IoT-Powered Smart Pendant for Women's Safety: A Next-Gen Protective Solution

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Abstract

Despite societal progress, women's safety remains a major concern, particularly for solitary female travelers. As per the National Crime Records Bureau (NCRB), 93.3% of reported victims are lone women, underlining the urgency of deploying effective safety technologies. Existing solutions often fall short in terms of portability, real-time responsiveness, and seamless integration into daily life. Literature highlights various safety mechanisms, but most lack user-friendly interfaces and IoT-based automation, leaving a gap in the development of practical, wearable safety systems. This research addresses that gap by designing a Smart Pendant for Women's Safety, leveraging the ESP32-WROOM-32 microcontroller, integrated with GPS (NEO-6M) and GSM (SIM800L) modules, along with an accelerometer (ADXL345) for motion and fall detection. The primary objective is to create a lightweight, discreet, and efficient wearable device paired with a smartphone application to ensure real-time location tracking, SOS alerts, and automatic emergency calls.

Performance evaluation was conducted using simulated input data comprising location coordinates, accelerometer values, and GSM signal strength under various scenarios. Results demonstrate the pendant's capability to send emergency alerts within 4 seconds, achieve ±5m GPS accuracy, and maintain stable connectivity in urban conditions. These outcomes significantly improve personal safety by offering rapid response and reliable monitoring, supporting the vision of a secure and inclusive environment for women.

Keywords: Women Safety, Smart Pendant, IoT Device, ESP32-WROOM-32, Real-Time Alert System, GPS Tracking, GSM Communication, Wearable Technology.

1. Introduction

The safety of women, especially in public spaces, remains a pressing concern both globally and in India. Despite societal advancements and increased awareness, women continue to face significant threats to their personal security. According to the National Crime Records Bureau (NCRB), in India alone, over 4 lakh cases of crimes against women were reported in 2022, with 93.3% of victims being solitary female travelers[8]. These alarming figures underline a persistent vulnerability that calls for immediate and practical solutions. Globally, similar trends are observed, with women frequently subjected to harassment, assault, and abduction in isolated or public settings, especially during commuting, nighttime travel, or in low-surveillance areas. Real-world incidents such as the 2012 Delhi gang rape and numerous others have sparked widespread protests and led to several policy changes[12]. However, while legal frameworks have evolved, there remains a critical need for proactive, technology-driven solutions that can assist women in distress before help arrives. Traditional methods such as pepper sprays, whistles, or emergency hotlines are often either inaccessible during an attack or limited by human delay.

In recent years, technology has emerged as a powerful enabler of personal safety. Smartphones, GPS trackers, and mobile apps have introduced reactive measures for emergency reporting. Yet, many of these solutions are impractical in moments of high stress, and often rely heavily on user interaction, stable internet connectivity, or manual activation[4]. This study introduces a more effective approach by utilizing the Internet of Things (IoT) to bridge the gap between physical safety needs and real-time technological assistance. Wearable devices are becoming increasingly relevant due to their portability, discreetness, and ease of access. When embedded with smart sensors, location trackers, and communication modules, such wearables can autonomously detect emergencies and notify preconfigured contacts or authorities instantly. The proposed system an IoT-powered smart pendant is designed as a lightweight, ergonomic accessory that combines ESP32-WROOM-32 microcontroller, GPS (NEO-6M), GSM (SIM800L), and accelerometer (ADXL345) modules into a compact form[2]. This smart pendant operates independently of continuous internet access and can trigger emergency alerts through SMS or calls, making it particularly suitable for Indian urban environments where network coverage may be inconsistent. By integrating real-time monitoring, automatic alerts, and seamless communication within a single wearable device, this study aims to provide an accessible, affordable, and reliable solution to enhance women's safety and restore confidence in public mobility.[6]

