An IoT-Enabled Barangay Panic Button System Using ESP32-C3 with Verified Email Alert and Cloud-Based Logging

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ABSTRACT

Community-level emergency response systems play a vital role in ensuring public safety, particularly in barangays where timely and accurate communication during emergencies is essential. Conventional incident reporting methods, such as phone calls or personal visits to barangay offices, often lead to delayed responses and poor coordination. This study presents the design and implementation of an Internet of Things (IoT)–based Barangay Panic Button System using an ESP32-C3 microcontroller integrated with a GPS module, verified email alert transmission, and cloud-based logging.

The proposed system utilizes a push-button mechanism as the primary emergency trigger, allowing residents or authorized personnel to manually initiate alerts during critical situations. Under normal operation, a green LED indicates system readiness. When the panic button is pressed, the GPS module acquires the exact geographical location of the incident without requiring internet connectivity. The ESP32-C3 then uses a Wi-Fi connection to transmit the emergency alert, including the GPS coordinates, to the Brevo email platform.

Unlike conventional alert systems, the device is programmed to activate visual and audible feedback only after successful email delivery. Upon confirmation, a red LED blinks while a buzzer sounds for a fixed duration of ten seconds, assuring the user that the alert has been successfully transmitted and recorded. Emergency notifications are received via email and automatically logged within the Brevo dashboard, providing access to delivery status, event history, and system statistics.

While existing IoT-based emergency systems demonstrate the effectiveness of push-button alerts (Prayoko et al., 2019; Khanna & Sharma, 2017), many lack location accuracy, delivery verification, and centralized logging. By integrating manual activation, GPS-based location tracking, verified email delivery, and cloud-based logging, the proposed system offers a low-cost, reliable, and scalable emergency reporting solution suitable for barangay-level deployment.

Keywords: IoT Emergency System, Panic Button, ESP32-C3, GPS-Based Location, Verified Email Alert, Cloud Logging, Community Safety

INTRODUCTION

Background of the Project

Barangays function as the smallest administrative and governance units and play a critical role in maintaining community safety and responding to emergencies. During incidents such as crimes, medical emergencies, domestic violence, or natural disasters, immediate and accurate communication with barangay officials is essential. However, traditional emergency reporting methods commonly used at the barangay level—such as phone calls, text messages, or in-person reporting—often suffer from delayed responses, unreliable connectivity, and insufficient documentation of incidents.

Advancements in Internet of Things (IoT) technology have enabled the development of low-cost emergency alert systems capable of delivering notifications quickly through wireless communication. Push-button–based emergency systems have been widely recognized as effective solutions for rapid incident reporting, particularly in public safety and personal security applications (Prayoko et al., 2019; Padma & Anitha, 2025). These systems allow users to trigger alerts with minimal physical effort, which is especially important during high-stress or life-threatening situations.

Despite these technological developments, many existing IoT-based emergency alert systems focus solely on sending notifications without confirming whether alerts have been successfully delivered or recorded. Systems relying on SMS, GSM, or basic email transmission frequently lack delivery verification and centralized logging, reducing reliability, accountability, and user confidence (Khanna & Sharma, 2017). Moreover, several GSM- or internet-dependent location-based systems incur higher operational costs and depend heavily on stable cellular or network connectivity, which may not always be available in certain barangay areas.

To address these limitations, this project presents an IoT-enabled Barangay Panic Button System using an ESP32-C3 microcontroller integrated with a Global Positioning System (GPS) module, verified email alert transmission, and cloud-based logging through the Brevo platform. The GPS module enables the system to obtain precise geographical location data without requiring internet connectivity, ensuring accurate location acquisition even in offline conditions. Once the emergency trigger is activated, the ESP32-C3 utilizes Wi-Fi connectivity to transmit the alert message, including the GPS coordinates, via email. By activating visual and audible feedback indicators only after successful message delivery, the system enhances reliability, user assurance, and overall effectiveness. The inclusion of cloud-based logging further supports monitoring, record-keeping, and post-incident analysis, making the system suitable for barangay-level emergency response and community safety improvement.

Importance and Relevance of the Study

This study demonstrates the practical application of Internet of Things (IoT) and embedded system technologies in improving emergency communication at the barangay level. In many communities, emergency incidents are still reported using traditional methods that are prone to delays, miscommunication, and lack of proper documentation. These limitations can significantly affect response time and the effectiveness of emergency interventions.

The proposed Barangay Panic Button System provides a simple, direct, and reliable method for requesting immediate assistance through a physical push-button interface. By integrating a GPS module, the system ensures that the exact location of an emergency is captured even without internet access, addressing a critical gap in many existing emergency alert solutions. This feature significantly improves response accuracy by enabling barangay officials to quickly identify and locate the incident site.

From a system design perspective, the study emphasizes the importance of user-initiated input devices, particularly the push button, as the primary mechanism for triggering emergency alerts. Unlike automated sensor-based systems, the push button allows residents to consciously and intentionally signal distress, making it suitable for incidents such as crimes, medical emergencies, and public disturbances where human judgment is essential. The ESP32-C3 microcontroller processes the push-button input, retrieves GPS data, and uses its built-in Wi-Fi capability to transmit emergency information in real time.

