installation involves assembling and integrating the tracker onto the portable unit and the base unit. The entire setup uses appropriate wiring, a reliable power source, and an enclosure that maintains stable operation and signal integrity.

5.1.1 Raspberry Pi

The fixed station has been carefully configured to provide a secure connection of each wire to its appropriate GPIO connection on the SOS help button, LED, and buzzer. The fixed Pi station will also use a reliable 5-volt power supply that has been configured to provide continuous, uninterrupted power regardless of whether you are using the fixed Pi station or not.

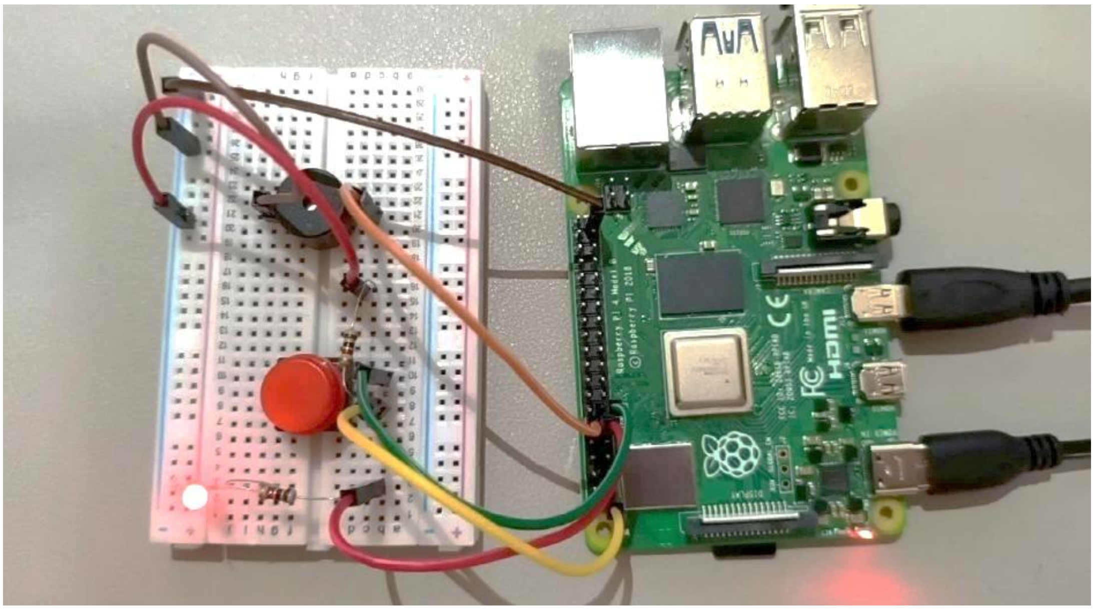

Figure 5.1 Raspberry Pi Wiring Connection

Once verified all electrical connection points and functionality of each component has been checked, then we will install the complete tracker assembly into an enclosure that will maintain signal integrity, protect against mechanical damage, and allow for adequate ventilation to provide proper cooling to ensure continued reliability during continuous operation.

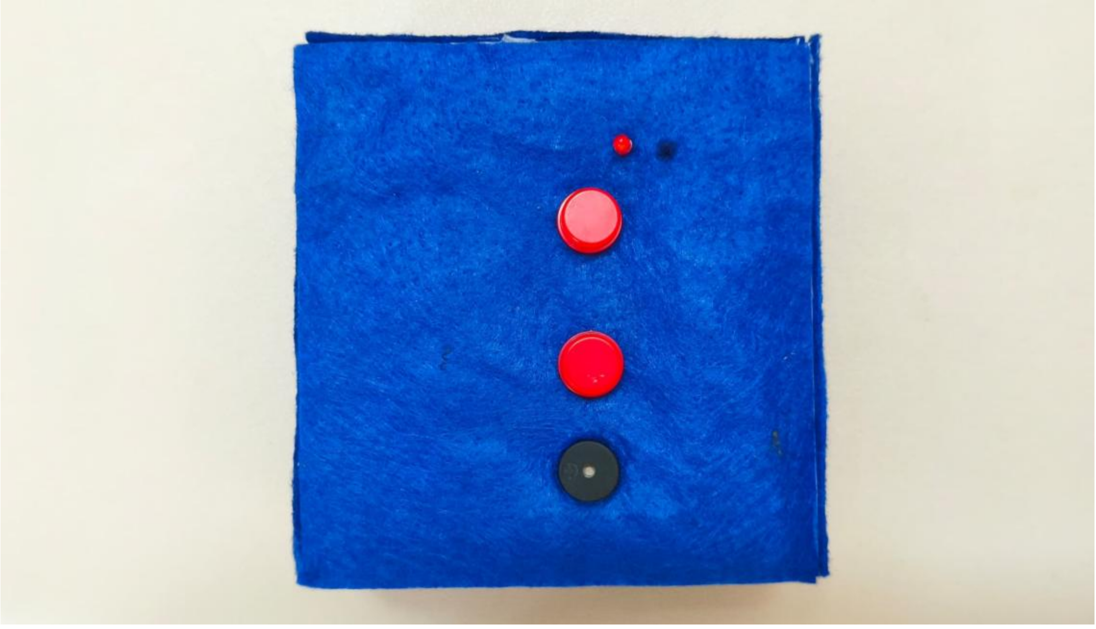

Figure 5.2 Raspberry Pi Prototype

5.1.2 TTGO T-beam

The TTGO T-Beam portable tracker is carefully assembled and secured to have all wiring connections secure, and has the antenna installed in accordance with national frequency regulations. The battery has been tested to verify that all operational specifications are satisfied, and can be charged directly via cable to make it more convenient and reliable.

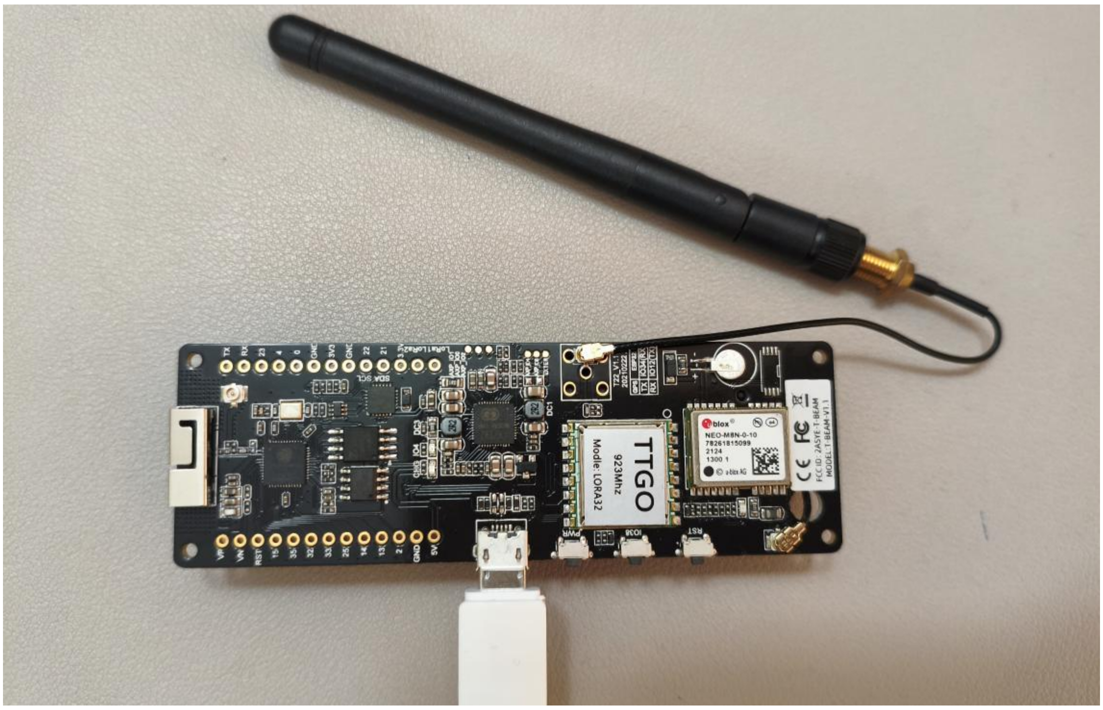

Figure 5.3 TTGO T-beam Wiring Connection

After passing all tests successfully, the tracker will be placed in a very small, strong, durable case that will protect the internal parts of the tracker while at the same maintaining the wireless performance of the tracker to assure reliability of the tracker in actual use cases.

Figure 5.4 TTGO T-beam Prototype

5.2 Software Setup

The software installation discusses the development and configuration of the Telegram Bot and web interface for easy SOS alerting to security personnel via GPS monitoring, real-time GPS, and RSSI monitoring, and also for user-to-security contact via the Telegram Bot.

5.2.1 Telegram

The Telegram Bot serves as the designated user interface through which users will communicate with security personnel and has a secure token for authentication of each party. In addition, the system has employed role-based access control; therefore, individual users are granted the ability to send SOS alerts with one-touch activation in the case of emergencies.