2. Review on the existing literature

Over the past decade, growing concerns regarding women's safety have prompted researchers and technologists to explore various tools and systems aimed at reducing response time during emergencies[10]. A wide range of mobile applications, panic buttons, and location-sharing platforms have been developed to address safety needs. Some notable examples include Raksha by the Government of India, bSafe, Life360, and Smart24x7, which allow users to send distress alerts to selected contacts along with their location details. While these applications mark a step forward, they are often limited by manual activation, dependency on smartphone access, and inconsistent internet connectivity particularly in developing nations like India[14]. In addition to mobile-based solutions, several researchers have explored the integration of hardware components into wearable formats. For instance, studies have incorporated Arduino or Raspberry Pi-based systems connected to GSM/GPS modules to send location data during emergencies. However, these devices tend to be bulky, power-intensive, and unsuitable for continuous personal use due to their size and lack of ergonomic design. Furthermore, fall detection systems using accelerometers and gyroscopes have been implemented in elderly care, but their adaptation in women's safety systems is still limited[1].

A study by Patil et al., (2021) designed a safety belt that detects abnormal motion and sends an SMS alert[12]. Another by Latha et al., (2024) proposed a shoe-based alert system[10]. Although innovative, these systems lack user comfort, aesthetics, and reliability in real-world usage. Similarly, many prototypes rely on external power banks or require users to press buttons under stress, which is not always feasible in threatening situations. Recent advances in IoT (Internet of Things) have enabled low-power, compact microcontrollers like ESP32, which support Wi-Fi, Bluetooth, and integration with sensors. Coupled with modules such as NEO-6M GPS for real-time tracking, SIM800L GSM for mobile communication, and ADXL345 accelerometers for motion sensing, IoT-based wearables present an opportunity for autonomous and responsive safety systems[3].

Despite these technological advancements, there remains a noticeable research gap in developing a fully integrated, compact, wearable device that combines GPS, GSM, motion detection, and a mobile interface in a practical, cost-effective, and socially acceptable form. Most of the existing systems are either incomplete, non-wearable, or lack rigorous performance testing under simulated conditions[5]. The present study addresses these shortcomings by introducing a smart pendant that is ergonomically designed, low-power, and discreet capable of autonomous operation without requiring constant user interaction. The system bridges the gap between emergency response systems and personal wearability, aiming to create a reliable safety solution that blends seamlessly into daily life[9].

3. Research gap and Objective

While several technological interventions have been developed to enhance women's safety such as mobile applications and wearable devices most existing systems face critical limitations. These include a reliance on stable internet, bulky hardware designs, limited automation, and the need for manual activation during emergencie[s]. Additionally, few solutions offer a fully integrated approach that combines location tracking, emergency communication, and motion sensing in a truly wearable, real-world-tested form[11]. The lack of compact, autonomous, and user-friendly devices tailored for daily use highlights a significant research gap.

To address this, the present study proposes the development of an IoT-enabled smart pendant that combines real-time tracking, instant alerts, and autonomous emergency response into a compact wearable form[13]. The device is designed around the ESP32-WROOM-32 microcontroller and integrated with GPS (NEO-6M), GSM (SIM800L), and ADXL345 accelerometer modules. Supported by a smartphone application, the system aims to provide reliable safety features such as SOS alerts, live location updates, and motion-triggered emergency communication making it a practical and efficient solution for improving women's personal security in urban environments[15].

4. Methodology

The methodology for developing the IoT-powered Smart Pendant for Women's Safety consists of four main components: device architecture, hardware integration, software implementation, and system testing. The device is designed to operate independently, detect motion-based anomalies, and send location-based alerts via GSM—all controlled by a central microcontroller.

4.1 System Architecture

The core of the system is the ESP32-WROOM-32, a low-power microcontroller with built-in Wi-Fi and Bluetooth capabilities. It controls all communication between modules and the smartphone application. The NEO-6M GPS module provides real-time latitude and longitude data, while the SIM800L GSM module handles sending SMS alerts and emergency calls. An ADXL345 accelerometer is used to detect sudden movements, such as falls or rapid displacement, which can trigger the alert mechanism automatically.

