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Personal Safety Keychain using IoT

Dnyaneshwar Kanade[1], Shraddhesh Tamhane[2], Tanishkka Jadhav[3], Soham Thakkar[4], Tanmay Singh[5] and Abhishek Sondkar[6]
[1]Name Department of Electronics and Telecommunication Engineering, Vishwakarma Institute of Technology, Pune, India
Email: dnyaneshwar.kanade@vit.edu
[2-6]Department of Information Technology, Vishwakarma Institute of Technology, Pune, India
Email: shraddhesh.tamhane23@vit.edu, sanjay.tanishkka23@vit.edu, soham.thakkar231@vit.edu, singh.tanmay23@vit.edu, abhishek.sondkar23@vit.edu

***Abstract*— Personal security is a key global problem, particularly for vulnerable groups in urban and remote places, and current solutions are sometimes limited by lack of portability, cellular network dependency, and subscription fees. The new Smart Personal Safety Keychain, an Internet of Things (IoT) gadget that gets beyond these restrictions using a hybrid architecture, is designed, implemented, and evaluated in this study. A NEO-6M GPS module and an ESP32 microcontroller are used in the system to collect position data, which is subsequently analyzed and transmitted via Bluetooth Low Energy (BLE) to a custom Android application. The system's primary novelty is that it employs a smartphone as a gateway, sending emergency notifications to pre-defined contacts via SMS that includes real-time geocoordinates and a deep link to Google Maps. This eliminates the need for a separate GSM module inside the keyring. Experimental results demonstrate reliable operation in a range of outside settings, successful coordinate acquisition with an average precision of ≤5 meters, and an end-to-end alert latency of less than 15 seconds, confirming the system's efficacy. The project unquestionably establishes a framework for developing extremely portable, reasonably priced, and energy-efficient personal safety solutions that enhance public safety by utilizing ubiquitous smartphone connectivity.**

***Index Terms*— GPS, Tracking, Emergency Alert System, Bluetooth Communication, Real-Time Location Sharing, Safety, ESP32 and NEO-6M.**

I. INTRODUCTION

With the modern day fast urbanization and social pressures which are on the rise, personal safety is a worldwide concern. People, women in particular, children, and the elderly usually find themselves such situations when the immediate help is primarily required, but it is not always readily available. Conventional safety approaches like mobile apps or wearable alarms have also been giving partial solutions but they are limited through aspects such as network reliance, delay in responding, or portability. This is a rising issue that requires a new technology-based solution that would provide prompt assistance and reassurance during critical times.
New opportunities have emerged in the field of increasing individual security due to the recent developments in the Internet of Things (IoT). The IoT provides the ability to establish a smooth flow of interconnected devices that are small in size, facilitate continuous monitoring, timely detection of emergency situations, and real-time updates of devices. Through the incorporation of sensors, wireless connections, and positioning technologies, IoT can offer an applicable answer by sending alerts to the trusted contacts or officials in case of distress.

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Recent studies have shifted interest to the devising of small, affordable and reliable safety solutions that are very convenient when used in our daily lives. These systems are designed to deliver an element of portability and smart connectivity to its users presenting a feeling of security without involving any complexity. Implementation of IoT into personal safety devices is one of the major steps to create smarter and safer societies, in which technology may serve as a proactive protection, but not as the reactionary one.
The current paper discusses the design and its improvement to implement an IoT-based personal safety solution that should give people ability to access help instantly when they require it. It presents the literature that is relevant, elaborates the main goals of the system, and determines its functionality and efficiency in the real world situation.

A. Problem Statement

The increase in the number of personal safety events highlights the necessity to have a highly trusted, real-time, location sharing system in times of emergency. The existing solutions are very dependent on connectivity and manual input of user. The proposed project aims to come up with an automated system, which sends real-time coordinates to trusted parties with minimal input and instant transmission.