On the contrary, security personnel are given full permissions to activate and deactivate all sent SOS alerts and have access to comprehensive victim information through an easy-to-use dashboard. The system provides a structure in which security personnel can respond to emergencies as quickly as possible, while maintaining operational security and providing controlled access to critical functions.

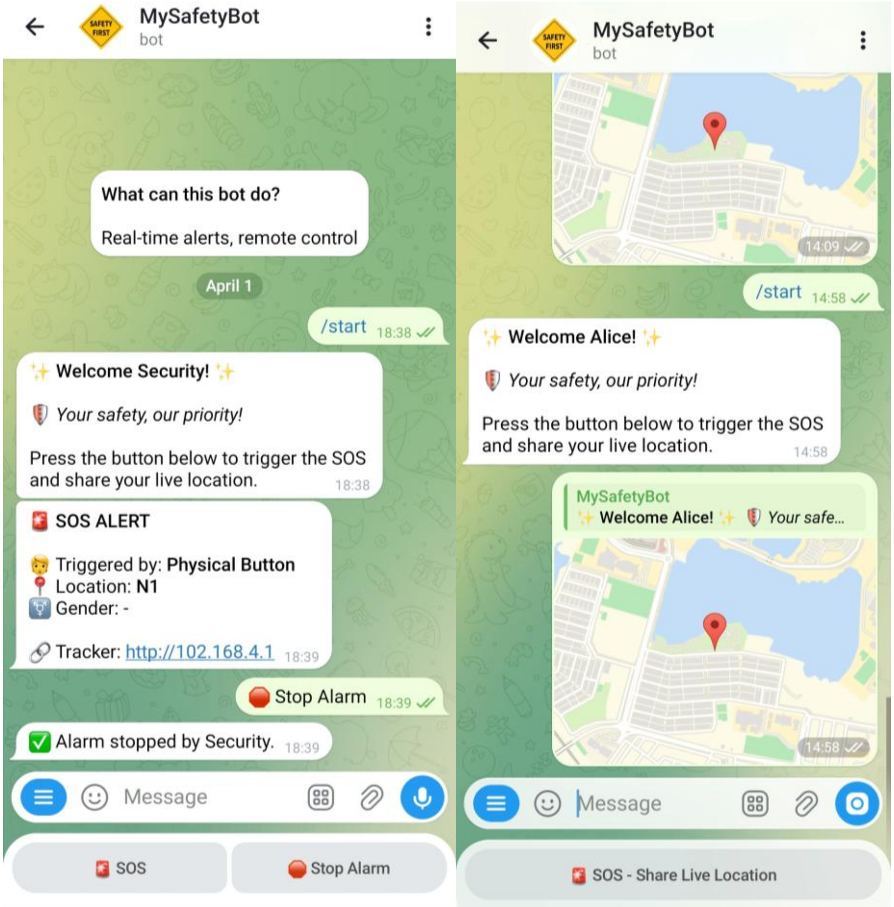

Figure 5.5 Telegram Bot Interface

5.2.1 TTGO T-beam Web

The web interface of the portable tracker provides real-time and device-specific tracking and monitoring for security personnel. This tracking system provides real-time GPS coordinates (latitude and longitude) as well as a hyperlink to Google Maps for fast location verification. To verify that GPS information from the device is trustworthy and accurate, the tracking system will provide how many satellites have been located and whether there are any UART communication errors logged.

Additionally, the web interface is a functionality known as RSSI. This feature shows detected Wi-Fi SSIDs within range of the device being tracked and will map them to a specific room number in the database. Other than that, battery levels will continuously be monitored so that service to the device continues to be provided.

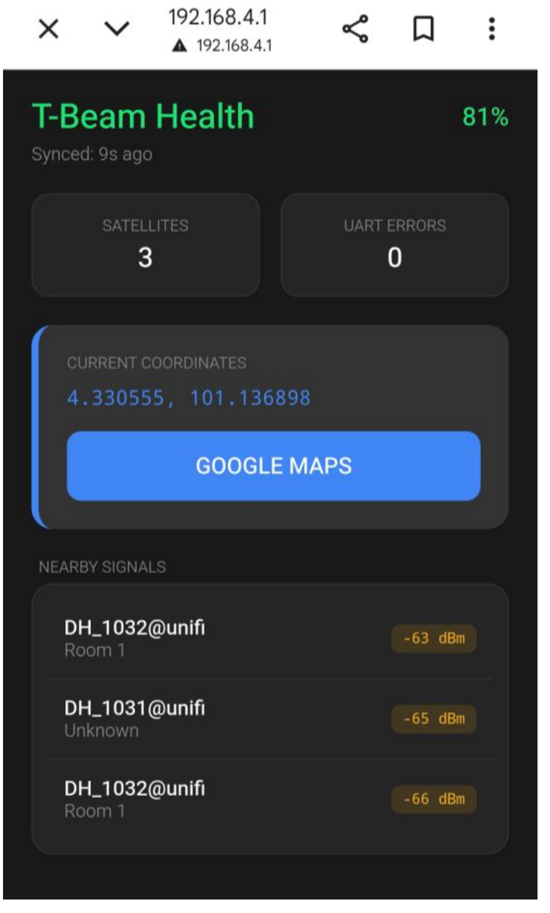

Figure 5.6 TTGO T-beam Web Interface

5.3 Setting and Configuration

The system initialization section provides the metrics needed to initialize the database, install necessary libraries, assign GPIO pins, and implement role-based access control in order to ensure that the system is always available, secure, and usable in the event of an emergency situation.

5.3.1 Raspberry Pi

On the Raspberry Pi, the system acts as the central processing unit of the main station. A dedicated database is in place to hold user registration and security personnel details so that only authorized people can send or receive SOS alerts issued by the station. Also, the Raspberry Pi is set up with the Telegram Bot token so that the main station, mobile app, and database can communicate securely with one another.

```
# ----------------------------
# Telegram config
# ----------------------------
BOT_TOKEN = "8310622848:AAH3jccfW7AekDPT_Amq5AFF1FQBpK26_2I"
ALLOWED_USERS = {
    6579976035: {"name": "Alice", "office": "N101", "gender": "Female"},
    8459857883: {"name": "Security", "office": "D112", "gender": "-"},
}
SOS_RECEIVER = 8459857883
AUTHORIZED_STOP_USER = 8459857883
LOCATION_SENDER = 6579976035
LOCATION_RECEIVER = 8459857883
```

Figure 5.7 Raspberry Pi User Configuration

Furthermore, necessary libraries for GPIO control, networking, and database communication are installed.

Table 5.1 Raspberry Pi Libraries Setting

No	Library Name	Function
1	python-telegram-bot	Used to create and manage your Telegram bot (send messages, receive commands, handle live location, buttons UI)
2	RPi.GPIO	Controls Raspberry Pi GPIO pins (LED, buzzer, push buttons)
3	asyncio	Handles asynchronous operations like sending Telegram messages without blocking
4	python3-venv	Create a virtual environment (clean project setup)
5	threading	Runs background tasks (alarm loop, button monitoring) simultaneously
6	time	Used for delays (e.g., blinking LED, buzzer timing)

The GPIO pins are configured to interface with the SOS button, buzzer, and LED, and to each pin is assigned a corresponding assignment in order to connect to those devices.

```
# ----------------------------
# GPIO setup
# ----------------------------
LED_PIN = 17
BUZZER_PIN = 26
BUTTON_PIN = 27
SECOND_BUTTON_PIN = 22

GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
GPIO.setup(LED_PIN, GPIO.OUT)
GPIO.setup(BUZZER_PIN, GPIO.OUT)
GPIO.setup(BUTTON_PIN, GPIO.IN, pull_up_down=GPIO.PUD_DOWN)
GPIO.setup(SECOND_BUTTON_PIN, GPIO.IN, pull_up_down=GPIO.PUD_DOWN)
```

Figure 5.8 Raspberry Pi GPIO Pin Configuration

5.3.2 TTGO T-beam

The TTGO T-Beam portable tracker is configured with a **database** that stores RSSI values associated with room locations, allowing accurate indoor localization.

```
struct WifiRoom { const char* ssid; const char* room; };
WifiRoom wifiDB[] = {
  {"DH_1032@unifi", "Room 1"}, {"DH_1033@unifi", "Room 2"},
  {"DH_1034@unifi", "Room 3"}, {"DH_1035@unifi", "Room 4"}
};
```

Figure 5.9 TTGO T-Beam RSSI Configuration

The TTGO T-Beam portable tracker is configured with a database that stores RSSI values associated with room locations, allowing accurate indoor localization. Based on predefined RSSI thresholds, the system estimates the user’s proximity to known access points and maps the detected signal to the nearest room location.

Table 5.2 RSSI Thresholds Configuration

RSSI Range (dBm)	Signal Strength	Proximity	Interface Display Colour
$\geq$ -60	Strong	Near	Green
-61 to -80	Moderate	Medium	Amber
< -80	Weak	Far	Red

The necessary libraries for GPS, RSSI scanning, LoRa/Wi-Fi communications, and reading sensors are all included.