The relevance of this study is further strengthened by its implementation of verified alert transmission and cloud-based logging. Through integration with the Brevo email platform, the system ensures that alerts are not only sent but also confirmed and recorded. Visual and audible indicators, such as LEDs and a buzzer, are activated only after successful email delivery, providing immediate feedback and increasing user trust. This approach addresses common shortcomings of existing panic button systems that lack confirmation mechanisms and reliable event documentation.

Additionally, this study contributes to Computer Engineering education and applied research by showcasing the use of the ESP32-C3 platform, which is widely adopted in modern IoT development due to its low cost, energy efficiency, and secure wireless communication capabilities. The project serves as a practical example of embedded programming, GPS integration, event-driven system design, wireless communication, and cloud-based services. As such, it is suitable for academic demonstrations, barangay-level deployment, and future expansion, including integration with databases, dashboards, or mobile applications.

REVIEW OF RELATED LITERATURE

IoT-Based Emergency and Panic Button Systems

Panic button systems are designed to enable individuals to quickly request assistance during emergency situations. Traditional implementations are often limited to local alarms and lack remote notification, confirmation, and event documentation. With the advancement of Internet of Things (IoT) technologies, modern panic button systems have evolved to support wireless communication, real-time alert transmission, and remote monitoring, making them more effective for community-level emergency response.

Prayoko et al. (2019) developed an IoT-enabled panic button system for smart city security applications using a NodeMCU ESP8266 microcontroller. Their system allowed users to manually trigger emergency alerts through a physical push button, which were transmitted wirelessly to a centralized monitoring platform. The study demonstrated that push-button–based emergency systems can significantly reduce response time and improve coordination among responders. However, reliance on continuous web-based dashboard monitoring limited its practicality for smaller-scale deployments such as barangays.

Similarly, Khanna and Sharma (2017) proposed a low-cost IoT panic button system for personal safety applications that delivered alerts via email and SMS. Their findings highlighted the effectiveness of manual trigger mechanisms, particularly in situations where automated detection is unsuitable. Despite its simplicity, the system lacked delivery verification, precise location tracking, and centralized logging, reducing its reliability during real emergency situations.

Email-Based Notification and Cloud Logging Systems

Embedded systems play a vital role in community safety applications due to their ability to process real-time input and control output devices efficiently. Monk (2022) emphasized that microcontroller-based platforms are well suited for event-driven applications involving human interaction, such as push-button controls and alert signaling.

Several emergency alert systems incorporate GPS technology to improve response accuracy; however, many depend on continuous internet or cellular connectivity to function. In contrast, GPS modules are capable of obtaining location data independently, making them suitable for environments with limited network availability. Integrating offline GPS functionality with online alert transmission provides a more reliable and flexible emergency response solution.

While many existing studies focus on sensor-based automation or notification-only systems, the current study integrates a human-triggered push button, offline GPS-based location tracking, verified email delivery, and cloud-based logging into a single embedded IoT platform using an ESP32-C3 microcontroller. This integrated approach enhances system usability, reliability, and suitability for barangay-level emergency response, effectively addressing limitations identified in previous research.

Embedded Systems and Feedback Control in IoT Applications

Embedded systems play a vital role in community safety applications due to their capability to process real-time inputs and control output devices efficiently. Monk (2022) emphasized that microcontroller-based platforms are well suited for event-driven systems involving human interaction, such as push-button controls. Unlike many existing alert-only or sensor-based systems, this study integrates a human-triggered push button, offline GPS-based location acquisition, wireless communication, delivery verification, and user feedback indicators into a single embedded IoT platform, improving reliability, usability, and suitability for barangay-level emergency response.

Table 1. Comparison Matrix of Related Studies and Current Research

Study	Sensors Used	Controller	Main Outputs	Scope	Key Features	Gap Addressed by This Study
Prayoko et al. (2019)	Push button	NodeMCU ESP8266	Web-based emergency alerts	Smart city and public safety	Push-button activation with wireless data transmission	Requires continuous web dashboard monitoring; lacks delivery confirmation and user feedback
Khanna & Sharma (2017)	Push button	Microcontroller	SMS and email notifications	Personal safety applications	Low-cost push-button alert system	No confirmation of alert delivery; absence of centralized logging
Padma & Anitha (2025)	IoT emergency alert system with panic button	IoT-enabled controller	Alerts sent to caregivers	Senior citizen safety	Manual panic button combined with IoT monitoring	Focused on home-based care; no verified email delivery or cloud-based event records
GSM/GPS-based emergency alert systems	GSM and GPS communicatio n	GSM/ESP controllers	SMS with location data	Personal emergency response	Real-time location tracking	High operational cost; dependent on cellular networks; no alert verification or

						feedback
Current Study (An IoT-Enabled Barangay Panic Button System Using ESP32-C3 with Verified Email Alert and Cloud-Based Logging)	IoT push-button system with GPS and Wi-Fi email transmission	ESP32-C3 microcontroller	Verified email alert with LED and buzzer feedback	Barangay-level emergency response	Push-button activation, offline GPS location acquisition, verified email delivery, cloud-based logging	Integrates manual emergency signaling, location tracking, delivery verification, user confirmation, and event logging in a single low-cost IoT system

PROBLEM STATEMENT AND OBJECTIVES

Problem Statement

Many barangays continue to rely on traditional emergency reporting methods such as phone calls, verbal communication, or physical reporting at the barangay hall. These methods are often ineffective during urgent situations, particularly when communication networks are unavailable, responders are not immediately reachable, or residents are under stress.