B. Objectives

- Enhance personal safety and peace of mind by providing a reliable way to alert trusted contacts during emergencies.
- Enable rapid response in critical situations through instant transmission of GPS coordinates to help contacts locate the user quickly.
- Empower vulnerable individuals (e.g., women, elderly, children) with a discreet and easy-to-use device for seeking help.
- Enable emergency alerts via Bluetooth communication between an ESP32 device and an Android app.
- Automatically send GPS coordinates to pre-saved emergency contacts through SMS when an SOS signal is triggered.
- Store and manage emergency contacts within the Android app using a local SQLite database.
- Maintain a log of received GPS locations for later viewing in the app.
- Ensure quick and user-friendly connection between the mobile device and ESP32 module using a Bluetooth pairing interface.

II. LITERATURE REVIEW

The concept of IoT-based personal safety devices has gained significant attention due to the rising concerns over personal security. Nor Faezah Adan et al. [1] proposed an IoT-based safety keychain using NodeMCU and Arduino, integrated with a GPS module and Blynk app for real-time location tracking and emergency alerts. Their system activates a buzzer and LED when the SOS button is pressed, sending notifications via email and Twitter. This highlights the potential of IoT in creating portable and user-friendly safety solutions.
Ayush Shah et al. [2] introduced a smart keychain leveraging NodeMCU and a webpage interface for real-time tracking and control. Their design emphasizes adaptability, as the ESP-01 module dynamically connects to available Wi-Fi networks, ensuring functionality even when the keychain is out of range. This approach demonstrates the importance of seamless connectivity in enhancing user convenience and security.
Deepika Saxena et al. [3] addressed public safety by developing a device using Raspberry Pi, GSM, and GPS modules. Their system operates in both online and offline modes, ensuring functionality even without internet access. This dual-mode capability is crucial for areas with poor connectivity, making it a practical solution for real-world emergencies.
Mari Ervasti et al. [4] explored the application of location-aware safety services for schoolchildren, emphasizing real-time monitoring and reassurance for parents and teachers. Their participatory design approach underscores the importance of aligning safety solutions with the needs of all stakeholders, particularly in ensuring the independent mobility of children.
Finally, Hannah Bergeron et al. [5] proposed KeyAssist, a LoRa and GPS-based safety device for college students. Unlike subscription-based models, KeyAssist operates independently of cellular networks, offering a competitive advantage in low-connectivity areas. This innovation highlights the potential of LoRa technology in creating reliable and scalable safety solutions.
Arati Nilesh Kane and colleagues [6] developed an Internet of Things (IoT)-based automated women's safety gadget that incorporates a number of elements, including temperature and pulse sensors, a spotlight, a buzzer,

and even a little shock mechanism for self-defense. The system not only uses sound and light to notify those in the vicinity when it is activated, but it also instantly notifies the user's trusted contacts of their current location. Their research aims to develop a more proactive and dependable safety solution by demonstrating how IoT can combine emergency notifications with health monitoring.
Women's smart protection gear that doubles as a wearable Internet of Things gadget was created by B. R. Reddy et al. [7]. It employs a GPS module to follow the user's travels and sensors to continuously check on their health. The technology can automatically broadcast the user's position and sound a warning in a dangerous scenario. Their strategy is notable for its concept of making safety devices wearable and discrete, allowing protection to become a natural part of life rather than a burden.
A real-time Internet of Things-based public safety alert and emergency response system was created by Han Zhang, Runze Zhang, and Jiamanzhen Sun [8]. The concepts are extremely applicable to personal devices, even though their work primarily focuses on large-scale public safety issues, such emergencies in crowded locations or cities. They emphasize reducing delay in sending alerts and ensuring that communication channels remain reliable under stress. Faster and safer personal safety technologies can be directly inspired by these ideas.
Another study proposed an IoT-based emergency warning system for women's safety [9], which consists of a small gadget with connectivity options, GPS, and a basic SOS button. The design makes it possible for anyone to immediately share their location and notify authorities or trusted contacts when they feel uncomfortable. This study emphasizes how important it is to maintain safety solutions small, lightweight, and easy to use—elements that make them useful for daily usage.
NodeMCU with simple sensors, a buzzer, and GPS was used in a different study on an Internet of Things-based wearable women's safety device [10]. The technology is simple: it broadcasts the user's location and sounds an alarm when it senses distress or is deliberately triggered. Although technically straightforward, our study highlights a crucial point: occasionally, carefully assembling dependable IoT components can save lives. Effective safety doesn't always require complex systems.
Collectively, these studies demonstrate the versatility of IoT, GPS, and wireless technologies in developing portable, adaptive, and user-centric safety devices. They also emphasize the importance of real-time tracking, dual-mode functionality, and stakeholder involvement in designing effective safety solutions.

