Smart Safety cum Fitness Band for Women

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ABSTRACT

In this paper, an innovative wearable device is designed for women to enhance personal safety and health monitoring. An ESP32 microcontroller integrates a SpO2 sensor, heart rate monitor, and temperature sensor to track vital health parameters in real-time. The band has two buttons, namely an emergency button and a safe button, respectively. When the emergency button is pressed, it sends an alert with health data and live location to pre-defined contacts via Telegram. If a Safe Button is pressed, it will notify contacts that the user is safe.

Using ESP32's Wi-Fi, an optional GPS module for accurate location tracking, the device ensures timely assistance. With a rechargeable battery and compact design, the band offers portability, comfort, and continuous use, combining health tracking with emergency response for enhanced safety and peace of mind.

Keywords: Smart band, Women safety, SpO2, ESP32

1. INTRODUCTION

The Global adoption of wearable fitness activity trackers has grown significantly, with penetration rising from 2.29% in 2020 to an estimated 5.55% in 2025, demonstrating increasing consumer acceptance and reliance on these devices for monitoring health and safety. Women have slightly higher usage rates of wearable fitness and wellness technology than men in key markets such as the United States, affirming a significant target demographic for the Women Safety Band. These market insights underscore the strong demand and vast potential for a combined safety and fitness band designed specifically for women, leveraging real-time health data and emergency alert features to meet growing consumer needs.

Growing safety concerns for women especially those traveling alone or in vulnerable situations, make the need for innovative protective solutions more urgent than ever. Although some devices offer one or two of the desired features, such as health monitoring, GPS tracking, or personal emergency alerts, there is currently a lack of widely available wearables that fully integrate all of them into a single seamless device. Women often require immediate assistance or the ability to alert trusted contacts during emergencies and simultaneously monitor vital health parameters such as heart rate, blood oxygen saturation, and body temperature in real time. Many existing products are limited in functionality, bulky, or do not provide essential real-time tracking or communication, particularly in urgent scenarios. This project aims to develop a wearable safety band that integrates emergency alert systems, health sensors, real-time geolocation tracking, and seamless communication, ensuring immediate assistance while promoting overall health and security.

The integration of Internet of Things (IoT) and sensor technologies into wearable devices has led to the development of smart safety and fitness bands specifically designed to enhance the security and well-being of women. IoT-based smart safety and fitness bands for women represent a promising intersection of technology and personal security, offering real-time monitoring, rapid emergency response, and integrated health tracking. Recent advances include the use of physiological sensors (e.g. pulse, temperature, EMG), GPS tracking, and wireless communication modules to detect threats and trigger rapid responses, such as sending SOS messages with location data to trusted contacts or authorities. Smart safety bands for women typically integrate multiple sensors (pulse, temperature, vibration, EMG) with IoT modules (e.g., WiFi, GSM, GPS) to enable real-time monitoring and emergency response [1] - [5]. Devices like the FemmeBand utilize electromyographic sensors and heartbeat monitoring to detect distress signals, triggering automated SOS alerts with location data [2]. Many systems are designed for continuous health monitoring, combining safety and fitness functionalities [1], [3], [5]. Systematic reviews highlight the growing adoption of multi sensor approaches, machine learning algorithms for threat detection, and the need for user-friendly, reliable, and privacy-conscious designs [3], [4]. Despite significant progress, challenges remain in terms of device accuracy, power management, data security, and minimizing the need for user intervention during emergencies [4], [6]. This review synthesizes the latest research on the design, functionality, and impact of IoT-enabled smart bands for women's safety and fitness, drawing on both technical and user-centered perspectives.

Pulse-rate and pressure sensors are the most widely used, often combined with GPS and GSM modules for

alert transmission [1], [2], [4]. Advanced systems leverage wireless body area networks (WBANs) and cloud integration for robust data collection and communication [2], [6]. The use of machine learning algorithms (e.g., logistic regression, decision trees) is increasing for threat detection and reducing false alarms [4]. User-centric design is critical for adoption, with an emphasis on ease of use, minimal interaction required during emergencies, and reliable connectivity [3], [4], [5]. Privacy and data security remain significant concerns, especially given the sensitive nature of health and location data [4], [6]. Power management and device durability are also highlighted as ongoing challenges [4], [6]. There is a need for improved auto-activation features, better sensor fusion, and enhanced machine learning models to increase reliability and reduce user burden [2], [4]. While the field is advancing rapidly, especially with the integration of machine learning and cloud-based analytics, further research is needed to address gaps in auto-activation, data security, and user adoption [3], [4], [6]. In [7], a Wearable sleeve is introduced for physiotherapy assessment. This work discusses how these methods can improve patient assessment, personalize therapy, and support adaptive interventions.