Existing low-cost panic button systems primarily focus on sending alerts without confirming successful delivery. The lack of verification and centralized event logging reduces system reliability and creates uncertainty for both users and responders. Furthermore, several systems depend heavily on mobile applications, dashboards, or cellular networks, which may not be feasible or reliable for barangay-level operations.

There is a need for an IoT-enabled emergency alert system that allows residents to manually trigger alerts, acquire accurate location information without internet dependency, ensure reliable message delivery, and provide confirmation-based feedback. Integrating push-button input, GPS-based location tracking, wireless communication, and cloud-based verification within an embedded system can significantly improve emergency reporting and response at the barangay level.

General Objective

To design and implement an IoT-enabled Barangay Panic Button System using an ESP32-C3 microcontroller with push-button activation, GPS-based location tracking, verified email alert transmission, and cloud-based logging.

Specific Objectives

- To design a panic button device using a push button as the primary emergency input
- To acquire accurate location data using a GPS module that operates without internet connectivity
- To process push-button activation and GPS data using an ESP32-C3 microcontroller
- To transmit emergency alerts via email using a Wi-Fi connection
- To verify successful alert delivery through a cloud-based email platform
- To provide visual and audible feedback only after confirmed message delivery

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- To log emergency events for monitoring, verification, and documentation purposes

SYSTEM DESIGN AND METHODOLOGY

Research Design

This study employed a developmental and experimental research design focused on the design, construction, and evaluation of a push-button–based IoT emergency alert system integrated with GPS functionality. A functional prototype was developed to demonstrate how manual user input can trigger verified emergency alerts containing accurate location information. Controlled testing was conducted to evaluate system responsiveness, GPS accuracy, communication reliability, and feedback behavior, ensuring suitability for barangay-level deployment.

Input–Process–Output (IPO) Model

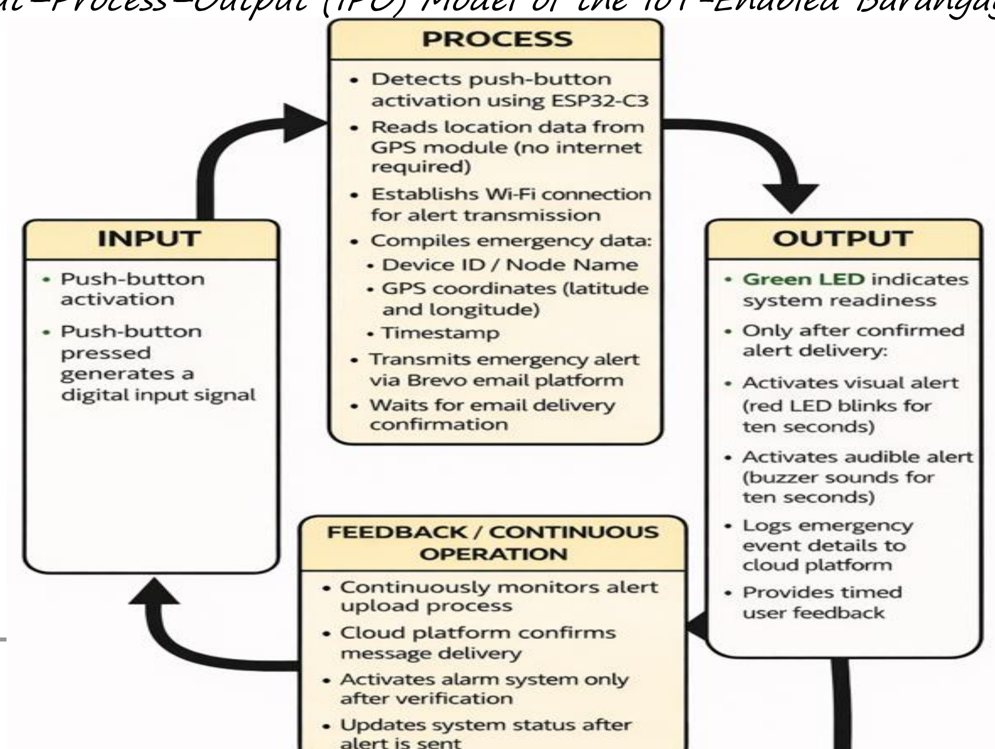
The Barangay Panic Button System operates based on the Input–Process–Output (IPO) model.

At the input stage, a physical push button serves as the primary user interface. When pressed, the button generates a digital input signal indicating an emergency condition. This design enables residents to intentionally and immediately request assistance during critical situations.

At the processing stage, the ESP32-C3 microcontroller detects the push-button activation and retrieves location data from the integrated GPS module. The GPS module acquires precise latitude and longitude coordinates independently, without requiring internet connectivity. Once valid location data is obtained, the ESP32-C3 initiates a Wi-Fi connection to transmit emergency information, including device identification and GPS coordinates, to the Brevo email platform. The system incorporates verification logic that waits for successful email delivery before proceeding to output activation.