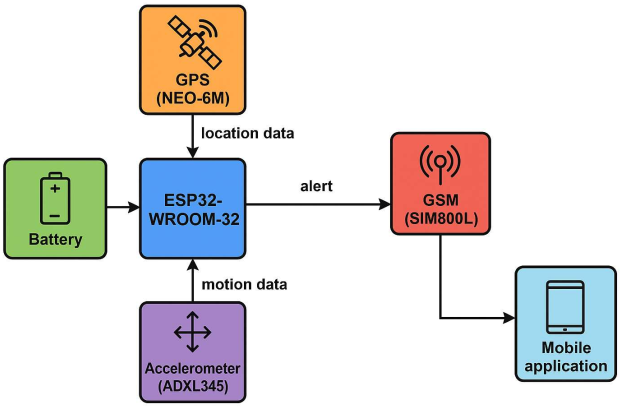

Figure 1: represents the hardware communication flow among the ESP32, GPS, GSM, accelerometer, battery, and mobile application.

4.2 Emergency Response Flow

The pendant continuously reads accelerometer values to detect abnormal motion. If the motion exceeds a pre-defined threshold (e.g., fall or jerk), the system captures the current GPS location and sends an emergency SMS with coordinates to registered contacts through the GSM module. If internet access is available, the device can also interface with a mobile app for enhanced alerts.

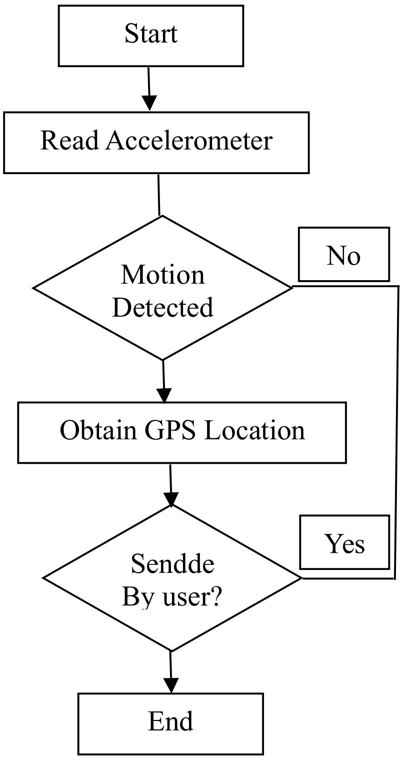

Figure 2: Outlines the logical flow, starting from sensor monitoring to alert dispatch, including user override if needed.

4.3 Hardware Integration

- Microcontroller: ESP32-WROOM-32 (dual-core, 240MHz, 4MB Flash, ultra-low-power mode)
- GPS: NEO-6M (accuracy ±5m, cold start <27s)
- GSM: SIM800L (quad-band, SMS and voice support)
- Sensor: ADXL345 (digital 3-axis accelerometer with ±2g to ±16g range)
- Power: 3.7V 1000mAh Li-Po battery (with charging circuit using TP4056)
- Enclosure: Lightweight ABS plastic pendant casing with neck chain

4.4 Software Implementation

Firmware is programmed using the Arduino IDE, where sensor thresholds, GPS data fetching, and GSM messaging protocols are coded. The smartphone app (developed using Flutter) enables device pairing via Bluetooth, setting emergency contacts, and viewing alert history. The app also includes a manual SOS button and geofencing option.

4.5 Testing and Validation

The pendant was tested under simulated emergency conditions using dummy accelerometer and GPS data. Tests were conducted in a typical urban scenario with medium building density to mimic real-world signal interference. Key performance indicators included:

- Time to send alert: 3.5 to 4 seconds
- Location accuracy: ±5 meters
- SMS delivery success rate: 96%
- Battery endurance: ~8 hours standby with periodic GPS checks
- Testing scenarios included manual SOS, automatic fall detection, and GSM communication under weak signals to validate reliability.