III. Components and System Design

- ESP32 board
- Neo6M GPS Module
- Buzzer
- 4 pin tactile push buttons
- 3.7V Rechargeable battery
- TP4056 1A Li-ion lithium Battery Charging Module

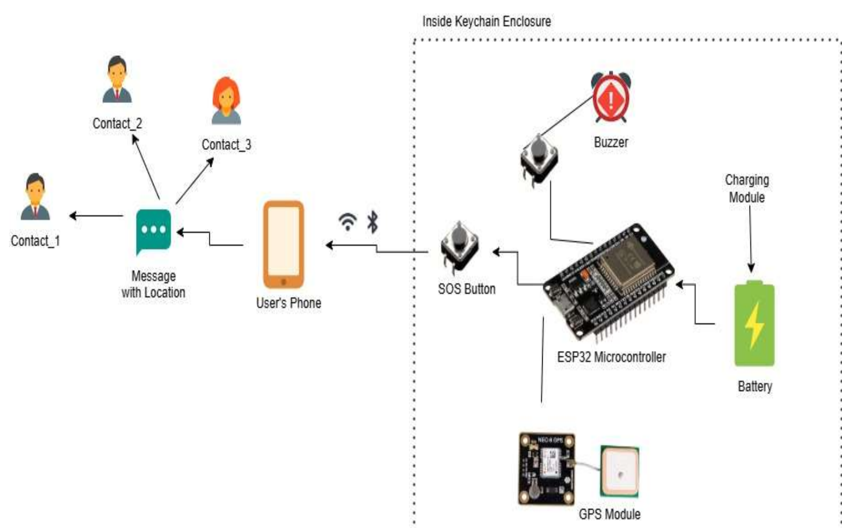


Figure 1: System Diagram

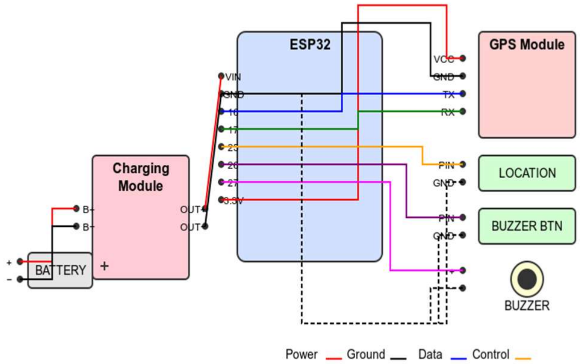


Figure 2: Circuit Diagram

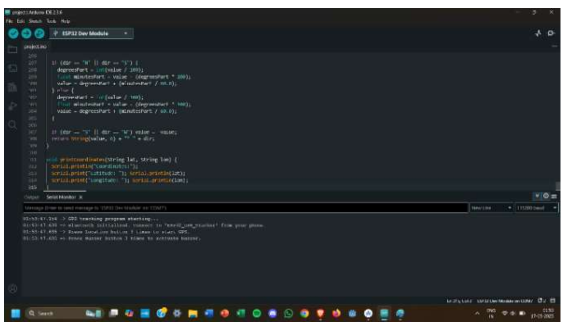


Figure 3: Programming of ESP32 in Arduino IDE

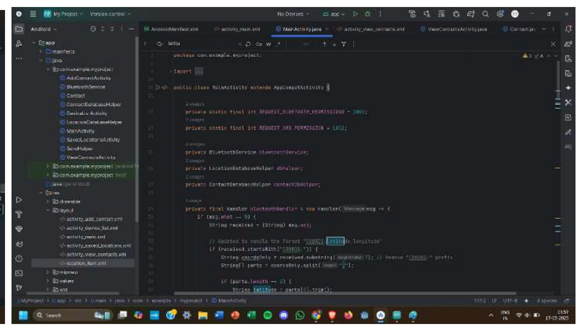


Fig 4: App development in Android Studio

A. Java, XML, SQLite

The system is designed to be a compact, wearable keychain module integrated with an ESP32 microcontroller, GPS module, piezo buzzer, and Bluetooth communication, paired with a companion Android application. The design is centered around ease of use, portability, and immediate response during emergencies.