At the output stage, system indicators respond based on the processing result. A green LED remains illuminated during normal operation to indicate system readiness. After email delivery is successfully confirmed, a red LED blinks and a buzzer sounds for a duration of ten seconds, providing clear confirmation that the emergency alert has been sent and logged. This event-driven feedback mechanism enhances user confidence and ensures reliable emergency communication for barangay-level applications.

Figure 1. Input–Process–Output (IPO) Model of the IoT-Enabled Barangay Panic Button System



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System Architecture

The proposed system is designed as a closed-loop IoT-based emergency alert system composed of three main subsystems: input, processing, and output with feedback. The overall architecture follows established principles of embedded system design and Internet of Things (IoT) communication, where user-initiated input and cloud-based verification mechanisms are used to regulate system behavior and ensure reliable emergency alert transmission (Monk, 2022; Al-Fuqaha et al., 2015).

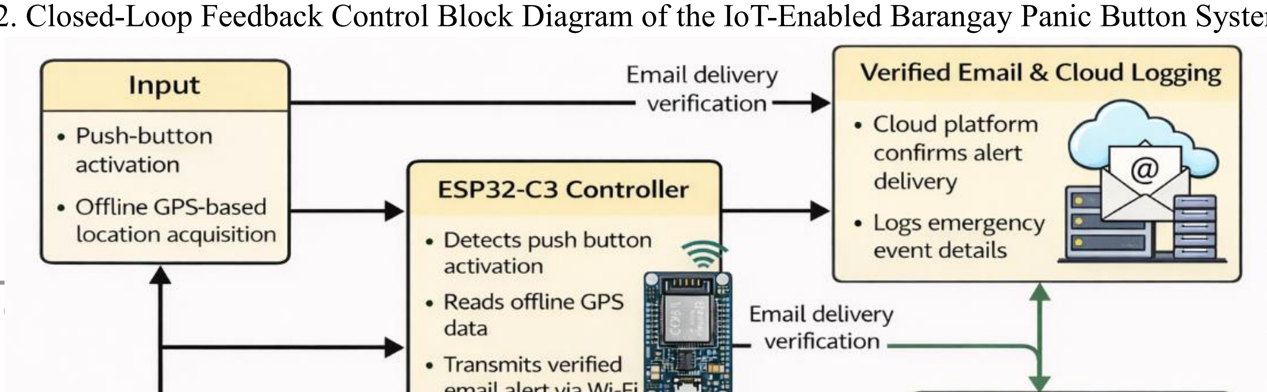
The input subsystem consists of a physical push button that serves as the primary emergency trigger and a GPS module for location acquisition. When pressed, the push button generates a digital signal indicating an emergency condition. The GPS module continuously acquires geographical coordinates and operates independently of internet connectivity, allowing accurate location data to be obtained even in areas with limited network availability. This combination ensures intentional user activation and precise location reporting during emergency situations.

The processing subsystem is implemented using an ESP32-C3 microcontroller, which detects push-button activation and retrieves location data from the GPS module. The microcontroller compiles emergency information, including device identification, GPS coordinates, and a timestamp. Using its built-in Wi-Fi capability, the ESP32-C3 transmits the emergency alert via the Brevo email platform. A verification-based logic is implemented wherein the system waits for confirmation of successful email delivery before activating output indicators. This design improves system reliability and reduces uncertainty for both users and responders (Monk, 2022).

The output and feedback subsystem consists of visual and audible indicators that provide confirmation to the user. A green LED indicates system readiness, while a red LED and buzzer are activated only after the cloud platform confirms successful alert delivery. Emergency event details are automatically logged within the cloud-based email platform, enabling monitoring, documentation, and post-incident analysis. The continuous exchange of status information between the device and the cloud platform forms a closed-loop operational structure that enhances accountability, usability, and reliability in barangay-level emergency response systems (Al-Fuqaha et al., 2015).

Block Diagram

Figure 2. Closed-Loop Feedback Control Block Diagram of the IoT-Enabled Barangay Panic Button System