Table 5.3 TTGO-T-Beam Libraries Setting

No	Library Name	Function
1	TinyGPS++	Parses GPS data (latitude, longitude, satellites, validity)
2	WiFi	Creates Access Point (AP mode) and scans nearby WiFi networks
3	WebServer	Hosts local web dashboard
4	Wire	I2C communication with AXP192 power management chip (battery reading)
5	HardwareSerial	Enables UART communication with GPS module
6	Arduino Core for ESP32	Provides all ESP32 functions (WiFi, GPIO, WebServer, etc.)

5.3.3 Telegram Bot

The Telegram Bot has been set up to separate between users and security personnel. This bot connects to the database to verify registered users and maintain SOS event. A user can raise an SOS alert with a few easy steps. Whereas, security personnel can see the real-time location of a victim, view detailed information about a victim, and control the fixed station SOS event status. The Telegram Bot has also been programmed to handle message formatting, sending notifications and error messages to allow for smooth operations during emergencies.

5.5 Implementation Issues and Challenges

According to the results of the IoT-based safety system implementation, there are several challenges that could negatively affect the reliability, scalability, and performance of IoT-based safety systems as they scale up.

First and foremost, the communication between the Raspberry Pi and Telegram interface is dependent on a stable Wi-Fi connection. If Wi-Fi is unavailable or inconsistent, there will be the potential for delays in transmitting SOS alerts or receiving responses from the safety system. This suggests the need to explore other methods of communication, such as mobile data or long-range communication technologies that could be used when Wi-Fi is not available in order to continue using the safety system.

The current database is set up for only a specific quantity of registered users, meaning if there are many more users that register, there will be problems with not being able to retrieve data as well as handling data. This means that an upgrade to the database might be necessary to make the IoT-based safety systems work effectively on a much larger scale.

Environmental variables such as physical barriers inside buildings, interference from other transmissions, and signal-to-noise ratio can hinder the accuracy of GPS and RSSI-based location systems. This could eventually lead to the inaccuracy of location information when an emergency response team is needed, particularly when responding to a situation inside a building. Possible upgrades include better calibration methods, additional reference points, or hybrid positioning techniques, which may lead to improvement in the reliability of GPS and RSSI-based location information.

Ultimately, though, despite being functional in lab-like scenarios, significant difficulties still exist when a system is brought into operation; all these issues will need resolution for a functioning/robust/capable enhanced version for use within a practical setting. The primary objectives to improve and maximise performance, and improve reliability, which together should create a much more mature system.

5.6 Concluding Remark

This chapter demonstrated extensively that the IoT-based emergency response system will succeed with a hardware system, software modules, and configuration of the total system. Among the integrated components are the fixed emergency station, the portable GPS-enabled tracker, and the mobile application, which all collaborate together as a complete functional system, providing real-time monitoring, accurate location tracking, and efficient SOS alerts.

The fixed emergency station functions by providing both physical and remote activation for emergencies, and provides immediate visual and audio alerts for an emergency. In addition, the portable GPS-enabled tracker provides real-time GPS and RSSI data for continuous tracking (outdoor) and estimating the location of the user indoors via the use of RSSI location estimates. Similarly, the mobile application and web interface allow security personnel the ability to access real-time location information, view live alerts, and respond to an emergency promptly. The multi-layered design of the System will ensure the continued functionality of the System regardless of how users utilize the System or the environmental conditions in which the System will be utilized.

Although several challenges were identified during implementation, including connectivity issues and variability in the GPS signal of the indoor environments and variability with the RSSI due to environmental interference, all the issues experienced during the implementation were expected issues, and these types of problems occur naturally with IoT-based tracking systems. Overall, the system is providing consistent and reliable performance at expected operating conditions.

Chapter 6
System Testing and Performance Metrics

6.1 System Verification Plan

This chapter describes the testing process for the proposed Women's Safety System. Testing included verification, functional testing, and performance evaluation of the system during a simulated emergency/crisis incident environment, in which to confirm that the fixed station, mobile platform, and portable tracking device performed within the parameters set forth by the project definition and met the requirements of the project. The purpose of the testing is to provide evidence of the reliability, responsiveness, and overall performance of the system in a real-world setting.

Testing activities were designed to ensure that all of the project goals were met. The project's first goal was to design a fixed-location emergency station with an intuitive activation method and alert system. The second goal was to utilize real-time communication and localization technologies (IoT, such as GPS) to provide both Alerting/Requesting Assistance in a real-time manner, as well as an Alerting method with no access point (i.e., activation from a mobile device). The third goal was to develop a remote request for Emergency SOS capability using the mobile platforms. The fourth goal was to determine how well the system performs by simulating the real-world conditions and through usability testing.

The overall testing process includes two major parts: functional test and performance metrics evaluation. The functional tests are designed to ensure that each component function is operating properly according to the design specifications; whereas, the performance metrics evaluation measures the overall system efficiency, accuracy, and precision, and experience related to system response during operational testing.

6.2 Function Testing

The purpose of function testing was to confirm that all components of the proposed system operate as designed and meet operational requirements. Function testing focuses on ensuring that emergency activation mechanisms will work properly, that communications will be reliable, that tracking can be done in real time, and that users will be able to access the system when connected or disconnected. This portion of the testing and evaluation will help determine if the entire project has met its objectives and whether or not the final developed system will provide effective operation for emergency response activities.

6.2.1 Online Function Testing

Online functional testing assesses how well the system works when it is connected to the internet. This portion of the online functional testing focused on communication between a fixed location and the Telegram platform to ensure that the SOS transmission was done correctly, notifications were made, and there was real-time monitoring.

6.2.1.1 Fixed Station

The goal of this type of testing is to ensure that an SOS can be initiated from the fixed location emergency station using the push button activation of an SOS. At the same time, local alerts will be activated, and the proper individuals or entities will be notified in real-time when this SOS has been initiated. This testing will verify the fixed location emergency station, how it is designed, and how well the activation mechanism operates toward achieving the first objective of the project. In addition, it will also evaluate how well the emergency activation mechanism is functioning, achieving the second objective of the project, and appraising the overall performance of the emergency activation mechanism/application system at a simulated emergency.

Testing Procedures:

1. Power on the fixed station (Raspberry Pi).
2. Confirm Telegram Bot is active and connected.
3. Ensure user and security accounts are registered.
4. Press the emergency push button.
5. Observe:
    a. LED activation
    b. Buzzer activation
6. Raspberry Pi wired-connected monitor, showing the station details in terminal
7. Verify security Telegram receives SOS alert.

8. Confirm station information in the alert message.
9. Deactivate alert using authorized security account.

Expected Results:

1. Immediate LED and buzzer activation
2. Successful SOS monitor in Raspberry Pi monitor
3. Successful SOS delivery to Telegram
4. Authorized deactivation only

Actual Results:

The test was executed successfully without issues. Pressing the emergency push button caused the LED to activate and the buzzer to sound immediately, indicating successful SOS detection, and the station details could be monitored in the Raspberry Pi wired-connected monitor

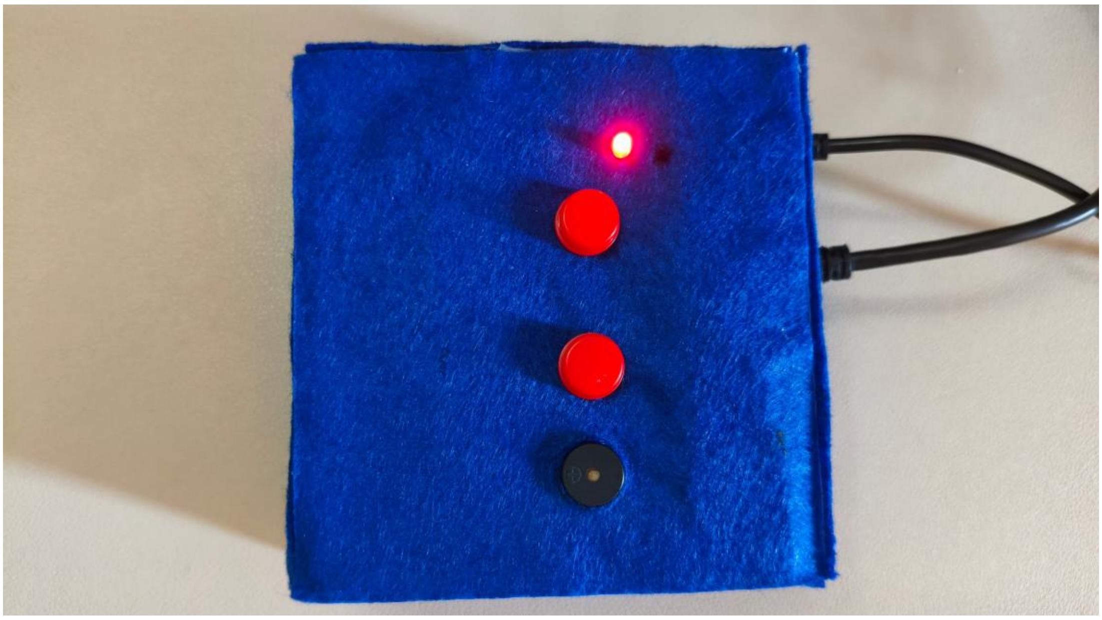

Figure 6.1 LED and Buzzer Activation

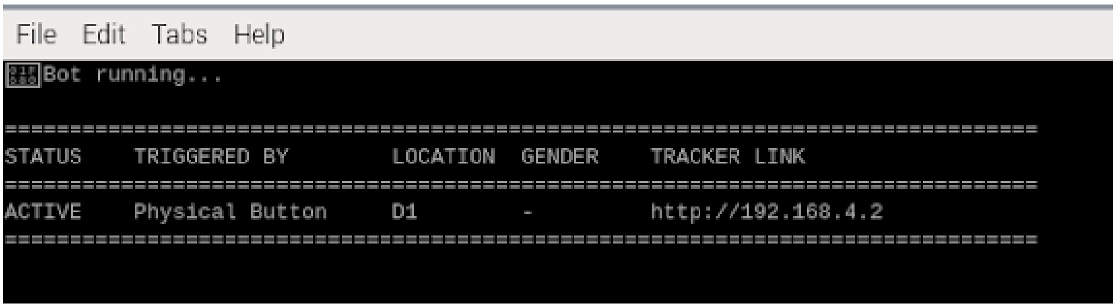

Figure 6.2 Terminal Details Display

At the same time, an SOS notification containing the correct station details was transmitted successfully to security personnel through Telegram.