An IoT-based wristband that continuously monitors pulse, temperature, and vibration. The device updates this information to well-wishers via a mobile application, providing real-time health and safety status. The system is designed to be accessible to women, children, and physically challenged individuals, offering a user-friendly interface and reliable alert mechanisms [1]. In [8], the authors present the smart safety band 'ResQ', which integrates multiple sensors with a microcontroller to monitor heart rate and detect falls. The device is designed to be lightweight and discreet, reminding one of a fitness band. Upon detecting a sudden spike in heart rate or a fall, the system automatically sends an alert with user details and location to emergency contacts and services if it is not canceled within 30 seconds. In [9], the authors propose an IoT-based protective system that takes advantage of artificial intelligence and smart sensors to enhance women's safety. The system is designed to detect abnormal physiological or situational cues using AI algorithms, enabling proactive emergency detection. It integrates real-time data collection and analysis, allowing immediate alerts to be sent to authorities or trusted contacts. A cloud server-enabled IoT smart wrist band for women's protection. The device integrates a pulse oximeter, pressure sensor, and sound detector. It activates when abnormal pressure (e.g., someone is grabbing the user's hand) or abnormal pulse SpO2 readings are detected. Data is transmitted to a cloud server via Wi-Fi, enabling remote monitoring and immediate notification to the victim's home or emergency contacts. The performance of the system is evaluated using real-time sensor outputs and cloud integration [11].

IoT-based safety device for women provides security

through fingerprint-based connectivity, automatically alerts nearby people and police, and features a shockwave generator for first-hand safety [17]. The smart band/watch can protect women by reporting potential dangers, providing location, body posture, pulse rate, and other information to help authorities find victims and prevent crime [18]. A wearable wrist band that uses GPS, GSM, IoT, and neurostimulator to provide women with safety alerts and can be passed on anywhere [20]. The IoT-based smart bracelet for women security provides a low-cost, user-friendly solution for ensuring their safety and independence in public places [21]. This IoT-based smart band can enhance the security and safety of women in India by tracking their location, generating electric shocks, and sending emergency messages to authorities [23].

The authors in [10], describe a smart wearable device that utilizes IoT for women's safety. The device incorporates sensors to monitor vital signs and environmental conditions and is capable of sending real-time alerts through IoT connectivity. The system emphasizes ease of use and portability, ensuring that women can discreetly carry the device. Alerts are triggered either manually or automatically based on sensor data, and notifications are sent to preregistered contacts and authorities. Most proposed systems utilize microcontrollers such as Arduino or Raspberry Pi as the central processing unit, communicating with a variety of sensors, such as heartbeat, temperature, motion, pressure, and sometimes EMG, to monitor physiological and situational parameters [1], [2], [8], [12], [22]. These sensors enable manual and automatic emergency detection, with some systems activating alerts based on abnormal vital signs or sudden movements [8], [2], [12], [23]. IoT connectivity is achieved through modules such as GSM, Wi-Fi, Bluetooth, and cloud platforms, allowing real-time transmission of alerts and location data to emergency contacts, police, or cloud servers. GPS modules are commonly used for precise location tracking, while GSM modules facilitate SMS or call-based alerts [1], [8], [11], [12], [22], [24].

Several designs incorporate self-defense mechanisms such as neuro stimulators or shock circuits to deter attackers, as well as loud buzzers or alarms to attract attention [12], [20], [22]. Advanced models include cameras and microphones for evidence collection, capture images or audio during incidents [13], [14],[19], [22], [24]. Beyond safety, many bands offer continuous health monitoring, tracking parameters such as heart rate, SpO2, temperature, and body posture. Data are often uploaded to cloud platforms for remote monitoring and fitness tracking [1], [3], [11], [15], [16]. Some systems use sensor fusion and outlier detection algorithms to distinguish between normal and emergency states [2], [8], [19]. Manual activation using panic buttons is standard, but automation is increasingly emphasized. Systems can trigger alerts based on sensor thresholds, gesture recognition (e.g. EMG-based hand signals), or
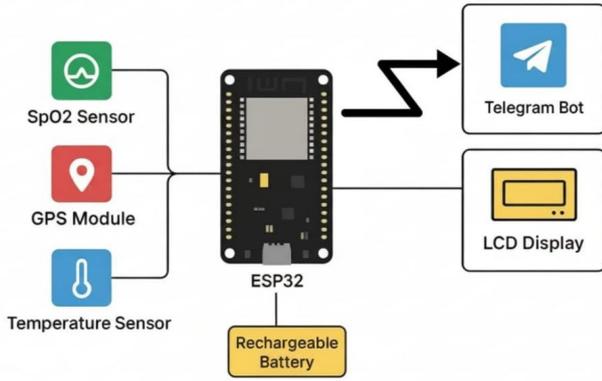
Fig. 1: *Proposed Block Diagram.*