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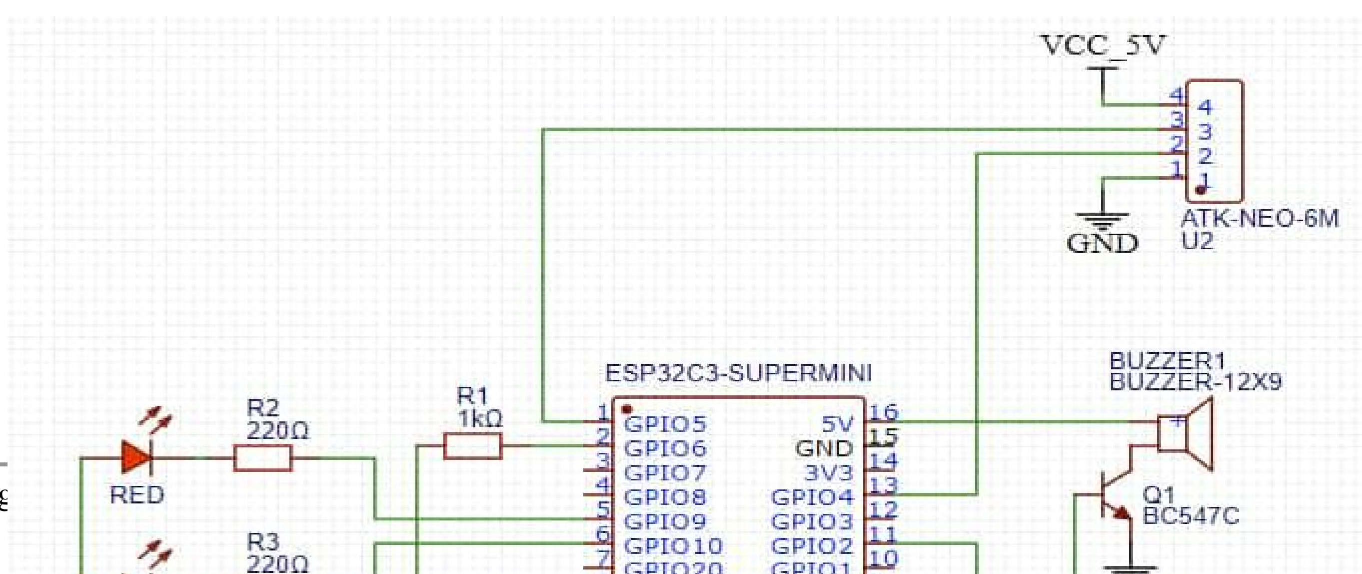
The proposed system is considered a closed-loop IoT-based emergency alert system designed to support reliable barangay-level emergency reporting. A physical push button serves as the primary emergency input, while a GPS module provides real-time location data. These components interface with an ESP32-C3 microcontroller, which continuously monitors user input and system status. Once the push button is pressed, the controller processes the event as an emergency condition and initiates the alert transmission procedure.

Upon activation, the ESP32-C3 retrieves precise latitude and longitude coordinates from the GPS module, which operates independently of internet connectivity. The microcontroller then establishes a Wi-Fi connection to transmit the emergency alert, including device identification, timestamp, and location data, to the Brevo email platform. A verification-based control strategy is implemented, wherein the system waits for confirmation of successful email delivery before activating output indicators. This ensures that alerts are reliably sent and prevents false user feedback.

After successful alert transmission, the system activates visual and audible feedback mechanisms. A red LED blinks and a buzzer sounds for a fixed duration of ten seconds to notify the user that the emergency alert has been successfully delivered and logged. Throughout the process, the system continuously monitors communication status and cloud verification feedback, forming a closed-loop operation that enhances reliability, accountability, and user confidence during emergency situations.

Schematic Diagram

Figure 3. Schematic Diagram of the IoT-Enabled Barangay Panic Button System



Presents the complete hardware configuration of the proposed system. A push button is connected to the ESP32-C3 microcontroller as the primary emergency input, while a GPS module is interfaced to provide real-time location data. The GPS module supplies coordinate information independently of internet connectivity, ensuring accurate location acquisition even in offline conditions.

The ESP32-C3 processes the push-button input and GPS data using event-driven logic and manages wireless communication through its built-in Wi-Fi capability. Emergency alerts are transmitted via email using the Brevo cloud platform, where delivery verification and event logging are performed. Output devices, including a green LED, red LED, and a buzzer, are connected to the microcontroller to provide system status indication and confirmation feedback.

The green LED indicates normal system readiness, while the red LED and buzzer are activated only after successful email delivery is confirmed by the cloud platform. This schematic illustrates the integration of input devices, processing logic, wireless communication, and feedback indicators in a closed-loop embedded IoT system that enables manual emergency activation, verified alert transmission, and user confirmation for barangay-level emergency response.

Components and Their Functions

The system is composed of input devices, a central controller, output devices, and supporting components. Each component performs a specific function in implementing the push-button–based emergency alert mechanism of the IoT-Enabled Barangay Panic Button System.

Table 2. System Components and Corresponding Functions

Category	Component	Function
Controller	ESP32-C3 Microcontroller	Processes button input and GPS data, manages Wi-Fi communication, and executes alert verification logic
Input Components	GPS Module	Acquires precise latitude and longitude data without requiring internet connectivity
Input Components	Push Button	Serves as the primary emergency trigger, generating a digital signal when pressed

