2025 4th International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)
11 – 12 January 2025, American International University – Bangladesh (AIUB), Dhaka, Bangladesh

IoT-Based Women Safety Device using Haversine Formula

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2025 4th International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) | 979-8-3315-3095-2/25/$31.00 ©2025 IEEE | DOI: 10.1109/ICREST63960.2025.10914400

***Abstract*— Women's safety is an urgent concern, and this paper introduces an IoT-based safety device designed to provide real-time monitoring and rapid emergency response. The device integrates sensors for heart rate and body temperature, GPS for location tracking, and GSM for sending alerts. A key innovation is the use of the Haversine formula to calculate the nearest police station, enabling faster response times during emergencies. The system automatically triggers alerts when vital thresholds are crossed, such as a heart rate exceeding 220 BPM or temperature surpassing 40°C, ensuring swift action. Testing confirmed high accuracy in detecting abnormal vitals, with heart rate measurements closely aligning with certified medical devices. Practical tests also validated successful emergency alert transmission and continuous real-time monitoring through cloud integration, making the device a reliable solution for women's safety in critical situations.**

Keywords*— women safety, IoT, real-time monitoring, GPS, haversine formula, nearest police station, health sensors, GSM

I. INTRODUCTION

In today's world, personal safety, particularly for women, has become a growing concern. With the increasing rate of violence and harassment, there is a pressing need for technological solutions that can ensure immediate assistance during emergencies. Wearable devices and smart technology provide an innovative approach to address these concerns, offering real-time monitoring, emergency detection, and instant communication with authorities or family members.

The issue of women's safety has become increasingly critical, driving the development of IoT-based solutions to offer real-time security. Patil et al. underscores the importance of IoT and GPS for tracking women's location and facilitating communication during emergencies [1]. However, the reliance on GPS presents limitations in areas with poor satellite connectivity, such as remote or indoor locations. Uganya et al. propose a smart women's safety device that integrates IoT with GPS tracking for manual and automatic operation modes, though network dependence could cause delays in response times [2]. Harikiran et al. introduce an IoT-based device that automatically detects and assists victims in emergencies [3]. While promising, its reliance on sensor accuracy might lead to false positives or missed alerts under real-world conditions. Vahini et al. focus on IoT-enabled tracking systems for women, particularly those aged 25 to 35, targeting students and full-time workers [4]. The system's limitation lies in its focus on a narrow demographic, reducing its applicability to other age groups and circumstances. Khandelwal et al. designed a wearable device that integrates IoT and machine learning to monitor temperature and heart rate, issuing alerts when necessary [5]. The main concern here is the privacy issue raised by continuous health data monitoring, which could compromise user consent and data security. Similarly, Sogi et al. introduced SMARISA, a Raspberry Pi-based smart ring for women's safety, highlighting the role of wearables [6]. However, the size and power consumption of the Raspberry Pi limits the device's practicality for everyday use. Hyndavi et al. developed a wearable device with automated emergency alerts using pressure, pulse-rate, and temperature sensors to prevent harm during emergencies [7]. Calibration complexities in the sensor system, however, may result in inconsistent detection accuracy. Gulati et al. presented a safety device that integrates multiple IoT modules and sensors to empower women's safety by reducing crime rates [8]. Yet, the system's reliability could be compromised by potential sensor or network failure during critical moments.

Venkatesh et al. developed a wearable wristband that communicates with smartphones to send continuous safety alerts [9]. This solution, however, is limited by its dependence on smartphones, which may be out of reach or have low battery power when needed most. Devi et al. proposed a compact IoT-based safety system with GPS and GSM circuits for sending emergency alerts and shock-triggering mechanisms for protection [10]. A limitation of this system is its manual activation requirement, which may be difficult in situations where the victim cannot initiate the alert. Manoje et al. extended IoT applications to military health services for tracking soldiers on battlefields, using GPS and health sensors [11]. While similar to personal safety systems, the rugged design and high power consumption limit its application for individual civilian use. Jiang et al. focused on real-time monitoring of underground miners using IoT for safety, incorporating wearable terminals for tracking and alerting personnel [12].

While the literature highlights the potential of IoT-based safety devices, several limitations persist, such as dependency on network connectivity, sensor accuracy, and manual intervention during emergencies. To address these challenges, the proposed system incorporates enhancements to improve reliability, usability, and real-time response capabilities. One key advancement is the integration of a GPS-based feature that calculates the nearest police station using the Haversine formula, which ensures timely assistance during emergencies. This feature allows the device to automatically locate the closest law enforcement agency and send an alert with real-time GPS coordinates, significantly reducing the response time.