voice commands, ensuring protection even if the user is incapacitated [2], [8], [13], [19]. While primarily designed for women's safety, many solutions are adaptable for children and the elderly, providing location tracking and health monitoring for vulnerable groups [2], [3]. Geo-fencing features notify guardians if users move outside predefined safe zones [14].

Taking into account all challenges, the objective of this project is to develop a compact and portable wristband that seamlessly integrates personal safety and fitness tracking functions. Using IoT technology, the device will enable real-time communication of health data and location during emergencies. It will feature a SpO2 sensor to monitor blood oxygen saturation and heart rate, along with a one-wire temperature sensor for accurate body temperature measurement. The wristband will include an LCD dis- play to visualize health parameters and device status in real time, while an intuitive interface with two push buttons will facilitate emergency alerts and notifications. In addition, the device will enable the seamless transmission of health data and location to emergency contacts through a Telegram chatbot. Designed to be energy efficient and portable, the wristband will be powered by a rechargeable battery. This solution aims to provide a reliable and user-friendly band to enhance personal safety and proactive health tracking, while fostering the adoption of wearable technologies to address the safety challenges faced by women.

Despite progress, research gaps remain in auto activation of alerts, long-term user studies, privacy preserving data architectures, and integration with broader safety and healthcare systems.

2. MATERIALS AND METHODOLOGY

A comprehensive block diagram is used to show the interconnections between the components, with the ESP32 serving as the central hub that receives data from sensors, push buttons, and optionally the GPS module shown in Fig. 1. It processes this data and transmits it to the Telegram chatbot.

2.1 Hardware Requirements

The methodology involves integrating various hardware components with the ESP32 microcontroller, chosen for its low power consumption and wireless communication capabilities, to facilitate seamless interaction with a Telegram chatbot. The wearable design ensures that the components are securely housed in a compact form factor. The design prioritizes user comfort while maintaining durability.

2.1.1 ESP32

The ESP32 microcontroller has emerged as a powerful platform for designing smart safety bands for women because it combines dual mode wireless connectivity, advanced peripheral support, and multiple low-power modes that make wearable designs feasible even on constrained battery budgets. To enable energy efficiency, the ESP32 supports light-sleep, deep- sleep, modem-sleep, hibernation modes etc., with power draw in some sleep modes dropping to just a few microamps, and higher current only when WiFi or camera modules are active. In a safety band application, these technical features enable a robust alert system. An emergency button can wake the ESP32 and then invoke WiFi, Bluetooth to send location data and alert messages to preconfigured contacts. Integration of a GPS module allows for continuous or periodic location tracking. For more advanced versions, inclusion of the ESP32-CAM module (with an OV2640 camera) enables image and video capture; however, the camera or flash draws significantly more power on the order of hundreds of milliamperes.

Other intelligent safety features possible through ESP32 include automatic fall detection or motion abnormalities via built-in accelerometers, with the ESP32 monitoring accelerometer interrupts. Geo- fencing can be implemented by comparing live GPS coordinates against stored safe-zone boundaries; alerts can be generated if the device crosses pre- defined geo-fence limits. For remote areas or low- connectivity zones, GSM or GPRS modules are essential fallback to ensure alerts go through even without WiFi. The compact form of ESP32, its multi-core capability, and its support for low-power sleep states make it well-suited for wearables. Designing a waterproof, rechargeable enclosure can enhance durability, and placing most peripherals in sleep state until needed helps prolong battery life.