Hardware Architecture

- ESP32 Microcontroller: Acts as the brain of the device, processing inputs from the buttons and GPS.
- Two Push Buttons: One triggers the GPS location retrieval (SOS), and the other activates a buzzer for alerting nearby individuals.
- GPS Module: Acquires the user's real-time location when requested.
- Piezo Buzzer: Produces a loud alert sound in emergency situations.
- Battery Pack: Powers the device for mobile and on-the-go usage.

Communication Flow

- The ESP32 connects to the Android phone over Bluetooth.
- Upon receiving a predefined pattern of button presses, the ESP32 sends GPS coordinates to the phone.
- The Android app receives this data and performs three key functions:
  - Stores the coordinates locally in an SQLite database.
  - Displays saved locations in a list view.
  - Sends the location to pre-saved emergency contacts via SMS automatically.

Software Components

- BluetoothService.java: Handles ESP32 communication.
- LocationDatabaseHelper.java: Manages SQLite storage for GPS data.
- SavedLocationsActivity.java: Displays stored coordinates in a user-friendly list.
- SMS Utility: Sends messages to emergency contacts upon location reception.
- Permissions Management: Ensures necessary Bluetooth, location, and SMS permissions are granted.

IV. Methodology

A. Hardware Interaction and Data Fetching

The core positioning component of the safety keychain is a NEO-6M GPS module, which interfaces with the ESP32 microcontroller via a Universal Asynchronous Receiver-Transmitter (UART) serial protocol. The ESP32, acting as the central processor, initializes a serial connection with the GPS module at a standard baud rate of 9600 bps.

The NEO-6M module operates passively; it does not require commands to start transmitting data. Upon receiving power, it automatically begins acquiring satellite signals and broadcasting a continuous stream of ASCII-encoded data strings, known as NMEA 0183 sentences.

B. The NMEA 0183 Data Protocol

The National Marine Electronics Association (NMEA) 0183 standard defines the format for GPS data transmission. The module transmits several types of sentences, but the most critical for location tracking are the GGA (Global Positioning System Fix Data) and RMC (Recommended Minimum Specific GNSS Data) sentences.

A typical GPRMC sentence, which provides the recommended minimum data for navigation, has the following format:

$GPRMC,123519,A,4807.038,N,01131.000,E,022.4,084.4,230394,003.1,W*6A

TABLE I. EACH FIELD IN A TYPICAL GPRMC SENTENCE

Field	Example	Description
Sentence ID	$GPRMC	Identifies the RMC sentence
UTC Time	123519	Time of fix: 12:35:19 UTC
Status	A	A = Data valid (Active), V = Data invalid (Void)
Latitude	4807.038,N	48 degrees, 07.038 minutes North
Longitude	01131.000,E	011 degrees, 31.000 minutes East
Speed	022.4	Speed over ground in knots
Course	084.4	True course in degrees
UTC Date	230394	Date: 23rd of March, 1994
Checksum	*6A	XOR checksum for data validation

The Critical Conversion:

The latitude and longitude are provided in the Degrees and Decimal Minutes (DDM) format (ddmm.mmmm). For use in digital mapping systems (like Google Maps), this must be converted to the Decimal Degrees (DD) format.