Figure 6.3 Security Receive SOS from Fixed Station

6.2.1.2 Mobile Platform

The objective of this test is to verify that the fixed-location emergency station can successfully trigger an SOS event through a push button mechanism while activating local alerts and notifying security personnel in real time. This test supports the first project objective by validating the fixed emergency station design and its activation mechanism. It also supports the second and fourth objectives by evaluating communication functionality and overall system performance under simulated emergency conditions.

Testing Procedures:

1. Power on the fixed station.
2. Confirm Telegram Bot is connected.
3. Ensure user and security accounts are registered.
4. Open Telegram Bot.
5. Press “SOS – Sharing Live Location”.
6. Observe:
    a. LED activation
    b. Buzzer activation
7. Raspberry Pi wired-connected monitor, showing the station details in terminal
8. Verify security receives SOS.
9. Confirm correct user details and live location.
10. Deactivate alert using authorized account.

Expected Results:

1. Immediate LED and buzzer activation
2. Successful SOS monitor in Raspberry Pi terminal
3. Successful SOS delivery to Telegram
4. Accurate live location sharing
5. Authorized deactivation only

Actual Results:

According to the specified test protocol, the system was successfully tested under controlled conditions. Upon using the "SOS - Share Live Location", the system was triggered and activated at the fixed site to demonstrate successful detection of an SOS Event.

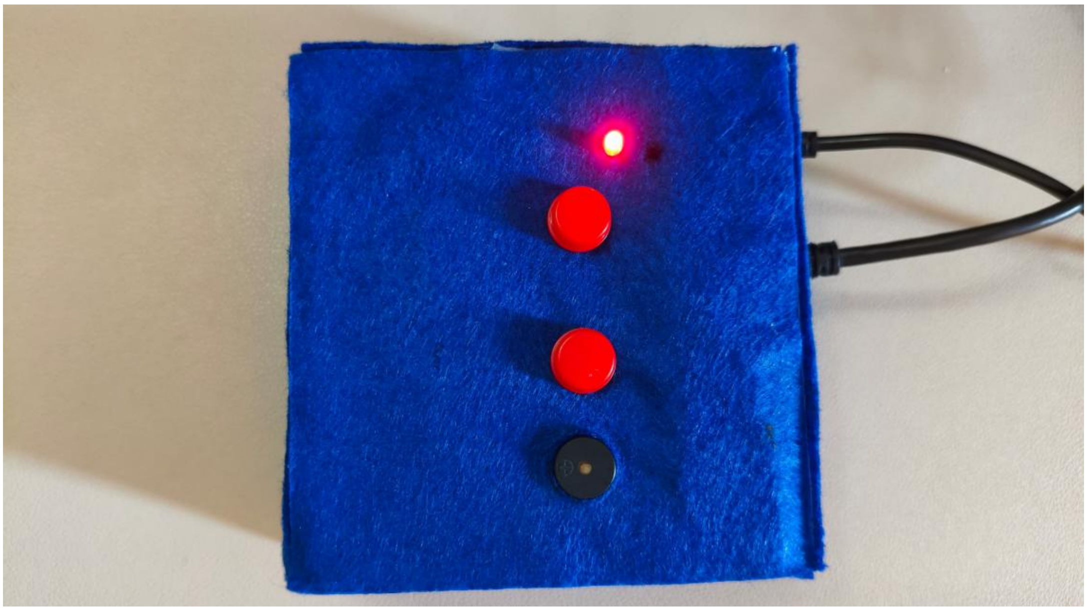

Figure 6.4 LED and Buzzer Activation

In addition, a Telegram SOS alert was sent to security personnel, providing both accurate user information and current user location information in real time, to demonstrate that the system provided real-time user location at the time of an emergency SOS activation.

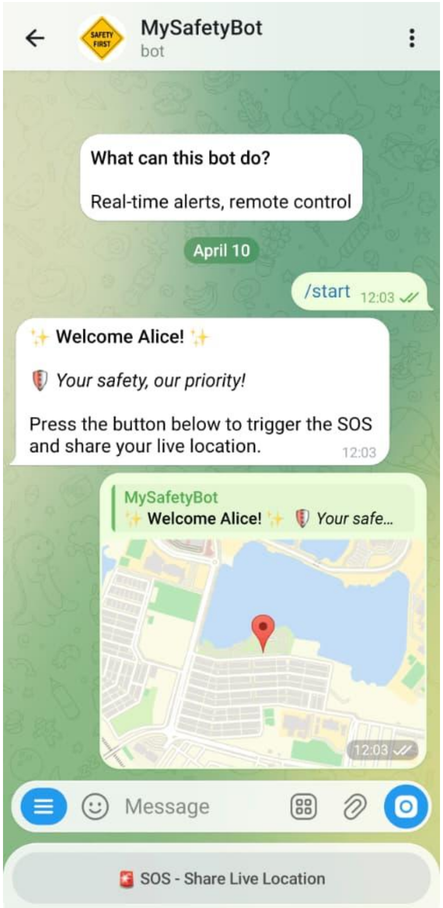

Figure 6.5 User sends SOS

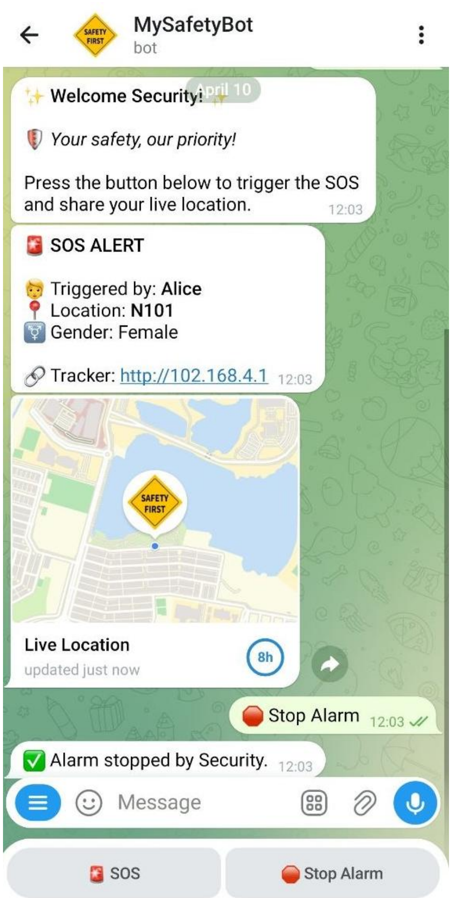

Figure 6.6 Security Receive User's SOS

The overall system operated reliably by providing an effective remote SOS activation and accurate data transfer, as well as proper enforcement of authorization.

6.2.2 Offline Function Testing

Offline function testing determines the ability of a system to provide emergency functions if the system is unable to connect to an Internet source.

6.2.2.1 Fixed Station

The purpose of this test will be to validate that the fixed emergency station can continue to provide the local emergency response functions without being connected to an Internet source. Validating the fixed emergency station and its local response capabilities will support both of the first and fourth project goals, thereby providing operationally reliable emergency response functions in a network outage condition.

Testing Procedure:

1. Power on the fixed station (Raspberry Pi).
2. Ensure user and security accounts are registered.
3. Press the emergency push button.
4. Observe:
    a. LED activation
    b. Buzzer activation
5. Raspberry Pi wired-connected monitor, showing the station details in terminal

Expected Results:

1. Immediate LED and buzzer activation
2. Successful SOS monitor in Raspberry Pi monitor
3. Unable to deactivate until the internet is reconnected or manually turn off the system

Actual Results:

The test was executed successfully without issues. Pressing the emergency push button caused the LED to activate and the buzzer to sound immediately, indicating successful SOS detection, and the station details could be monitored in the Raspberry Pi wired-connected monitor.