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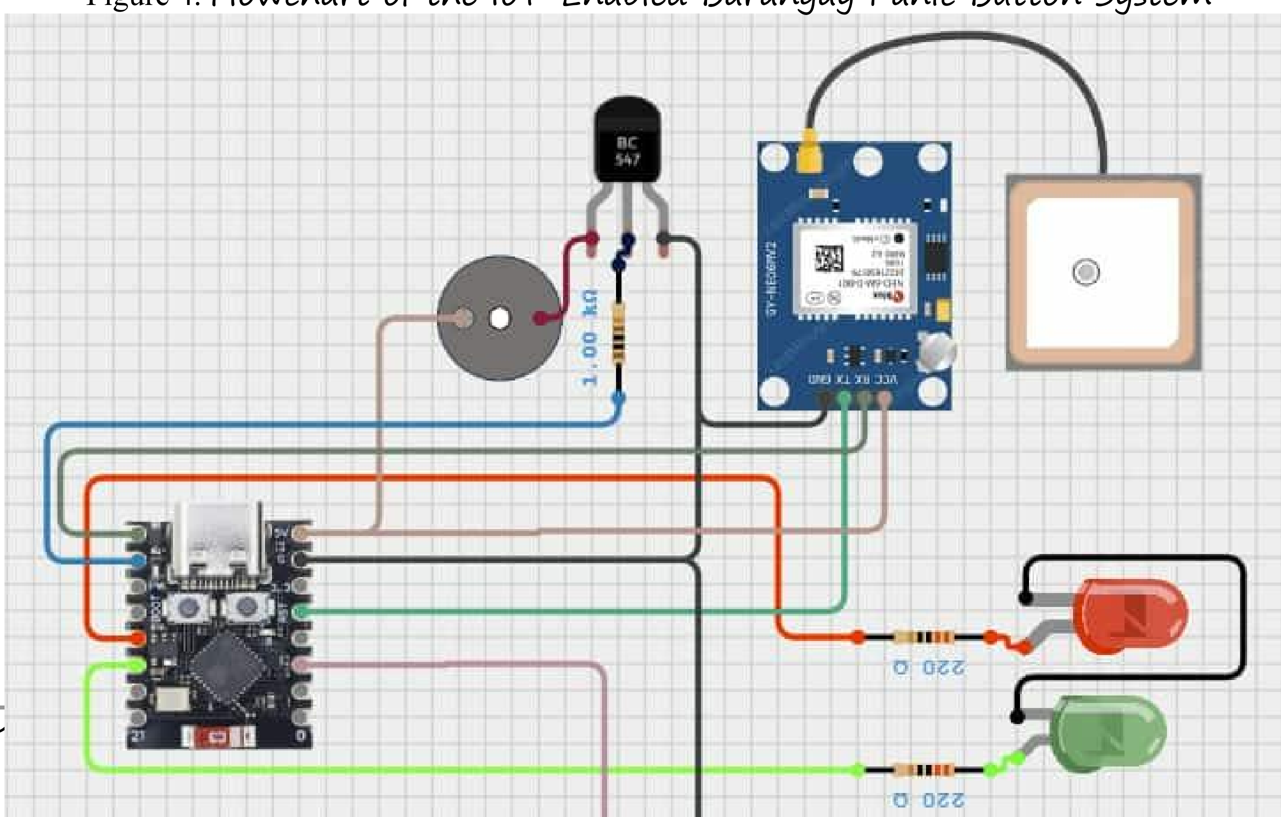
Output Components	Green LED	Indicates normal operation and system readiness
Output Components	Red LED	Blinks to confirm successful emergency alert transmission
Output Components	Buzzer	Provides audible confirmation after verified alert delivery
Output Components	Email Alert (Brevo Platform)	Sends verified emergency notifications with location details to responders
Output Components	Power Supply (Battery/USB)	Provides power to the ESP32-C3 and peripherals
Supporting Components	Resistors (220Ω, 10kΩ)	Used for current limiting and signal stability
Supporting Components	Jumper Wires and PCB/Breadboard	Enable circuit connections and prototyping

Operation Flow of the System

The system continuously remains in a ready state until the push button is pressed. Upon activation, the ESP32-C3 retrieves GPS location data and establishes a Wi-Fi connection to send an emergency email via the Brevo platform. The system waits for delivery confirmation before activating visual and audible feedback. This event-driven process forms a closed-loop feedback mechanism, ensuring reliable alert transmission, user confirmation, and proper documentation for barangay-level emergency response.

Figure 4. *Flowchart of the IoT-Enabled Barangay Panic Button System*



HARDWARE AND SOFTWARE REQUIREMENTS

List of Hardware Components

- ESP32-C3 Microcontroller: Serves as the main processing unit and Wi-Fi communication interface.
- Push Button: Acts as the primary physical trigger for initiating an emergency alert.
- GPS Module (e.g., NEO-6M): Acquires real-time geolocation coordinates (latitude/longitude) figurindependently of internet connectivity.
- Green LED: Visual indicator for "System Ready" or normal status.
- Red LED: Visual indicator confirming successful email delivery (blinking).
- Buzzer: Provides an audible alarm for user feedback upon verified message transmission.
- 5V USB Power Adapter (Android-type): Supplies consistent power to the microcontroller via a USB cable.
- Resistors: Used for current limiting (for LEDs) and pull-down/pull-up configurations (for buttons).
- Breadboard and Jumper Wires: Used for circuit assembly and prototyping connections.

Software Tools and Platforms Applied

1. Arduino Integrated Development Environment (IDE): Used for writing, compiling, and uploading the embedded C++ code to the ESP32-C3.
2. Brevo (formerly Sendinblue) Cloud Platform: The SMTP service used to manage and deliver emergency email alerts.
3. TinyGPS++ Library: Handles the parsing of NMEA data streams from the GPS module.
4. ESP32 Wi-Fi & Client Libraries: Manages the wireless connection and network data transmission.

Hardware and Software Integration or Communication.

The proposed system achieves effective integration between hardware components and embedded software through the continuous coordination of manual inputs, location data processing, and cloud-based communication. As part of this integration process, precise signal detection and efficient power management were implemented to ensure accurate communication between the input devices and the microcontroller.