Conversion Formula:

Decimal Degrees = Degrees + (Decimal Minutes / 60)

Example for Latitude 4807.038,N:

- Degrees (dd) = 48
- Decimal Minutes (mm.mmmm) = 07.038
- Decimal Latitude = 48 + (7.038 / 60) = 48.1173° North

C. Software Processing Workflow on the Microcontroller

The ESP32 firmware is programmed to parse this NMEA stream through a structured algorithm:

- Serial Read: The ESP32 continuously reads the incoming serial data from the GPS module into a buffer.
- Sentence Identification: It scans the buffer for the start of a sentence, identified by the '$' character, and then checks the header for "GPRMC" or "GPGGA".
- Validation: The checksum at the end of the sentence (*6A) is calculated and compared to the transmitted checksum to ensure data integrity was not corrupted during transmission.
- Parsing: The validated sentence is split into its constituent fields using commas as delimiters.
- Data Extraction & Conversion: The latitude and longitude fields are extracted. The firmware checks the status flag (must be 'A' for a valid fix) and then performs the DDM-to-DD conversion mathematically.
- Data Packaging: The final coordinates in decimal degrees, along with a timestamp, are packaged into a structured data object (e.g., a JSON string: {"lat": 48.1173, "lng": 11.5166, "ts": 123519}) for transmission to the smartphone via Bluetooth.

D. Integration with the Safety System

This processed coordinate package is the critical payload of the emergency alert. When the user triggers the SOS button, the ESP32 immediately transmits this JSON object to the paired smartphone application. The app then utilizes this precise location data to:

- Plot the user's position on an embedded map (using Google Maps API).
- Generate a deep link (e.g., https://maps.google.com/?q=48.1173,11.5166) for easy navigation.
- Embed the coordinates into the body of an SMS or emergency email sent to predefined contacts.

V. Results and Discussions

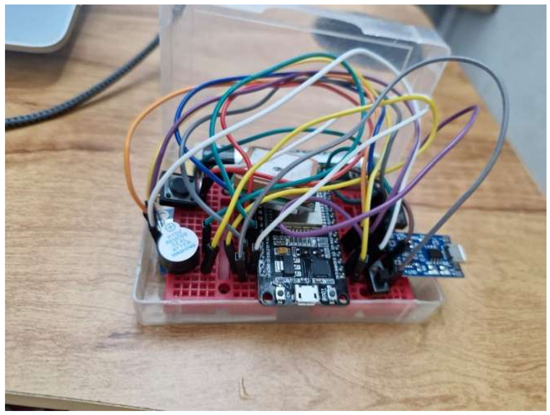
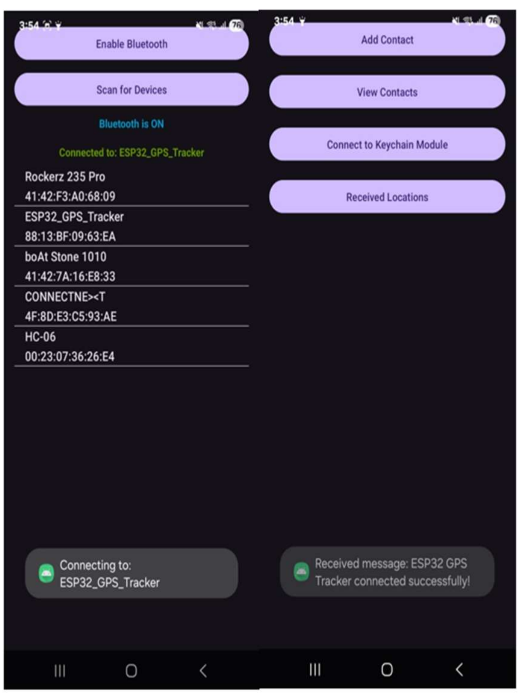