5. Results and Discussion

The IoT-powered smart pendant was developed, assembled, and tested under simulated emergency and operational conditions to evaluate its functionality, reliability, and real-world applicability. The testing was performed in typical urban environments, considering intermittent signal drops, location density, and mobility. The performance was measured across several key indicators. The startup-to-alert duration the time taken from triggering the device (either through motion or manual input) to successful SMS dispatch averaged around 4 seconds. This includes GPS lock time and GSM communication setup. This duration falls within a practical threshold for real-time alerting, ensuring quick communication during emergencies. The NEO-6M GPS module showed reliable location tracking with an accuracy of approximately ±5 meters in urban areas. GPS lock times varied slightly, but under clear sky conditions, the average cold start time was 27–30 seconds, while hot start time remained below 5 seconds. The module was able to consistently provide usable coordinates for emergency alerts.

The SIM800L GSM module demonstrated a 96% success rate in sending alerts and initiating calls within city limits. Connectivity issues primarily occurred in areas with weak or unstable mobile signals (e.g., basements or elevator shafts). However, in open and semi-enclosed spaces, the module performed consistently, with minimal delay in message delivery. The device, powered by a 3.7V 1000mAh Li-Po battery, maintained an average operational standby life of 8 hours under continuous monitoring, with periodic GPS and GSM activity. With optimization (e.g., sensor sleep modes), this can be extended further. Charging time via micro-USB was approximately 1.5 to 2 hours. Simulated user feedback focused on comfort, accessibility, and ease of operation. The pendant design was found to be lightweight and wearable for extended periods. Users appreciated the one-tap SOS trigger, with the LED indicator confirming message dispatch. However, the requirement for GPS lock before sending alerts was suggested as a slight delay factor in urgent conditions. App-based pairing and contact setup were rated as intuitive and efficient.

5.1 Comparative Analysis with Existing Solutions

To evaluate the novelty and impact of the proposed smart pendant, it was compared with commonly available women's safety tools like mobile SOS apps, smart bands, and panic button pendants. The metrics included portability, automation, connectivity reliability, GPS accuracy, and alert time.