The device integrates multiple sensors, including heart rate and temperature sensors, along with GPS and GSM modules, to ensure continuous monitoring of the user's condition and location. In the event of an emergency, the system automatically triggers an alert based on predefined thresholds or manual activation by the user. The alerts, including the user's real-time location, are sent via SMS to both emergency services and designated contacts, providing vital information for swift response.

The paper is structured as follows: Section II reviews existing IoT-based women safety devices, identifying their limitations. Section III focuses on the design and implementation of the proposed system, including sensor integration, GPS tracking, and the use of the Haversine formula for locating the nearest police station. Section IV concludes by summarizing the system's performance and highlighting its effectiveness in enhancing women's safety through real-time monitoring and emergency alerting.

II. Methodology

The development of the women's emergency safety device involved both hardware and software integration. Key sensors, such as heart rate and temperature sensors, were used alongside GPS and GSM modules to monitor the user and send emergency alerts. The system was programmed using Arduino IDE to ensure real-time data processing and communication during emergency situations.

A. System Architecture

The women's emergency safety device is built using an Arduino Uno microcontroller that integrates key sensors and communication modules. It monitors heart rate using the MAX 30100 sensor, and body temperature with the LM35 sensor and includes a touch sensor for manual activation in emergencies. The device uses a GPS module to track the user's location and a GSM module to send SMS alerts to emergency contacts, including location data and a Google Maps link. Data from these sensors is processed and transmitted in real-time to a Firebase cloud server via the NodeMCU (ESP8266). The system is powered by an 11V battery, with a buck converter stepping down the voltage for different components.

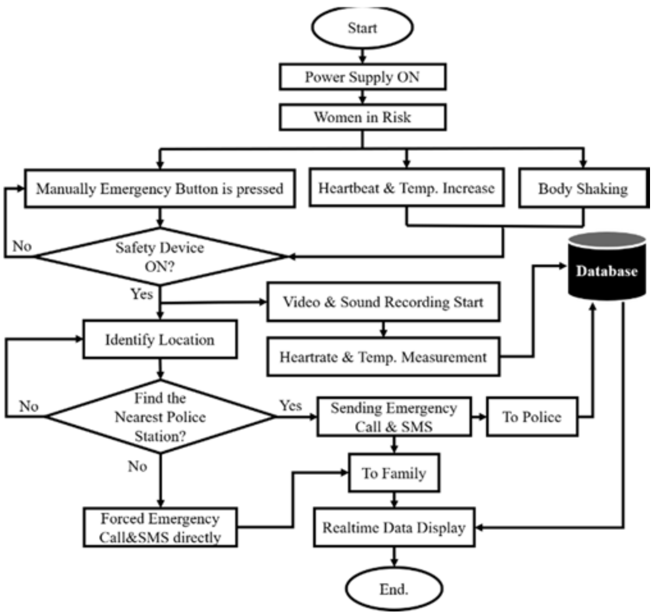


Fig. 1. Flowchart of the emergency process.

Fig. 1, represents a step-by-step flowchart of how the emergency safety device operates, starting from detection to alerting emergency responders.

Step 01: Start & Power ON: The device is powered on and monitors the user for emergency signs.

Step 02: Women at Risk: The system monitors for signs of distress (e.g., increased heartbeat, temperature, or body shaking).

Step 03: Manual Button Activation: The user can manually activate the emergency system by pressing the button.

Step 04: Safety Device ON?:

- **Yes:** If the system detects distress, the safety device is automatically ON and it moves to step 05.
- **No:** It moves to step 03 for manually pressing the emergency button.

Step 05: Video & Sound Recording: The device starts recording audio and video for documentation.

Step 06: Heartbeat & Temperature Measurement: Continuous monitoring of the user's vitals (heartbeat and temperature) occurs.

Step 07: Identify Location: The GPS module captures the user's real-time location.

Step 08: Find Nearest Police Station?:

- **Yes:** Identifies the closest police station using the Haversine formula and proceeds to send Emergency Calls and SMS.
- **No:** If no police station is found, the system may retry or notify predefined emergency contacts directly.

Step 09: Sending Alerts: Emergency alerts (SMS and call) are sent to the nearest police station and family with location and vitals data.

Step 10: Real-time Data Display: The user's data is continuously monitored and displayed on a remote server for authorized personnel.