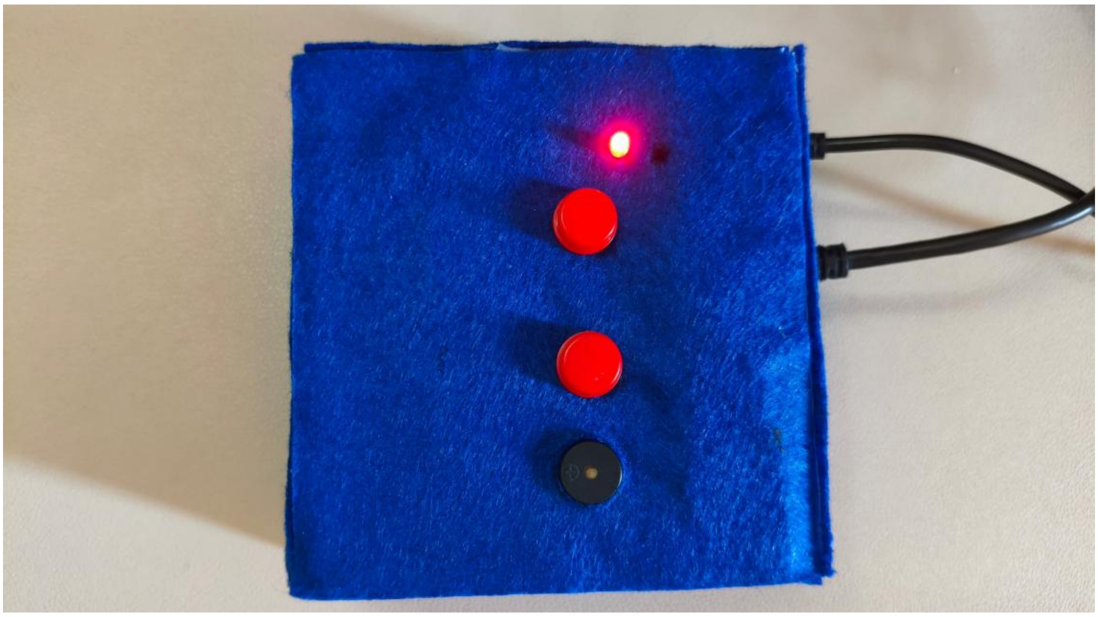

Figure 6.7 LED and Buzzer Activation

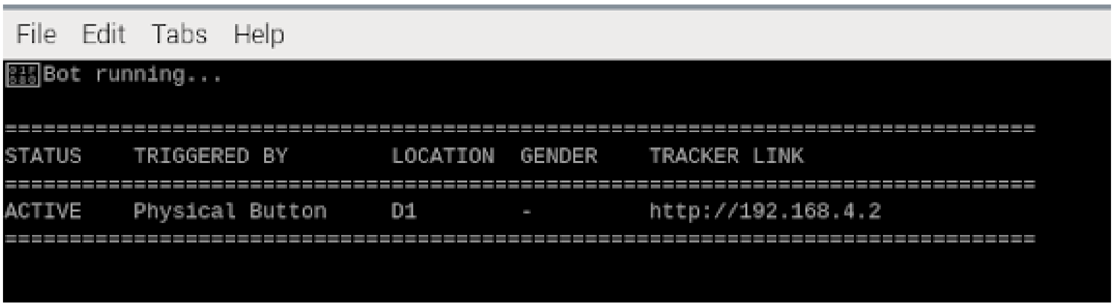

Figure 6.8 Terminal Details Display

The Telegram platform did not receive subsequent notifications while an active SOS alert was ongoing, and it was also unable to stop or deactivate the SOS alert.

6.2.2.2 Portable Tracker

The objective of this test is to verify the standalone operation of the TTGO T-Beam without internet connectivity while maintaining GPS tracking and local monitoring services. This supports the second and fourth project objectives.

Testing Procedure:

1. Power on the TTGO T-Beam and ensure it is connected to a power source.
2. Connect a device (phone/laptop) to the TTGO access point or network.
3. Open the web interface using the TTGO IP address.
4. Observe the displayed data:
    a. GPS coordinates (latitude and longitude).
    b. Google Maps link.
    c. Number of satellites detected.
    d. UART status.
    e. RSSI values and mapped room location.
    f. Battery percentage.
5. Move the tracker to different locations (indoor and outdoor).
6. Observe changes in GPS coordinates and RSSI readings.
7. Monitor the system continuously for a fixed duration.

Expected Results:

1. GPS coordinates update accurately in real time.
2. RSSI values correctly correspond to predefined room locations.

3. Web interface remains accessible and stable.
4. Battery level is displayed correctly.
5. The system provides continuous data without interruption.

Actual Result:

The test was executed without issues according to the test plan. When the TTGO T-Beam was powered on, it established stable operation, transmitting GPS and RSSI data continuously to the web interface while it was running. By using the assigned IP address via a mobile device, the web interface was determined to be accessible via the network, allowing access to the web interface successfully.

Real-time GPS coordinates (latitude and longitude) were displayed accurately through the web interface, along with a hyperlink that brought security to the Google Maps application for location verification. The number of satellites being detected by the system was displayed and updated in real-time as the GPS signal was detected. UART status was monitored during operation and confirmed to remain stable.

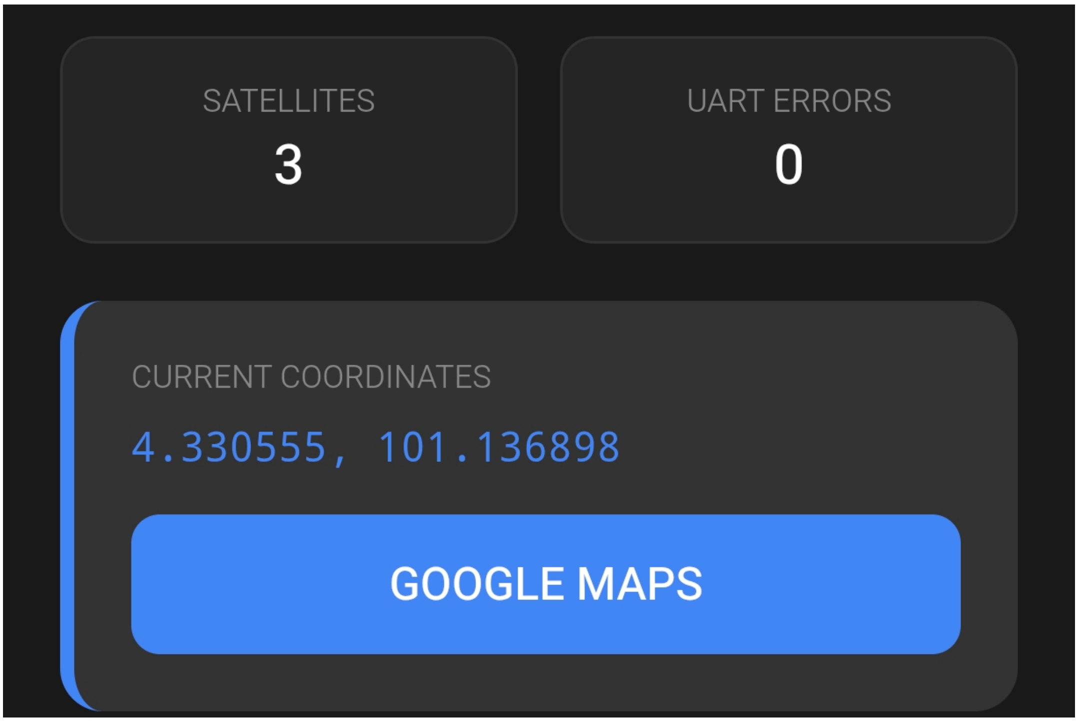

Figure 6.9 GPS Display Interface

In addition, RSSI readings were successfully detected and accurately mapped to the location of rooms within the system's database. The projected battery levels were displayed accurately and updated continuously in real-time.

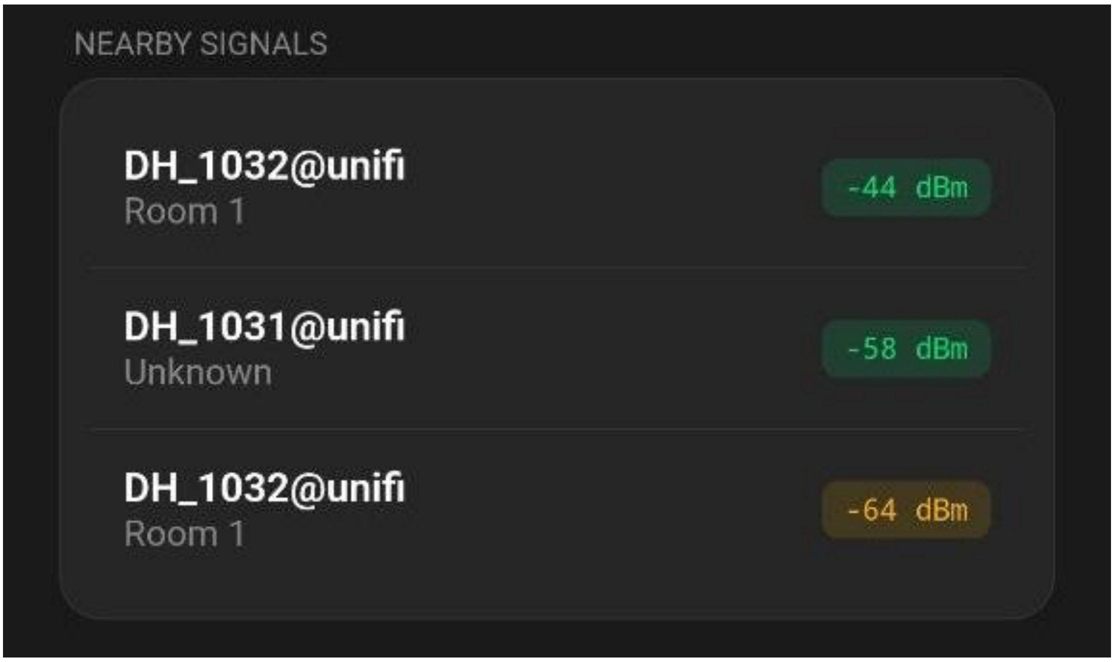

Figure 6.10 RSSI and Room Display Interface

Throughout the test period, all measurements were tracked in real time for each location type, for example, moving from inside to outside by using GPS and RSSI to determine the location change. For the entire test period, data transmission and access to the web interface were uninterrupted, and the tested systems performed consistently.