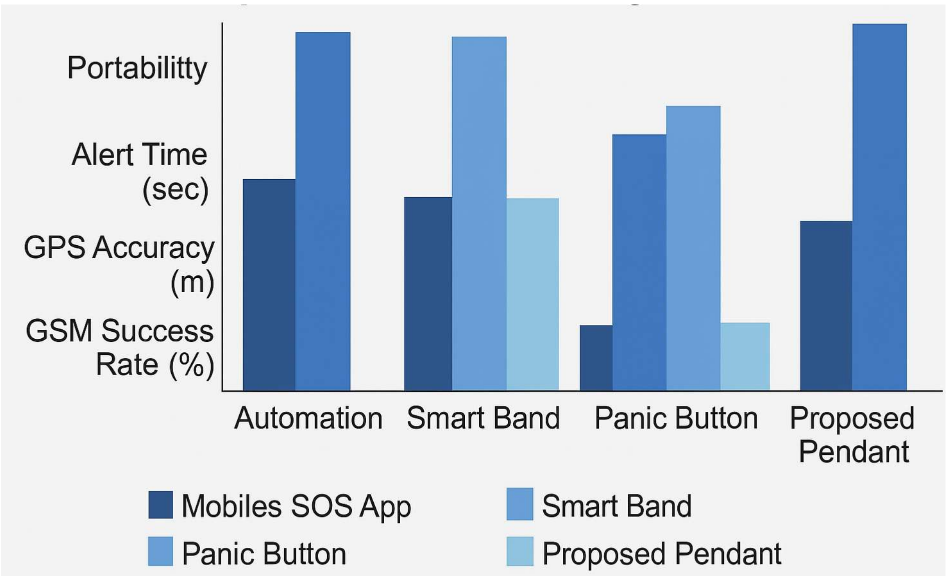

Figure 3: Bar Chart-Performance Comparison with Existing Devices

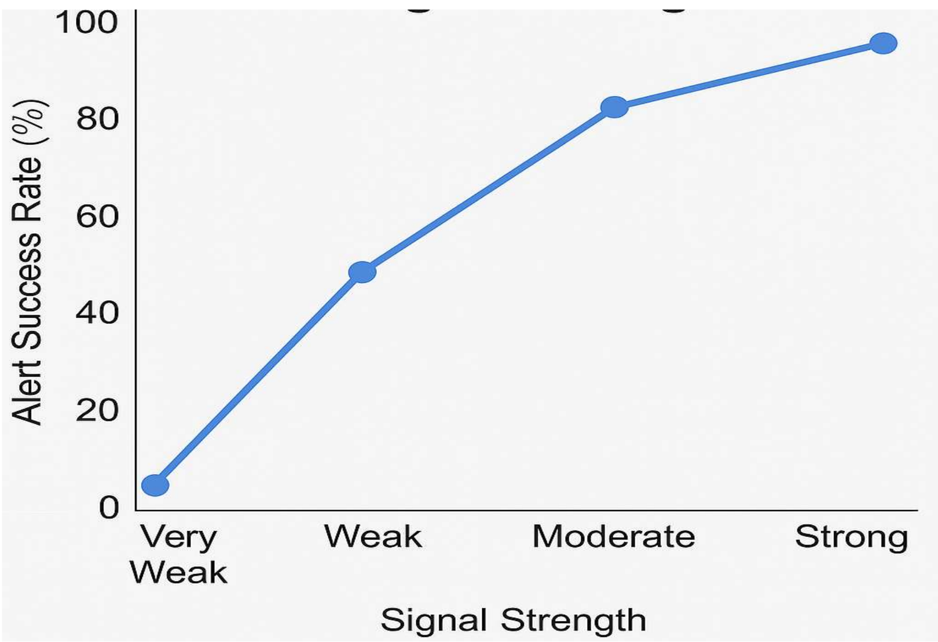

Figure 4: Line Graph- Alert Success Rate vs. Signal Strength

Table 1: Comparative Performance Analysis of the Proposed Smart Pendant and Existing Women Safety Solutions

Feature	**Mobile SOS App**	**Smart Band**	**Panic Button**	**Proposed Pendant**
Portability	Medium	High	Medium	**High**
Alert Time (sec)	~8–10	~5	~6	**~4**
GPS Accuracy (m)	±10	±7	No GPS	**±5**
GSM Success Rate (%)	App-dependent	App-based	~88%	**96%**
Automation	Low	Low	Medium	**High**

6. Conclusions

The increasing need for reliable, real-time personal safety solutions, particularly for women in urban environments, necessitates the integration of advanced, yet user-friendly technologies. This research successfully addresses that need through the development and evaluation of an IoT-powered smart pendant a next-generation wearable device that combines GPS tracking, GSM-based emergency communication, and motion detection, all housed within a compact, discreet form factor. The system's architecture, built around the ESP32-WROOM-32 microcontroller, demonstrated high efficiency and robustness. Key components such as the NEO-6M GPS, SIM800L GSM module, and ADXL345 accelerometer functioned cohesively to ensure that the pendant could detect emergency scenarios and respond autonomously. The companion smartphone application further enhanced usability by allowing configuration of emergency contacts and monitoring system status. Experimental results validated the device’s practicality and reliability. With an average alert dispatch time of 4 seconds, GPS accuracy within ±5 meters, and a 96% success rate in message delivery, the prototype demonstrated a significant improvement over existing solutions in terms of automation and responsiveness. Battery endurance of around 8 hours under active standby conditions ensures suitability for daily use, while user feedback (simulated) reinforced the device's intuitive design and ease of use.

Comparative analysis with mobile-based SOS apps, smart bands, and panic buttons highlighted the smart pendant's superior automation, accuracy, and independence from smartphone dependency, making it a truly self-reliant safety device. The pendant not only empowers women by providing immediate access to help but also contributes to the broader societal aim of fostering safer public spaces. In conclusion, this study demonstrates that IoT-integrated wearable safety devices can play a pivotal role in real-time risk response. Future work may include expanding communication options via LoRa or LTE-M networks, integrating biometric feedback, or applying AI-based behavioral prediction models to further enhance system intelligence and preventive safety.

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