Step 11: End: The process ends after alerts are sent, and real-time monitoring continues until the situation is resolved.

The Firebase Realtime Database, Fig. 3, enables continuous monitoring of the user's vitals and location, providing real-time updates to a secure web interface.

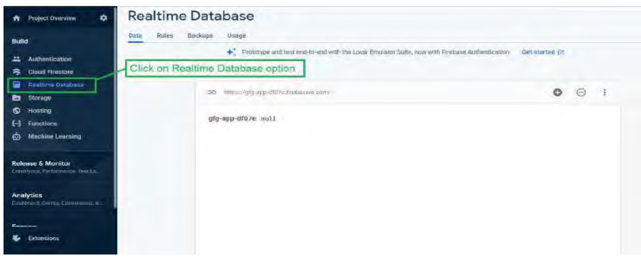


Fig. 2. Firebase-based server for real-time database.

B. Sensor Triggers

The system operates using three primary sensor triggers: heart rate, temperature, and touch. The MAX 30100 heart rate sensor continuously monitors the user's heart rate, and if it exceeds the threshold of 220 BPM, the device records a timestamp and initiates the emergency response. The heart rate (BPM) is calculated using the formula:

$$BPM = \frac{60000}{CBT - PBT} \tag{1}$$

$$T(°C) = \frac{V_{out} \times 1000}{10} \tag{2}$$

$$Touch\ Status = \begin{cases} 1, & if\ touched \\ 0, & if\ not\ touched \end{cases} \tag{3}$$

Where CBT is the current beat timestamp, PBT is the previous beat timestamp, and V_{out} is the output voltage from the sensor (in millivolts). The LM35 temperature sensor monitors the user's body temperature (T), and if it rises above 40°C, it triggers an emergency alert. In the event that neither the heart rate nor temperature sensors detect abnormal readings, the touch sensor acts as a manual override, allowing the user to initiate the alert by simply touching (value 1) the sensor.

C. Location Tracking and Notification

Once any of the sensors are triggered, the device calculates the user's current location using the GPS module. The system uses the Haversine formula to compute the shortest distance (d) between the user's current location and the nearest police station to send emergency notifications. The formula is as follows:

$$d = 2r\ acrsin\left(\sqrt{sin^2\left(\frac{\Delta\theta}{2}\right) + cos\theta_1 cos\theta_2 sin^2\left(\frac{\Delta\lambda}{2}\right)}\right) \quad (4)$$

$$Nearest\ Station = min(d_1, d_2, d_3, d_4, d_5) \quad (5)$$

Where θ and λ are the latitude and longitude coordinates of the user and the police stations. The device identifies the nearest station from a pre-programmed list of five locations as d_1, d_2, d_3, d_4, d_5. Once the closest station is determined, the GSM module sends an SMS containing the user's location and a Google Maps link to the identified station, allowing authorities to respond swiftly.

D. Software Implementation

The software implementation, Fig. 4, of the women's safety device is developed using Arduino IDE to manage sensor data, decision-making, and communication. The system includes the MAX30100 heart rate sensor, LM35 temperature sensor, GPS module, and GSM module. The heart rate sensor monitors the BPM, triggering an emergency alert if it exceeds 220, while the temperature sensor triggers an alert at 40°C. The GPS module tracks real-time location, and the GSM module sends SMS alerts with the user's vitals and location to predefined contacts using AT commands. The LCD display shows real-time data, such as heart rate and temperature, with updates every second. The software ensures continuous monitoring, processing data in real-time, and triggers emergency alerts if any thresholds are breached.

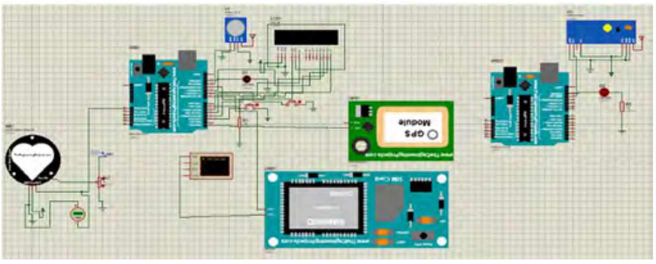


Fig. 4. Proteus simulation implantation for the proposed safety device

E. Hardware Implementation

The women's safety device, Fig. 5, integrates key components, with an Arduino Uno microcontroller at the core to process sensor data and manage communication. It includes an MAX30100 pulse oximeter for heart rate monitoring, an LM35 temperature sensor, and a touch sensor for manual emergency activation. The system tracks the user's location via a GPS module and sends emergency alerts through the GSM module to contacts like police stations and family members. The Li-Po battery (11.1V) powers the system, and a buck converter steps the voltage down to 5V for components. A real-time LCD display shows heart rate and temperature, with thresholds set at 220 BPM for heart rate and 40°C for temperature. Upon detecting an emergency, the device calculates the nearest police station using the Haversine formula based on GPS coordinates and sends an alert. The compact system ensures real-time monitoring via server integration, with seamless alerts and data transmission in critical situations.