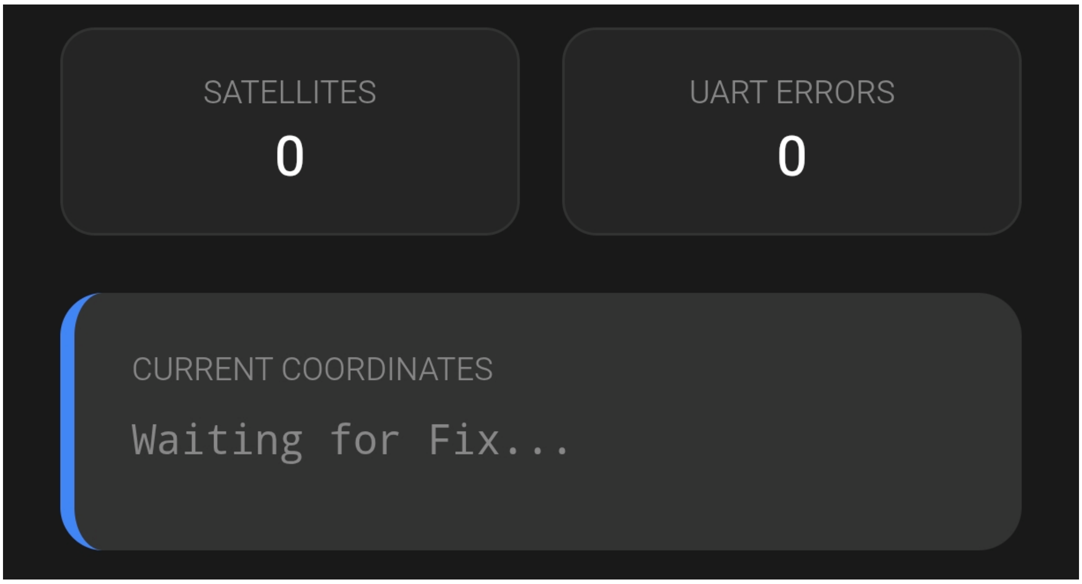

Figure 6.11 GPS Display Interface without Signal

Overall, both the portable device and the web interface operated without error and continuously provided real-time location, GPS signal strength, and system status.

6.3 Performance Metrics

The focus of this section is to evaluate the performance of the IoT-based safety system through the results gathered from functional testing of the system. Performance will be evaluated based on response time and accuracy of the location. Performance will then be analyzed to determine the extent to which the system is effective and reliable throughout multiple operational scenarios.

6.3.1 Fixed Station Performance

The objective of this evaluation is to assess the response speed and reliability of the fixed station during emergency activation. This supports the first and fourth project objectives.

6.3.1.1 Response Time

Response time is defined as the interval between when the SOS button is pressed and when there is a response from the safety system in the form of an LED and Buzzer activation and notification to Telegram. The distance between each device is within 1 meter.

Table 6.1 Fixed Station Physical Alert Response Time

Trial	**Fixed Station Physical Alert (LED and Buzzer) Delays (s)**	
	Triggered by Fixed Station Push Buttons	Triggered by Telegram Interface
1	1.2	1.4
2	1.3	1.5
3	1.1	1.3
4	1.4	1.6
5	1.2	1.4
Average	**1.24**	**1.4**

Response time is significantly faster for both types of SOS Alert, which are both ideal for use in emergencies. The hardware-activated SOS button is slightly faster for SOS

Alert than the network-activated SOS button, which has a small delay due to the time it takes for the network to send the packet. Both methods of SOS Alert provide acceptable response time for real-time notification in the event of an emergency.

6.3.2 Portable Tracker Performance

The objective of this evaluation is to assess tracking accuracy and energy efficiency of the portable device while validating its suitability for continuous emergency monitoring. This supports the second and fourth project objectives.

6.3.2.1 GPS Accuracy

The system performance evaluation assesses the performance of this GPS-based portable tracking device in various environments, such as indoors, near a window, and outdoors. Performance testing will focus on establishing stable GPS positioning.

Table 6.2 GPS Performance Fix Time

Trial	Condition	GPS Fix Time (min)	Stability
1	Indoor	Unable to obtain GPS fix	No satellite signal detected
2	Near Window	5	Moderate
3	Outdoor	2	Fast and stable

The performance of the GPS is highly affected by environmental conditions. When used in an indoor environment, the GPS is unable to receive a GPS signal because satellite signals are blocked by physical structures. When an indoor GPS unit is located near a window, there is partial exposure to satellites, meaning there is some ability to establish a GPS fix. This process requires approximately five minutes.

In contrast to the poor performance of GPS indoors, when a GPS unit is used outdoors, it will establish a stable GPS fix within two minutes. When the device has an unobstructed line of sight to the satellites outside, the GPS unit performs significantly better compared to indoor use. Accordingly, the performance of the GPS will depend on the environment used to perform the tracking, and thus, providing reliable performance when used in outdoor environments, but limits performance in indoor environments due to environmental conditions.

6.3.2.2 RSSI Localization Accuracy

The accuracy of the RSSI-based mapping for identifying a device’s location is investigated in this section. The system classifies the locations by comparing the Wi-Fi signal strengths that were set in advance and held in a database as they arrive at the device.

Table 6.3 RSSI-Based Location Detection Comparison

Trial	Actual Location	Detected Location	Result
1	Room 1	Room 1	Correct
2	Room 2	Room 2	Correct
3	Room 3	Unknown	Incorrect
4	Room 4	Room 3	Slight Error

The RSSI-based localization system is found to accurately identify predefined room locations to an acceptable degree of accuracy. The device successfully maps Wi-Fi signals to their corresponding database entry in most cases where the Wi-Fi signal strength was known. The device receiver will classify a location as ‘unknown,’ however, when there are other Wi-Fi signals.

Further, the incorrect classification of rooms to a limited extent (e.g., Room 3 detected as Room 2) could be a result of fluctuations in signal strength due to dimament, blockage, interference, or environment. Despite the potential inaccuracies, the system is effective for general indoor positioning at the room level for most purposes.

6.3.2.3 Battery Consumption

The battery performance is one of the key factors in how long the system will operate under real-world conditions. For the system, we will be using a 4200 mAh 18650 Li-Ion battery as the primary source of electrical power for the TTGO T-Beam system.

In order to have adequate theoretical analysis, I will be using the average current drawn by each of the components in the system: the ESP32, GPS, Wi-Fi/Mobile Network Scanning & Web/IP updates.

Table 6.4 Portable Tracker Average Current Consumption

Parameter	**Current**
TTGO T-beam base operation	100mA
GPS module	30mA
RSSI scanning	50mA
Web/IP update	40mA
Total	**220mA**

The battery percentage drop is calculated using the following formula:

$$Drop\ \% = \frac{Current\ \times Time}{Battery\ Capacity} \times 100$$

For a 2-hour operating interval:

$$Drop\ \% = \frac{220mA\ \times 2}{4200} \times 100$$

$$Drop\ \% = 10.48\ \%$$

The calculated result shows that approximately 10.48% of the total battery capacity will be depleted after about every two (2) hours of constant operation of the system, which supports GPS tracking, wireless scanning, and transmitting data.

Table 6.5 Battery Consumption Analysis Over Time

Time Interval (Hours)	0	2	4	6	8	10	12	14	16	18	20
Expected Battery Percentage	100	89.52	79.04	68.56	58.08	47.6	37.12	26.64	16.16	5.68	0
Actual Battery Percentage	99	73	69	55	38	12	0	0	0	0	0

Results suggest battery life is significantly shorter than predicted under realistic use conditions because the actual rate of use during actual use shows 10.48% drained every second hour and therefore equals about a 19-hour life. Yet with all the measuring being complete, the user experiences 11–12 hours maximum use for these types of models.