2.1.2 Sensors

SpO2 and temperature sensors play a crucial role in smart safety bands by monitoring health metrics and enabling faster response in emergencies. The SpO2 sensor ie MAX30102 uses photoplethysmography (PPG), which means it emits red and infrared light through skin and measures how much light is reflected back. Differences in absorption between oxygenated and deoxygenated blood allow it to estimate the oxygen saturation level. One-wire temperature sensors such as the DS18B20 monitor body

temperature and can detect fever or sudden temperature changes, which may signal illness or stress. Because it is a one-wire device, it only needs one digital pin to communicate with the microcontroller. When combined with an ESP32, the band can continuously or periodically sample these sensors, compare values to safe thresholds, and generate alerts when abnormal readings appear, ie low SpO2, high temperature, or sudden drops, allowing timely intervention.

2.1.3 LCD Display

LCDs are often used in smart bands because they offer good visibility and relatively modest power draw for static content. They provide much better contrast, lightweight form, and when rendering dark backgrounds, very low power consumption because unlit pixels draw nearly no current. For smart bands, where clarity, energy efficiency, and compact size matter, a small OLED display tends to be the best overall choice.

2.1.4 Battery

The Li-ion 18650 battery life was measured under two operating conditions. When the system performed continuous monitoring, collecting health sensor data, and updating location periodically, it lasted about 10 hours on a single charge. In standby mode, where only health metrics were tracked, it kept running for up to 18 hours. Battery life is a crucial factor for portability and usability. Although 10 hours of continuous operation is moderate, further optimizations such as using the ESP32's low power sleep modes, reducing sensor polling rates, disabling unnecessary peripherals, and optimizing transmission intervals could extend this duration significantly, minimizing the need for frequent charging.

2.2 Software Development

The ESP32 is programmed using the Arduino IDE, which include libraries for sensor and module integration. The initialization code sets up communication protocols like I2C and UART. It reads and processes the data continuously from SpO2 and temperature sensors. Button press detection is implemented with debouncing to ensure reliable emergency and safe status alerts. The Telegram API is integrated for sending health data and location updates to emergency contacts, with a bot created using Bot Father. The ESP32 sends HTTP requests to the Telegram API, enabling bidirectional communication. The LCD is programmed for clear data display, and extensive testing ensures reliability, including verification of message transmission.

2.2.1 Arduino IDE

Arduino IDE is an open source platform that is used to write, compile, and upload code to microcontrollers such as Arduino boards and ESP32. Supports C, C++ programming with built-in libraries for sensors, displays, and communication modules. The interface includes a code editor, serial monitor, and compiler, making

development easy. The code can be uploaded via USB or wirelessly for supported devices like ESP32. The Board Manager allows compatibility with multiple boards.

2.2.2 Embedded C

It is an extension of the C programming language designed for microcontrollers and embedded systems, allowing direct hardware access through registers and memory manipulation. It includes features like interrupts, timers, and low-level I/O control, making it suitable for real-time operations. Unlike desktop C, it lacks standard libraries and relies on hardware specific APIs for functionality.

2.3 Prototype Development

The SpO2 sensor is tested for accuracy in measuring heart rate and oxygen saturation, while the temperature sensor is calibrated with standard sources for reliability. The emergency button is evaluated through simulated scenarios to verify alert transmission and data display. GPS accuracy is assessed in outdoor environments to ensure reliable tracking. The Telegram chatbot is tested for prompt and accurate message delivery. All components are securely housed within the wristband with proper insulation for protection. The final assembly undergoes durability testing to withstand daily wear, ensuring a lightweight, ergonomic, and comfortable design.

2.4 Emergency Alert system

2.4.1 Emergency and Safe Button

Pressing the emergency button successfully triggered an alert message, which was sent via Telegram to the preconfigured contacts. The message contained the user's health data as well as real time location of the user. The emergency button was effective in triggering immediate alerts. It proved to be a simple, user-friendly interface for emergencies. The system successfully sent data and alerts without delays, ensuring prompt response. The safe button allowed the user to send a safe status update to the emergency contact. The safe button worked effectively in non- emergency situations. This feature reassures users and their contacts of their safety.