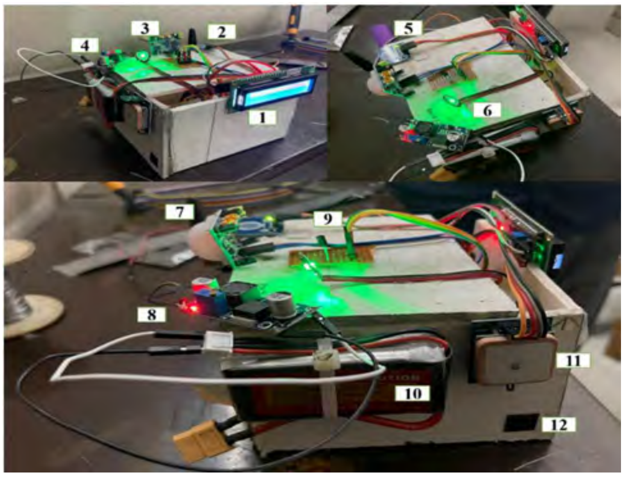


Fig. 5. Proposed safety device hardware setup.

Note: 1. LCD Display, 2. GSM Module, 3. Node MCU, 4. Arduino Uno, 5. Touch sensor, 6. Heart Rate Sensor (MAX30100), 7. Motion Sensor (HC-SR501), 8. Buck Converter, 9. Temperature Sensor (LM35), 10. Li-Po battery, 11. GPS Module, 12. Push Button.

III. Result and Discussion

The safety device was evaluated through real-time simulations and practical tests in both software and hardware implementations, assessing its effectiveness in monitoring vital signs, detecting emergencies, and communicating with emergency responders and family members.

A. Software Result

The software results from the simulation, Fig. 6, demonstrate the effective operation of the women's emergency safety device. The system successfully detects abnormal heart rates, as indicated by the "A Heartbeat Happened" message in the virtual terminal, and promptly sends emergency SMS alerts to predefined contacts. The GPS and GSM modules are integrated seamlessly, providing accurate location data alongside the alerts. The Arduino Uno processes sensor data in real-time, ensuring immediate responses to emergencies. Overall, the simulation validates the device's capability to monitor vitals, detect emergencies, and communicate with responders swiftly and reliably.

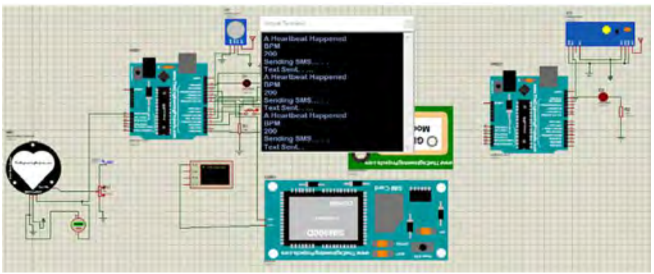


Fig. 6. Simulation of safety device showing real-time heart rate monitoring and SMS alert transmission.

B. Hardware Result

The hardware implementation of the women's emergency safety device was evaluated through a series of practical tests. The results indicate that the system successfully performs its intended functions under different real-world conditions.

1) System automatic activation: As shown in Fig. 7, the system successfully detects an emergency when the user's temperature exceeds the threshold (in this case, 60.05°C). The LCD displays "EMERGENCY! Help Coming!!!", confirming that the device automatically initiated the safety protocols. The real-time heart rate (BPM: 73) and temperature (60.05°C) are displayed on the screen, demonstrating the system's ability to monitor vital signs.