Thus, it can be deduced that the real-time consumption on the portable tracker is much higher than what was predicted based on theoretical estimation. When performing the original calculations, it was assumed that the average current draw is similar to 220 mA. Since the actual average draw probably exceeds the original calculations during normal operation, this will also affect how long this particular design can provide a power source for its intended application.

Several different variables will account for how quickly the battery drains as measured by users of said device. Usage with continuous GPS receivers has higher power requirements than originally thought, primarily when signal strength is considered minimal due to delayed acquisition times once the satellite signal becomes reliable. Additionally, constant scanning of Wi-Fi RSSI levels, continual web/IP connectivity activities, processor workload, voltage conversion losses, and even fluctuation(s) in wireless network activity may contribute to the discrepancy found in the actual measurements of energy used while using the portable tracker.

6.4 Objective Evaluation

Functional testing and performance testing demonstrate clearly that the project objectives have been met to a significant degree. The extent to which the four project objectives were achieved will be described in terms of testing results and performance results for each specific objective.

Objective 1: To create an emergency station with user-friendly alert and activation functions.

First, the project objective concerning the development of an emergency station was completed. The emergency station includes a push button, LED indicator, and buzzer to provide immediate activation of the emergency station and an audible local alert when the emergency station has been triggered. Before functional testing, the emergency station's ability to respond to both push button and remote online activation were validated. The station is reliable and provides an intuitive way to activate an emergency response that would satisfy public safety applications.

Objective 2: To utilize IoT technologies like GPS to establish real-time communication and location tracking.

The second project objective relating to supporting real-time communication and localization is achieved by providing a two-way communication link and GPS/RSSI-based location tracking. The portable tracker continually transmitted data to the tracking and communication system via the web-based interface, allowing for successful communication of all emergency notifications. Although GPS tracking does not work particularly well indoors from an accuracy standpoint, and the portable tracker's battery lasts longer than anticipated, the overall objective of providing IoT devices for real-time communication and localization was achieved.

Objective 3: To incorporate a mobile platform-based remote SOS request option for increased accessibility.

Third, the third project objective to enable users to activate SOS notifications is completely fulfilled. Users can create an SOS alert remotely through the Telegram app, which permits direct entry of their exact location with respect to the fixed emergency stations. The remote SOS activation workflow greatly enhances the accessibility of emergency services to any user when the user has no direct access to the fixed emergency stations.

Objective 4: To assess system performance in a realistic setting using usability testing and simulations.

Functional testing and performance evaluation have confirmed that the system meets its intended goals. Multiple scenarios were evaluated for performance with respect to their online and offline capacities, GPS and RSSI performance, response times, and battery consumption. The data collected indicates that the system reliably functions as designed when subjected to simulated emergency conditions, and that limitations exist relative to the system that could be addressed through enhancements in the future.

All project objectives have been realized, and the results of the testing confirm that the system operates properly, is user-friendly, and meets all specifications needed to provide a means of enhancing a woman's personal safety.

6.5 Concluding Remark

Completed assessments were performed on the women’s safety system. The system is fully functional in both online and offline modes and meets the project requirements for emergency alerting, communications, and locational needs.

Functionality testing of the fixed station was successfully performed with both the SOS push button and the Telegram mobile platform. The response time to activate the LED and Buzzer at the fixed station was all within the allowable timeframes outlined for testing, and the SOS notification generated by the fixed station successfully reached the security personnel. Therefore, this verifies that the system provides emergency alerting in an expedient fashion, regardless of the SOS activation method.

The fixed station provides local emergency response operations without an established or lost network connection and continues to operate as an alert to the end user when the internet connection is not available. The portable tracker also operates independently at the Access Port and Web Interface and continually transmits GPS coordinates, Room Mapping (RSSI), and Battery Monitoring without requiring a network connection.

Testing has proven that fixed-station response times are suitable to be used within the emergency response system as an emergency response method. A physical push button provided a faster response time than using Telegram to initiate activation because it did not depend as much on the network.

GPS testing outside worked well, but not as well indoors near windows because of little to no reliable satellite connections. RSSI was a good way to determine which room of a building someone was in; however, mistakes occurred primarily because physical obstructions hindered the accuracy of measurements.

The performance of the battery in the portable tracker indicates that although the theoretical model predicted an average operating time of 19 hours, in practice, the average operating time was only 11-12 hours of continuous use. There is a significant difference in the theoretical battery drain versus actual battery drain due to consistently utilizing GPS, RSSI scanning, and transmission of communications to/from other devices, which contributes to the burden on battery systems.

Chapter 7
Conclusion and Recommendation

7.1 Conclusion

The project has achieved its intended outcome, as it successfully provides dependable, scalable, and always-available for women, primarily in office and on campuses, through the use of IoT technology, utilizing real-time monitoring capabilities, tracking methods and alerting measures has created an effective solution to help women be more aware of potential dangers to their safety or themselves, enabling them to get emergency assistance when needed through fast activation of an SOS signal, accurate tracking of their locations and reliable communication between users and security personnel, while utilizing both hardware and software systems.

The completion of this project has been demonstrated by the functioning of the overall system through the completed implementation and testing. The fixed station provides SOS signals from both physical push button activation and mobile phone activation; The portable tracking device provides real-time data using GPS for outdoor location estimation and for indoor location estimation of the user using RSSI signal strength. The alerting function through the use of the Telegram application will allow for the immediate notification of security personnel when someone needs emergency assistance, which should result in improved response times when someone requires immediate assistance.

Although there are limitations when utilizing the overall system, such as indoor GPS deficiency, occasionally fluctuating RSSI readings, the system is still operational, reliable, functional, and meets the established requirement for the system to work properly to provide a viable safety option for everyone. Therefore, this project is complete because it has accomplished its objectives of providing a low-cost, scalable, and user-friendly safety option that promotes improved community safety, especially for women living in or attending school on campuses.

7.2 Recommendation

To improve the system's performance, reliability, and overall functionality of the proposed Internet of Things (IoT) based Safety System, several recommendations have been developed based on limitations identified during the development and testing process and are intended to increase the capability of the system in terms of communication, monitoring, and practical use in the real world.

Firstly, perform a redesign of the system architecture utilising a centrally located and integrated web-based platform that allows the user to communicate directly with their portable tracker and the fixed station using a worldwide web-based platform rather than through Telegram as a communication medium. This will help alleviate the challenges of internet dependency and interruption of communications that will occur when the user is operating the system offline. A centralised web-based system would also improve the scalability of the system and provide more efficient control over and monitoring of all devices that are connected to the system through a single user interface.

In addition, an enhancement by performing to the portable tracker by adding additional biometric sensors, such as a heart rate sensor, to the portable tracker. The enhancement of the portable tracker will allow the security to continually monitor the user's physical state to help identify and more accurately predict whether or not the user is in an emergency. By combining physiological data with GPS location data and RSSI-based location technologies, the system can become more efficient at identifying distress or emergency conditions.

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APPENDIX

A.1 Raspberry Pi Sample Code

```
async def live_location_handler(update: Update, context:
ContextTypes.DEFAULT_TYPE):
    global alarm_active, alarm_triggered_by
    user_id = update.effective_user.id
    if user_id != LOCATION_SENDER:
        return

    location = update.message.location
    if location is None:
        return

    user_info = ALLOWED_USERS.get(user_id, {})
    triggered_name = user_info.get("name", f"User {user_id}")
    office = user_info.get("office", "N/A")
    gender = user_info.get("gender", "-")
```

A.2 TTGO T-beam Sample Code

```
void updateBattery() {
  Wire.beginTransmission(AXP192_ADDR);
  Wire.write(0x78); // Battery voltage register
  Wire.endTransmission();
  Wire.requestFrom(AXP192_ADDR, 2);

  if (Wire.available() >= 2) {
    uint16_t v = Wire.read() << 4 | (Wire.read() & 0x0F);
    float volt = v * 1.1 / 1000.0;
    // Map 3.3V-4.2V to 0-100%
    batteryPercentage = (volt - 3.3) / (4.2 - 3.3) * 100;
    if (batteryPercentage > 100) batteryPercentage = 100;
    if (batteryPercentage < 0) batteryPercentage = 0;
  }
}
```