2.4.2 Telegram Chatbot Integration

The Telegram chatbot feature provided seamless and reliable communication. The bot was able to handle multiple messages simultaneously, sending alerts in a structured format that was easy for the recipient to understand. This ensures that in case of an emergency, contacts can immediately take action based on the received health data and location. The integration with Telegram was successfully implemented, allowing the system to send health data, real time location, and status updates directly to the emergency contacts. The response time between pressing the emergency button and receiving the message on Telegram was approxi-
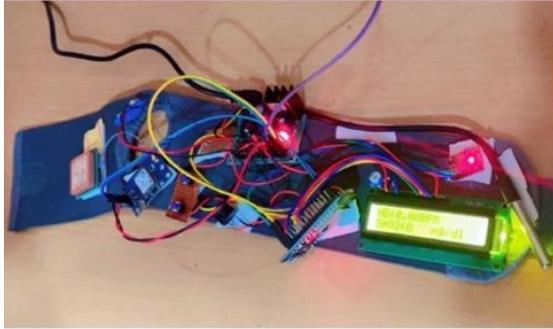
Fig. 2: *Proposed Smart Band.*

Fig. 3: *Push Buttons.*

mately 5-10 seconds, which is acceptable for emergency communication.

2.4.3 Location Tracking and Real-Time Monitoring

Real time location tracking was tested using both Wi-Fi triangulation and GPS, with the system sending accurate location data in the Telegram alert. The location was updated every 30 seconds during emergencies, and GPS-based tracking was accurate within 5-10 meters, while Wi-Fi triangulation was accurate within 20-50 meters, depending on the available network. The location tracking feature provided reliable and accurate positioning, which is critical in emergencies. GPS performed better in outdoor environments, while Wi-Fi was used as an alternative option in areas with weak GPS signals, such as indoors or urban settings. Future improvements could focus on reducing power consumption by adjusting the frequency of location updates based on the situation's urgency. Real-time location tracking was tested using GPS, and the system sent accurate location data in the Telegram alert.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The prototype of the proposed smart band is shown in Fig. 2. The Women Safety Band underwent extensive testing to evaluate its precision, reliability, and effectiveness in real world scenarios. The emergency button was tested under various conditions, ensuring prompt transmission of alerts via Telegram with an average response time of less than three seconds. Two buttons are provided to notify whether the woman is in emergency or safety conditions, as shown in Fig. 3.

The SpO2 sensor consistently provided accurate blood oxygen and heart rate measurements is shown in Fig. 4, with minimal deviation from standard medical-grade devices. A one-wire temperature sensor measures body temperature and demonstrated precise readings is shown in Fig.5 within an acceptable margin of error.

The comparison of precision between the SPO2 sensor and the clinical grade oximeter, as well as between the 1 wire temperature sensor and the clinical grade thermometer for four subjects, is presented in Table 1 and Table 2, respectively. In Table 1, the readings of both the clinical grade oximeter and the SpO2 sensor are

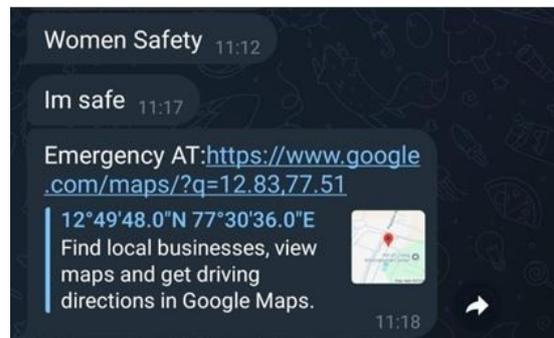**Fig. 4**: *SpO2 Reading.*

Fig. 5: *Temperature Reading.*

Fig. 6: *Shared GPS Link.*

Table 1: *SpO2 sensor accuracy.*

Sub.	Clinical reading	SpO2 reading	E(%)	A(%)
1	98.2	97.5	0.71	99.28
2	95.1	96.0	0.93	99.06
3	92.5	93.4	0.96	99.03
4	90	90.5	0.55	99.44