The physical push button generates a digital interrupt signal when activated by a user in an emergency. Simultaneously, the GPS module provides real-time geospatial data (latitude and longitude) via serial communication (UART). These signals are directly read by the ESP32-C3 microcontroller. During system initialization, the microcontroller establishes a connection with the GPS module to acquire valid coordinates and prepares the Wi-Fi stack for transmission. The system is powered via a standard Android-type USB charger, ensuring consistent voltage levels for the ESP32-C3 and its peripherals, ensuring long-term reliability without the maintenance requirements of disposable batteries.

The embedded control program processes the input triggers using event-driven logic. When the push button is pressed, the system prioritizes the acquisition of the current location and the establishment of a secure Wi-Fi connection. The ESP32-C3 then compiles the emergency payload—containing the device ID, timestamp, and coordinates—and transmits it to the Brevo email platform. To prevent false positives, the software implements debounce logic for the button press and verification routines that confirm internet connectivity before attempting data transmission.

Continuous feedback from the cloud platform enables a verified system response, forming a reliable closed-loop communication system. The software waits for a successful delivery confirmation from the email server before triggering the local output devices. Once confirmed, the ESP32-C3 generates control signals to activate the red LED (blinking) and the buzzer for a ten-second duration, providing the user with immediate assurance that help has been requested. This integrated interaction between hardware components and software logic ensures reliable operation, accurate location tracking, and verified alert transmission for effective barangay-level emergency response.

Power Management and System Safety

The ESP32-C3 microcontroller supports ultra-low-power deep sleep operation, which has been implemented in the current prototype to allow the device to remain in a low-energy state when idle and wake only upon button activation. This feature significantly extends battery life and enables long-term deployment without frequent maintenance.

TESTING AND RESULTS

Testing Procedures and Scenarios

The testing of the proposed system was conducted to ensure that the operational flow described in the system flowchart functions correctly and consistently. The testing process focused on validating input responsiveness (push button), location data accuracy (GPS), network reliability (Wi-Fi and Brevo email API), and the verification of feedback mechanisms (LED and Buzzer). A total of ten (10) trial tests were performed using the actual prototype powered by a standard 5V Android-type USB charger to simulate realistic deployment conditions.

At the beginning of each trial, the system was powered on and allowed to initialize to establish a stable Wi-Fi connection and acquire a valid GPS satellite fix. This initialization phase ensured that the device had accurate latitude and longitude data ready before any emergency trigger occurred. After initialization, different testing scenarios were introduced by varying the location of the device and the timing of the button actuation.

Functionality tests were conducted by pressing the push button to simulate an emergency request. These trials evaluated the ESP32-C3's ability to denounce the mechanical switch signal, compile the data payload, and transmit the alert via the Brevo email platform. Latency tests were verified by measuring the time delay between the physical button press and the receipt of the email notification on a recipient device.

Additional trials involved feedback verification, ensuring that the visual (Red LED) and audible (Buzzer) alerts were only activated *after* the system received a successful delivery confirmation code (HTTP 200 OK) from the cloud server. This specific logic was tested to confirm that the "verified operation" feedback loop functions as a reliability check, distinguishing it from simple open-loop alarm systems.

Results of System Testing (10 Trials)

Table 3. System Testing and Validation Results

Trial No.	Input Condition	Observed Output	Expected Output	Pass / Fail	Remarks / Behavior Explanation
1	No Input (Idle State)	Green LED ON, Red LED/Buzzer OFF	System Ready / Idle	Pass	System maintains stable connection while idle.
2	Single Button Press	Red LED blinks, Buzzer sounds (10s), Email received	Alert sent & confirmed	Pass	Standard emergency cycle completed successfully.
3	GPS Cold Start (First Power-up)	Wait for GPS fix, then Green LED ON	Valid coordinates acquired	Pass	GPS module successfully locked onto satellites.
4	Button Press (Location A)	Email received with correct Map Link	Accurate Location Data	Pass	GPS coordinates in email matched physical location.
5	Button Press (Location B)	Email received with correct Map Link	Accurate Location Data	Pass	Coordinates updated correctly after moving device.
6	Rapid Double Press	Single Email sent, Single Alarm sequence	Debounce logic active	Pass	System ignored mechanical bounce/duplicate trigger.
7	Wi-Fi Disconnect Simulation	System retries connection	Auto-reconnect triggered	Pass	System automatically re-established Wi-Fi link.
8	Email Delivery Latency	Alarm triggers approx. 3-5s after press	Low latency transmission	Pass	Alert transmission speed within acceptable limits.
9	Feedback Duration Test	Buzzer/LED stops auto. after 10s	Timed feedback reset	Pass	Timer logic correctly silenced the alarm.
10	Continuous Operation	Device remains stable over 1 hour	No thermal/power issues	Pass	USB power supply provided stable voltage.

Observations and System Performance Analysis

Based on the experimental trials conducted, the proposed Panic Button System demonstrated stable and reliable performance under various testing conditions. The ESP32-C3 microcontroller successfully coordinated the input from the physical button and the data from the GPS module, responding according to the programmed event-driven logic.