A.3 Raspberry Pi GPIO Alternate Functions Datasheet

GPIO	Default Pull	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5
0	High	SDA0	SA5	PCLK	SPI3_CE0_N	TXD2	SDA6
1	High	SCL0	SA4	DE	SPI3_MISO	RXD2	SCL6
2	High	SDA1	SA3	LCD_VSYNC	SPI3_MOSI	CTS2	SDA3
3	High	SCL1	SA2	LCD_HSYNC	SPI3_SCLK	RTS2	SCL3
4	High	GPCLK0	SA1	DPI_D0	SPI4_CE0_N	TXD3	SDA3
5	High	GPCLK1	SA0	DPI_D1	SPI4_MISO	RXD3	SCL3
6	High	GPCLK2	SOE_N	DPI_D2	SPI4_MOSI	CTS3	SDA4
7	High	SPI0_CE1_N	SWE_N	DPI_D3	SPI4_SCLK	RTS3	SCL4
8	High	SPI0_CE0_N	SD0	DPI_D4	-	TXD4	SDA4
9	Low	SPI0_MISO	SD1	DPI_D5	-	RXD4	SCL4
10	Low	SPI0_MOSI	SD2	DPI_D6	-	CTS4	SDA5
11	Low	SPI0_SCLK	SD3	DPI_D7	-	RTS4	SCL5
12	Low	PWM0	SD4	DPI_D8	SPI5_CE0_N	TXD5	SDA5
13	Low	PWM1	SD5	DPI_D9	SPI5_MISO	RXD5	SCL5
14	Low	TXD0	SD6	DPI_D10	SPI5_MOSI	CTS5	TXD1
15	Low	RXD0	SD7	DPI_D11	SPI5_SCLK	RTS5	RXD1
16	Low	FL0	SD8	DPI_D12	CTS0	SPI1_CE2_N	CTS1
17	Low	FL1	SD9	DPI_D13	RTS0	SPI1_CE1_N	RTS1
18	Low	PCM_CLK	SD10	DPI_D14	SPI6_CE0_N	SPI1_CE0_N	PWM0
19	Low	PCM_FS	SD11	DPI_D15	SPI6_MISO	SPI1_MISO	PWM1
20	Low	PCM_DIN	SD12	DPI_D16	SPI6_MOSI	SPI1_MOSI	GPCLK0
21	Low	PCM_DOUT	SD13	DPI_D17	SPI6_SCLK	SPI1_SCLK	GPCLK1
22	Low	SD0_CLK	SD14	DPI_D18	SD1_CLK	ARM_TRST	SDA6
23	Low	SD0_CMD	SD15	DPI_D19	SD1_CMD	ARM_RTCK	SCL6
24	Low	SD0_DAT0	SD16	DPI_D20	SD1_DAT0	ARM_TDO	SPI3_CE1_N
25	Low	SD0_DAT1	SD17	DPI_D21	SD1_DAT1	ARM_TCK	SPI4_CE1_N
26	Low	SD0_DAT2	TE0	DPI_D22	SD1_DAT2	ARM_TDI	SPI5_CE1_N
27	Low	SD0_DAT3	TE1	DPI_D23	SD1_DAT3	ARM_TMS	SPI6_CE1_N

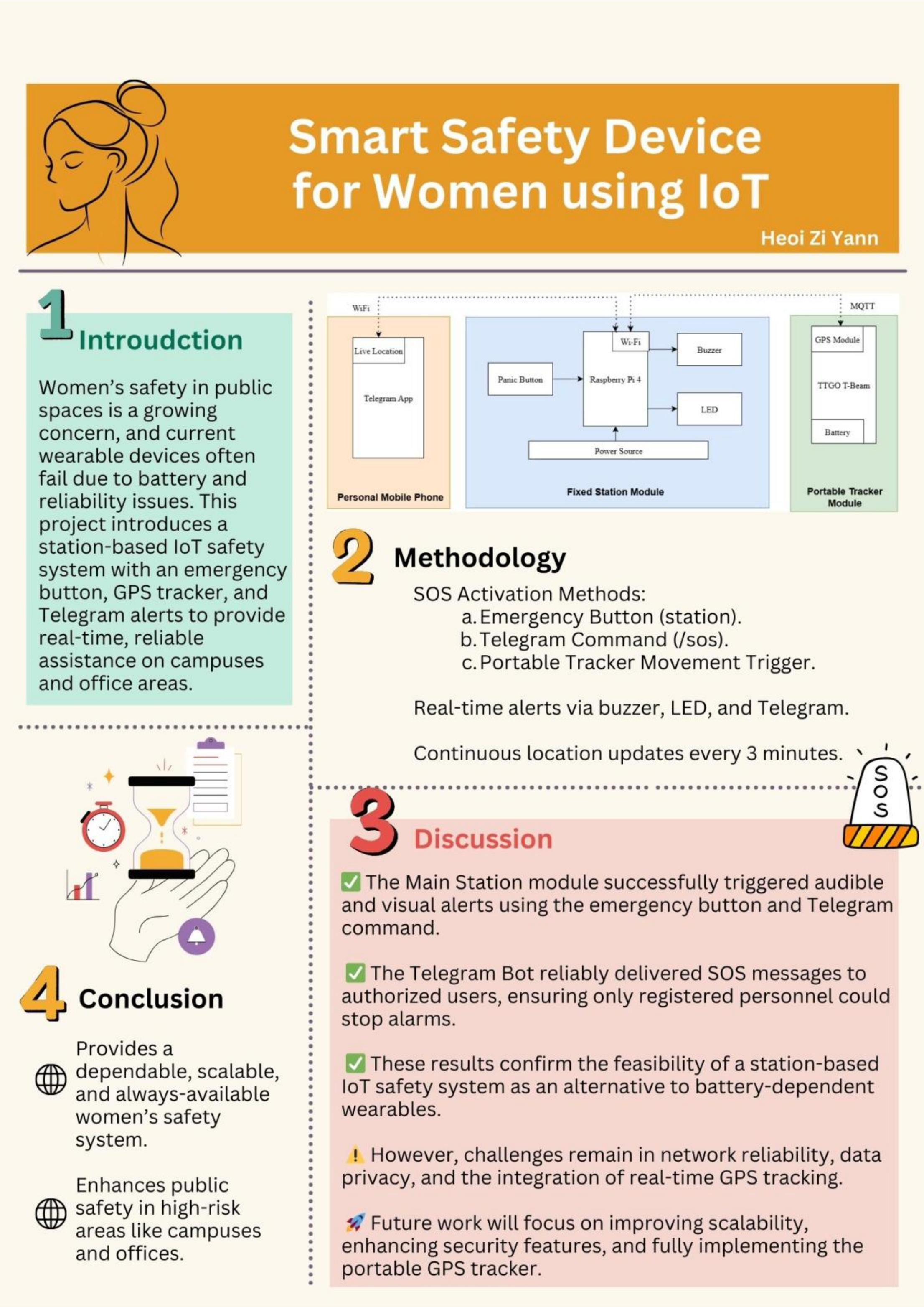
A.4 TTGO T-beam Default Board Configuration

Function	GPIOs	Remarks	Configuration
BUTTON0	GPIO38	low active	
ADC	GPIO0, GPIO2, GPIO4, GPIO13, GPIO25, GPIO32, GPIO33, GPIO35, GPIO36, GPIO39		ADC Channels
DAC	GPIO25		DAC Channels
PWM_DEV(0)	GPIO14, GPIO0, GPIO2, GPIO25		PWM Channels
I2C_DEV(0):SDA	GPIO21		I2C Interfaces
I2C_DEV(0):SCL	GPIO22	I2C_SPEED_FAST is used	I2C Interfaces
SPI_DEV(0):CLK	GPIO5	VSPI is used	SPI Interfaces
SPI_DEV(0):MISO	GPIO19	VSPI is used	SPI Interfaces
SPI_DEV(0):MOSI	GPIO27	VSPI is used	SPI Interfaces
SPI_DEV(0):CS0	GPIO18	VSPI is used	SPI Interfaces
UART_DEV(0):TxD	GPIO1	Console (configuration is fixed)	UART interfaces
UART_DEV(0):RxD	GPIO3	Console (configuration is fixed)	UART interfaces
UART_DEV(1):TxD	GPIO34	GPS (configuration is fixed)	UART interfaces
UART_DEV(1):RxD	GPIO12	GPS (configuration is fixed)	UART interfaces

A.5 Telegram Configuration

No	Telegram ID	Position	Access
1	6579976035	User 1	1. Allow to receive SOS notification 2. Allow the alarm to stop. 3. Allow to receive live location
2	8459857883	Security	1. Allow to send SOS notification with live location 2. Allow to send live location
3.	Other	Other	1. No access is allowed

POSTER


Smart Safety Device for Women using IoT
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1 Introudction
Women's safety in public spaces is a growing concern, and current wearable devices often fail due to battery and reliability issues. This project introduces a station-based IoT safety system with an emergency button, GPS tracker, and Telegram alerts to provide real-time, reliable assistance on campuses and office areas.
WiFi
Live Location
Telegram App
Personal Mobile Phone
Wi-Fi
Buzzer
Panic Button
Raspberry Pi 4
LED
Power Source
Fixed Station Module
MQTT
GPS Module
TTGO T-Beam
Battery
Portable Tracker Module
2 Methodology
SOS Activation Methods:
a. Emergency Button (station).
b. Telegram Command (/sos).
c. Portable Tracker Movement Trigger.
Real-time alerts via buzzer, LED, and Telegram.
Continuous location updates every 3 minutes.
SOS
3 Discussion
✅ The Main Station module successfully triggered audible and visual alerts using the emergency button and Telegram command.
✅ The Telegram Bot reliably delivered SOS messages to authorized users, ensuring only registered personnel could stop alarms.
✅ These results confirm the feasibility of a station-based IoT safety system as an alternative to battery-dependent wearables.
⚠️ However, challenges remain in network reliability, data privacy, and the integration of real-time GPS tracking.
🚀 Future work will focus on improving scalability, enhancing security features, and fully implementing the portable GPS tracker.
4 Conclusion
Provides a dependable, scalable, and always-available women's safety system.
Enhances public safety in high-risk areas like campuses and offices.