expressed as percentages (%). In Table 2, the thermometer measurements and the 1-wire sensor are recorded in degrees Celsius ($^{\circ}C$). The Error and the accuracy of sensor reading with respect to clinical reading are
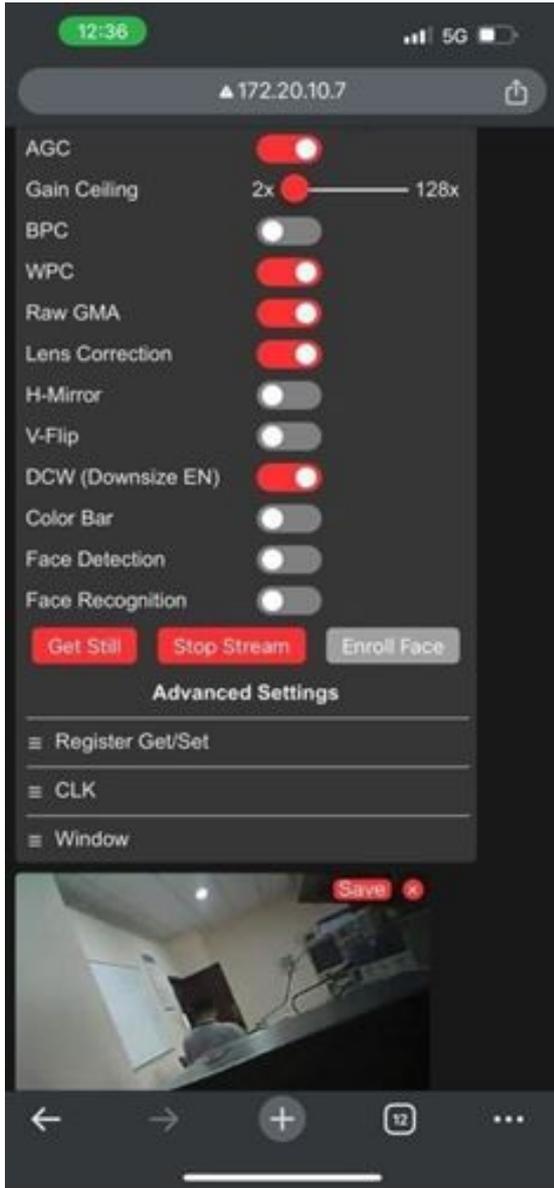
Fig. 7: *Camera Live streaming.*

Table 2: *1-wire sensor accuracy.*

Sub.	Thermo meter	1-wire sensor reading	E(%)	A(%)
1	36.8	36.9	0.271	99.72
2	37.2	37.1	0.269	99.73
3	37.5	37.6	0.265	99.73
4	38	38.2	0.523	99.47
5	28	28.15	0.528	99.47

calculated using Eqs. (1) and (2).

$$Error\ (E)\ in\ \% = \frac{C - S}{B}\ x\ 100 \qquad (1)$$

$$Accuracy\ (A)\ in\ \% = 100 - Error\ in\ \% \qquad (2)$$

where C is the clinical reading and S is the Sensor reading, respectively.

GPS accuracy tests in outdoor environments showed reliable location tracking, though minor deviations occurred in indoor settings due to signal obstruction. This project utilizes the Telegram application for communication between a user's smart band and the receiver, facilitated by a chatbot created with Bot Father. The Telegram chatbot effectively transmitted health data and emergency alerts, with real time responsiveness verified through test messages sent to predefined contacts. The power efficiency of the system was assessed, and the device successfully operated for extended periods with optimized power consumption. The wristband design was evaluated for comfort, confirming that it remained lightweight and wearable for long durations. The pressed safe blue button sends a safety alert via Telegram stating "I'm safe," in Fig. 6.The safe button worked effectively in non-emergency situations. This feature reassures users and their contacts of their safety. It is particularly useful in preventing unnecessary alerts, as contacts can differentiate between emergency and non-emergency status.

Pressing the red colour emergency button successfully triggered an alert message, which was sent via Telegram to the pre-configured contacts. The message contained the user's health data as well as the user's real-time location and also displaying the data on the LCD screen. Additionally, an ESP32 camera module captures and transmits live footage to the receiver in real time as shown in Fig. 7. The chart shown in Fig. 8 on battery life, shows the discharge behavior of Li-ion 18650 cells under different operating conditions. It clearly demonstrates that heavy use drains the battery much faster compared to nor- mal use, while in standby mode the battery lasts significantly longer, emphasizing how workload directly impacts energy consumption. The chart shown in Fig.9, presents the response time of Telegram bot alerts as a histogram, where most delays are observed in the range of 6-9 seconds. The frequency axis indicates how many alerts fall into each delay range, showing that the system maintains a consistent and acceptable delay within the 5-10 second window. The chart shown in Fig. 8, compares location accuracy using GPS and Wi-Fi triangulation. GPS provides high precision, typically within 5-10 meters, whereas Wi-Fi triangulation has larger errors, ranging from 25–50 meters, with greater variability. Together, these visualizations provide a comprehensive overview of device performance, demonstrating trade-offs between power consumption, communication speed, and positioning accuracy.