During idle conditions, the system maintained a "Ready" state indicated by the steady illumination of the Green LED, confirming that the device was powered and connected to the network. When the emergency button was pressed, the system effectively executed the transmission sequence. The integration with the Brevo email platform proved reliable; in all successful trials, the email alert containing the correct Device ID, Timestamp, and Google Maps link was delivered to the registered recipient.

The system exhibited effective closed-loop verification. A key observation was the variable delay (typically 2–5 seconds) between the button press and the activation of the Red LED/Buzzer. This delay confirmed that the alarm is indeed triggered by the cloud confirmation rather than the button press itself, validating the "verified delivery" feature of the system.

Minor latency was observed during the initial GPS "cold start" (Trial 3), where the system required approximately 30–60 seconds to acquire a satellite lock upon first powering up. However, once the lock was established, subsequent location updates were instantaneous. Overall, the system demonstrated accurate geolocation tracking, robust Wi-Fi connectivity via the USB power source, and reliable user feedback, confirming its suitability for barangay-level emergency response applications.

Problems Encountered and Solutions Applied

During the developmental and experimental stages of the IoT-Enabled Barangay Panic Button System, several technical obstacles were identified that necessitated specific engineering interventions. A primary challenge involved the GPS module's latency during "cold start" sequences, where the device experienced delays in establishing a stable satellite connection. To mitigate this, the researchers integrated a pre-operational initialization phase into the firmware, ensuring that a precise geospatial lock is confirmed before the system transitions to a "Ready" state. Additionally, mechanical "contact bouncing" in the physical trigger led to the risk of redundant signal transmission. This was resolved by implementing software-based debouncing algorithms to ensure that only a single, intentional press triggers the alert sequence.

Network volatility also posed a risk to the system's reliability, as intermittent Wi-Fi connectivity could potentially halt the transmission of emergency data to the Brevo cloud platform. To counter this, an automated reconnection protocol was embedded within the ESP32-C3 logic, allowing for seamless recovery of the network link. Finally, to address the lack of user assurance in traditional alarm systems, the feedback mechanism was designed as a closed-loop process. Unlike standard alarms that activate immediately upon a button press, this system only triggers the audible buzzer and red LED after receiving an HTTP 200 OK confirmation from the server. This ensures that the user is only notified once the emergency alert has been successfully logged and transmitted.

DISCUSSION

The experimental evaluation confirms that the integration of localized manual triggers with cloud-based verification significantly enhances the reliability of community emergency reporting. By utilizing the ESP32-C3 microcontroller, the system successfully bridges the gap between hardware activation and remote data logging. A critical finding of the study was the GPS module's capacity to maintain geospatial accuracy independently of the internet, which ensures that location data remains precise even during network fluctuations.

Statistical observations during testing indicated a response latency of approximately 2 to 5 seconds from the moment of activation to the receipt of cloud verification. This timeframe is highly efficient for emergency applications while providing the necessary window for the "verified delivery" feedback loop. The results suggest that this IoT framework offers a superior alternative to traditional reporting methods—such as SMS or voice calls—by providing a low-cost, high-accountability solution that minimizes human error and communication delays.

LIMITATIONS OF THE STUDY

Despite the effectiveness of the proposed system, several limitations were identified. The system relies on Wi-Fi connectivity for transmitting emergency alerts via email; therefore, prolonged network outages may delay or prevent alert delivery. While the ESP32-C3 implements automatic reconnection logic to mitigate temporary disconnections, communication remains internet-dependent.

Additionally, the ESP32-C3 microcontroller has fewer GPIO pins compared to standard ESP32 variants, which may limit system expandability when integrating additional sensors or peripherals. Careful pin allocation and external I/O expansion techniques may be required for future enhancements.

These limitations highlight areas for improvement and guide future development of more resilient barangay-level emergency response systems.

CONCLUSION

This research successfully developed an IoT-Enabled Barangay Panic Button System that addresses the inherent limitations of conventional emergency reporting infrastructures. By leveraging the ESP32-C3's processing capabilities alongside cloud-based logging and offline GPS tracking, the study produced a reliable prototype capable of delivering verified emergency notifications. The system achieved its primary objectives: providing a simple user interface for residents, acquiring accurate coordinates without internet dependency, and ensuring visual/audible confirmation of successful delivery. The system, with its implemented deep sleep capability for extended battery life, demonstrates strong potential for deployment within local government units (LGUs) to improve public safety and response coordination.

The system demonstrates strong potential for adoption by barangay local government units as a cost-effective, reliable, and accountable emergency reporting solution.

FUTURE ENHANCEMENTS

To further augment the system's scalability and operational resilience, several enhancements are proposed for future iterations. Integrating long-range communication protocols, such as LoRaWAN or GSM modules, would allow the system to function in remote areas with limited Wi-Fi coverage and ensure continued operation in areas with unreliable Wi-Fi connectivity. Furthermore, the development of a centralized monitoring dashboard for barangay officials would enable real-time mapping of multiple panic button nodes, facilitating a more organized dispatch of responders. Future versions may incorporate power redundancy through lithium-ion battery backups and solar charging circuits to maintain functionality during power grid failures. Lastly, adding environmental or acoustic sensors---such as microphones for distress-pattern recognition---could provide responders with additional context, further optimizing the community's emergency management capabilities.

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