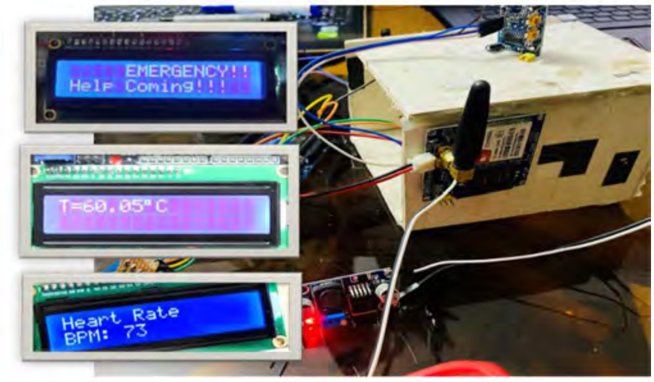


Fig. 7. Emergency detected due to high body temperature and automatic device activation.

2) Finding the nearest police station: In Fig. 8, the device calculates the distance to the nearest police station using the Haversine formula. The police station closest to the user is identified based on the latitude and longitude inputs. The system displays the distances to multiple nearby police stations, ensuring the most accurate location is used for emergency alerts.

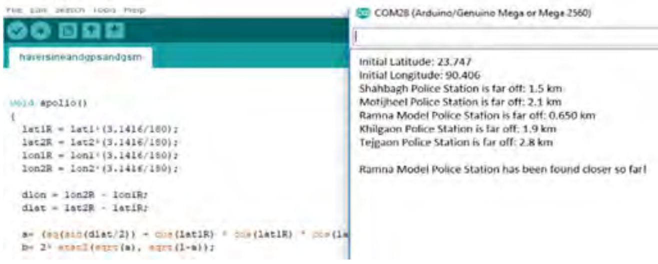


Fig. 8. Successful calculation of the nearest police station using the haversine formula.

3) Sending emergency notifications to the police: Fig. 9, demonstrates the successful transmission of SMS and call alerts to the nearest police station. The system sends the user's GPS coordinates along with a Google Maps link to assist responders in reaching the victim swiftly.

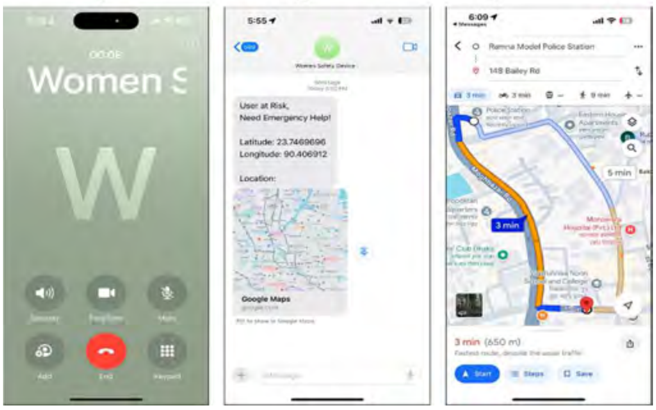


Fig. 9. Successful transmission of SMS and calls to the nearest police station.

4) Sending emergency notifications to the Family: In Fig. 10, the system also sends SMS and call alerts to the user's family members. The victim's location is shared via SMS, complete with GPS coordinates and a Google Maps link, ensuring family members are informed in real-time.

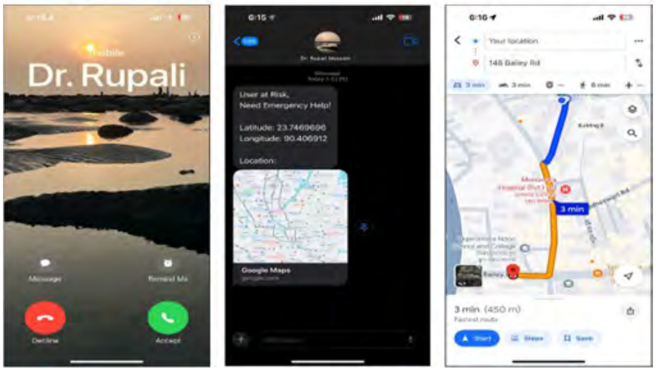


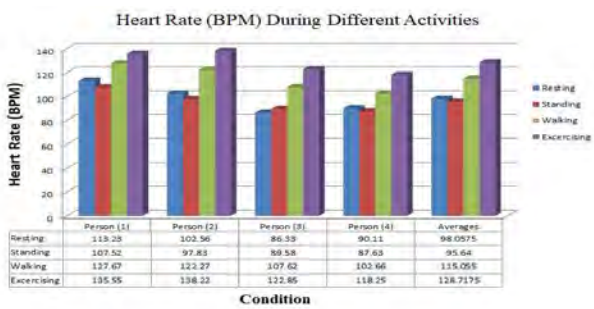
Fig. 10. Successful sending of SMS and calls to the family members.