The experimental results confirmed that the Women Safety Band has successfully achieved its primary objectives. It is a reliable and efficient solution for real-time health monitoring and emergency response. By analyzing health data such as SpO2, temperature, and heart rate, the system could detect early signs of medical conditions like heart attacks or heatstroke and automatically send alerts before the user is even aware of the situation. In near future, technology advancements
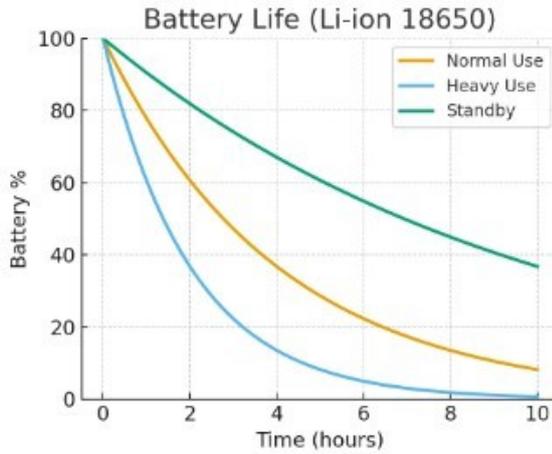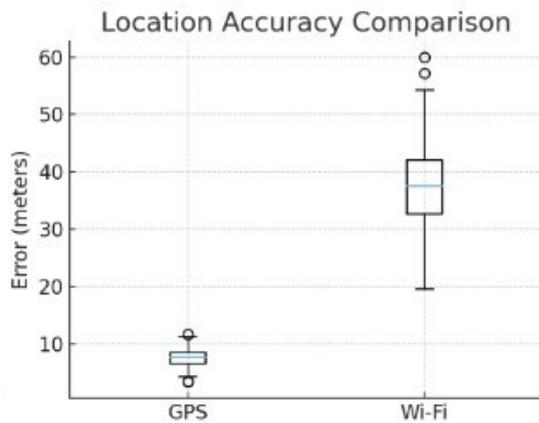
Fig. 8: Battery Life.
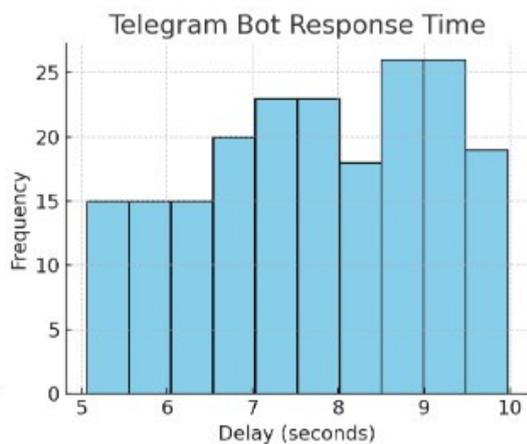

Fig. 9: Location Accuracy.

Fig. 10: Telegram Bot Response Time.

can make the device more robust, such as improving the performance of the GPS indoors, improving power efficiency, and expanding sensor capabilities, which can further optimize its functionality. The device also has the potential for global expansion by integrating local emergency services ie smart city infrastructures, multiple languages, and regional communication preferences.

4. CONCLUSION

The Women Safety Band successfully integrates health monitoring and emergency alert systems into a compact, portable device designed for user safety and well-being. Using an ESP32 microcontroller, it interfaces with sensors for SpO2, temperature, and emergency buttons to provide real-time health tracking and instant communication via Telegram. GPS integration ensures accurate location sharing in critical situations, enabling a rapid response. The lightweight, battery-operated design ensures continuous usability, and offers a comprehensive safety solution. Rigorous testing confirms its accuracy, reliability, and effectiveness as a personal safety device. SpO2 and one-wire temperature sensors are accurate in the range of 99.2% to 99.7% compared to the respective medical grade devices. Future improvements include optimizing battery life, improving sensor accuracy, integrating AI for predictive health alerts, and improving location tracking with BLE or 5G. Smart city integration could improve emergency response, making the device more efficient, user-friendly, and globally adaptable.

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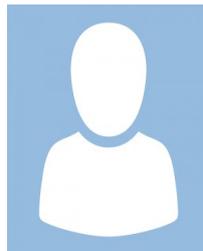
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