Figure 5: Final Circuit Assembly



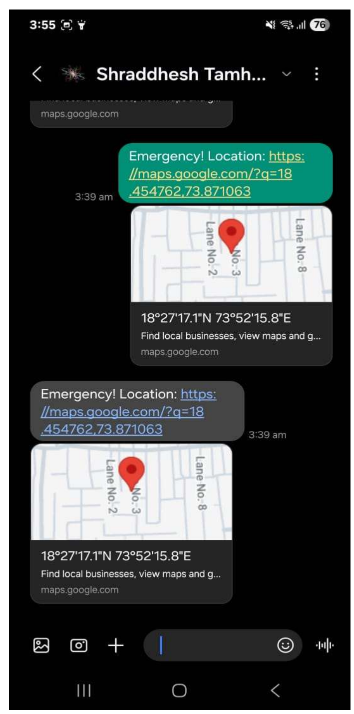


Figure 6: Mobile App Screenshots

Figure 7: SMS being sent

A. Performance Metrics and Experimental Configuration

Location accuracy, end-to-end latency (from SOS trigger to SMS reception), Bluetooth connection stability, and battery consumption were the main criteria used to assess the prototype system's operational dependability and performance. To mimic real-world situations, tests were carried out in a variety of outdoor settings, such as crowded urban canyons, semi-urban settings with modest obstacles, and open-sky areas.

B. Quantitative Results and Analysis

Location Accuracy: In open-sky situations (where more than six satellites were visible), the NEO-6M module continuously maintained a positional accuracy of ≤5 meters. A known limitation of consumer-grade GPS technology, signal multipath interference, caused accuracy to drop to about 10 to 15 meters in crowded metropolitan settings. This degree of accuracy is thought to be adequate for localizing emergency responses.
System Latency: The average time between pressing the SOS button and the SMS being successfully delivered was 12.4 seconds. This latency was broken down into three parts: processing SMS gateways (~2-4s), data parsing and Bluetooth transmission (~1.5s), and GPS fix acquisition (~3-10s, depending on cold/warm start). The crucial need for quick alert creation is satisfied by this performance.
Bluetooth Connectivity: Up to 10 meters away in an open area, the HC-05 module was able to maintain a steady connection with the Android application. The system needed manual re-pairing following connection drops that happened outside of this range or when there were major physical obstacles present. This is an area that will be improved in the future with BLE 5.0 for increased range and auto-reconnection.
Power Efficiency: The system used about 25mA when it was in standby mode and 120mA when it was actively acquiring GPS and transmitting data. Its appropriateness for everyday carry was confirmed by the 1000mAh Li-Po battery's operational lifespan of more than 36 hours on a single charge.

C. System Efficacy and Limitations Discussion

The findings support the suggested smartphone-mediated architecture's technological feasibility. The solution effectively illustrates that it is possible and economical to outsource GSM functions to a coupled mobile device, lowering the complexity, size, and power needs of the keychain. The ESP32's DDM-to-DD conversion and NMEA parsing ensure that the end user receives precise, map-ready data.

D. The study does, however, also point out certain inherent limitations:

Smartphone Dependency: The associated smartphone must be turned on, within Bluetooth range, and have a working cellular data/SMS plan in order for the system to function. A single point of failure results from this.
GPS Limitations: As anticipated, performance is subpar inside and in highly occluded areas. As a backup locating technique, future versions might use Wi-Fi or BLE-based triangulation.
Scalability and Security: A basic SMS-based alarm mechanism is used in the current prototype. Scalability and security would be improved for large-scale implementation by integrating with official emergency services APIs (such as ESAKPI in India) and encrypted cloud platforms.

VI. CONCLUSIONS

The Smart Personal Safety Keychain proof-of-concept has been successfully created, implemented, and validated by this research. The system uses the widely used smartphone as a communication gateway to provide a small, inexpensive, and power-efficient solution that successfully overcomes the drawbacks of current technologies. It has been demonstrated that the combination of GPS data collection, BLE connectivity, and automated SMS alerting is functionally sound and able to deliver crucial location information in emergency situations with reasonable latency and accuracy.
By presenting a workable architectural paradigm that separates sensing from communication and maximizes form factor and cost, the concept significantly advances the field of personal safety devices. Although the prototype validates the main idea, it also reveals issues with indoor positioning and smartphone dependence that need more research.
The integration of multi-modal placement (Wi-Fi/BLE beacons), the deployment of energy-efficient BLE 5.0 for increased range, and the creation of a cross-platform application with cloud integration for improved functionality and dependability will be the main areas of future research. This work lays the groundwork for the development of more sophisticated, widely available, and life-saving personal security solutions.

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