5) Realtime database server: Fig. 11, shows the real-time monitoring dashboard that family members or authorized users can access. Vital signs such as BPM, temperature, and location are displayed on a secure server. The victim's status is also shown (Situation 1 indicates the user is at risk), and touch input (value 0) confirms that the emergency was automatically triggered, not manually initiated.

Fig. 11. Real-time monitoring of the victim's status on the server.

C. BPM Accuracy

The accuracy of the women's safety device was evaluated by comparing the heart rate measurements (BPM) recorded by the device under different physical conditions and by comparing it to a certified hospital device. As shown in Fig. 12, the bar graph represents the heart rate (BPM) of four individuals during different physical activities such as resting, standing, walking, and exercising. The average BPM readings demonstrate that the safety device consistently detects variations in heart rate during these activities, ensuring that it can accurately monitor users' vitals under different conditions.



	Person (1)	Person (2)	Person (3)	Person (4)	Averages
Resting	113.23	102.56	86.33	90.11	98.0575
Standing	107.52	97.83	89.58	87.63	95.64
Walking	127.67	122.27	107.62	102.66	115.055
Excercising	135.55	138.22	122.85	118.25	128.7175

Fig. 12. Bar graph showing heart rate (BPM) during different activities with the safety device.

Table I, presents a direct comparison between the heart rate measurements from the safety device and a certified hospital device. The safety device's results are closely aligned with those of the hospital device, with minimal deviations. For instance, Person (1) recorded 115.38 BPM on the safety device compared to 135 BPM on the hospital device. These results confirm that the safety device provides reliable measurements, though slight differences exist due to sensor sensitivity. The overall accuracy is sufficient for emergency detection purposes, validating the device's use in real-world scenarios.

TABLE I. STATISTICAL ANALYSIS BETWEEN THE SAFETY DEVICE AND THE HOSPITAL DEVICE

This device	Result (BPM)	Certified Device	Result (BPM)
Person (1)	115.38	Person (1)	135
Person (2)	100.47	Person (2)	101
Person (3)	85.95	Person (3)	74
Person (4)	84.32	Person (4)	80

D. Comparative Study

The proposed IoT-based women's safety device offers key improvements over existing systems shown in Table II. It enhances GPS accuracy by using the Haversine formula to locate the nearest police station, ensuring faster emergency response. Unlike manual-only systems, it triggers automatic alerts based on health metrics like heart rate and temperature. Additionally, real-time monitoring through cloud integration provides continuous updates, and its low-power design ensures longer battery life. These features make the proposed system more reliable and efficient in ensuring women's safety.

TABLE II. COMPARATIVE STUDY OF IOT-BASED WOMEN SAFETY DEVICES

Feature	**[1]**	**[2]**	**[3]**	**[5]**	**Proposed System**
GPS Accuracy	Limited	Basic GPS	Inaccurate in some cases	Basic GPS	Nearest police station via Haversine formula
Emergency Alerts	Manual	Manual /Auto	Auto	Health-based alerts	Automatic alerts with vitals & location
Health Monitoring	No	No	No	Yes	Yes
Real-Time Monitoring	No	No	No	Yes	Yes
Power Efficiency	M	M	M	High power consum.	Low power consum.
N.B. M means Moderate.					

IV. CONCLUSION

This paper presents the development of an IoT-based women's safety device that integrates multiple sensors and communication modules to provide real-time monitoring and emergency assistance. The system uses heart rate and temperature sensors, GPS for location tracking, and GSM for sending alerts. A key feature is the use of the Haversine formula to identify the nearest police station, improving response times significantly. During testing, the device reliably detected emergencies when heart rate exceeded 220 BPM or temperature surpassed 40°C, automatically triggering alerts. The real-time location tracking system accurately calculated distances to police stations and successfully sent alerts to both authorities and family members. The device's performance demonstrated high accuracy, with heart rate measurements closely matching those of a certified hospital device, deviating by only small margins, such as 115.38 BPM compared to 135 BPM. Additionally, practical tests confirmed successful emergency alert transmissions and real-time monitoring of vitals and location data on a cloud-based server.

However, the system's reliance on GSM networks poses a limitation in areas with poor connectivity, which could delay alert transmission. Future work will focus on enhancing communication reliability by integrating alternative networks, such as LoRaWAN or satellite communication, and further improving sensor accuracy and battery efficiency for extended use in real-world conditions.

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