International Journal of Engineering Science and Advanced Technology (IJESAT)
Vol 26 Issue 3(1)(March)2026
Received: 10-1-2026 Accepted: 17-2-2026 Published: 27-3-2026

IoT-Enabled Smart Vehicle Anti-Theft System with Real-Time Tracking and Remote Engine Immobilization Using ESP32

1Dr. K. Suvarna, 2V Mahalakshmi, 3Thalari Dharani, 4Uppara Yarragudla Lalitha, 5VARADA KAVYA, 6NAGALDINNE AFREEN
1Professor & HOD, 23456STUDENT
DEPT OF ECE
St. JOHNS COLLEGE OF ENGINEERING & TECHNOLOGY YEMMIGANUR, KURNOOL
mahalakshmi4a3@gmail.com, dharanitalari75@gmail.com, lalithauppara5@gmail.com, varadakavya52@gmail.com, afreenaffu0702@gmail.com

Abstract

Vehicle theft has become a significant concern due to the limitations of conventional security systems that lack real-time monitoring and remote control capabilities. To overcome these challenges, this paper presents an IoT-enabled smart vehicle anti-theft system that integrates real-time tracking and remote engine immobilization. The proposed system is built around the ESP32 microcontroller, which interfaces with a SIM808 GSM/GPS module, vibration sensor, relay module, and web-based control interface. The system continuously monitors vehicle activity, and any unauthorized movement or vibration is detected using the vibration sensor. Upon detection, an immediate alert message along with the vehicle's real-time GPS location is sent to the owner via GSM communication. Additionally, the system enables remote engine locking through a web server hosted on the ESP32, allowing the user to immobilize the vehicle from anywhere. A dual 18650 Li-ion battery setup provides a stable and efficient power supply for prolonged operation. The integration of IoT, GPS tracking, and remote control enhances the reliability, responsiveness, and effectiveness of vehicle security systems. The proposed solution offers a cost-effective and scalable approach to reducing vehicle theft and ensuring improved safety.

I. INTRODUCTION

Vehicle theft has emerged as a major global concern, particularly in urban and semi-urban regions, due to the increasing number of vehicles and the limitations of traditional security systems. Conventional anti-theft mechanisms such as steering locks, alarms, and immobilizers provide only basic protection and fail to offer real-time monitoring or immediate response after a theft occurs [1], [2]. These systems are often reactive rather than proactive, making them ineffective against modern theft techniques. With the rapid advancement of embedded systems and wireless communication technologies, the integration of smart security solutions has become feasible. The Internet of Things (IoT) plays a crucial role in enabling real-time monitoring, remote access, and intelligent decision-making in vehicle security applications [3], [4]. IoT-based systems allow continuous tracking and instant communication between the vehicle and the owner, thereby improving response time and reducing the chances of vehicle loss.

Global Positioning System (GPS) technology has been widely used for vehicle tracking applications due to its ability to provide accurate real-time location data [5]. When combined with Global System for Mobile Communications (GSM), it enables efficient transmission of location information to users via SMS or internet-based services [6], [7]. Several existing systems utilize GPS and GSM modules to track stolen vehicles; however, many of them lack additional security features such as engine immobilization and real-time alerts [8]. Recent developments in microcontrollers such as ESP32 have significantly enhanced the capabilities of embedded IoT systems by providing built-in Wi-Fi, Bluetooth, and high processing efficiency at low cost [9], [10]. These features make ESP32 an ideal choice for implementing smart vehicle security systems that require both connectivity and real-time processing. Additionally, sensors such as vibration or motion detectors are widely used to detect unauthorized access or tampering attempts in vehicles [11].

To address the limitations of existing systems, modern vehicle anti-theft solutions incorporate remote control mechanisms that allow users to take immediate action when theft is detected. Remote engine locking or immobilization systems have gained attention as an effective way to prevent

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further movement of stolen vehicles [12], [13]. These systems can be controlled through web-based or mobile interfaces, providing flexibility and convenience to the user. In this context, the proposed system presents an IoT-enabled vehicle theft detection and notification system with remote engine locking using ESP32, SIM808 GSM/GPS module, and vibration sensor. The system detects unauthorized movement, sends real-time alerts with location details, and enables remote immobilization through a web interface. This integrated approach enhances vehicle security by combining detection, tracking, notification, and control in a single platform, making it a reliable and cost-effective solution [14], [15].

II. LITERATURE SURVEY

Recent research in vehicle anti-theft systems has focused on integrating IoT, embedded systems, and wireless communication technologies to enhance vehicle security. Several approaches have been proposed to overcome the limitations of traditional security systems by incorporating real-time monitoring, tracking, and remote control mechanisms. An IoT-based vehicle theft detection system using RFID authentication was proposed to restrict unauthorized access by allowing only registered users to start the vehicle. The system integrates GPS tracking and GSM communication to notify the owner and provide location updates during theft attempts [16]. However, such systems rely heavily on authentication mechanisms and may not detect physical tampering effectively.

GPS and GSM-based vehicle tracking systems have been widely studied due to their cost-effectiveness and reliability. A system designed using a microcontroller with GPS and GSM modules enables continuous monitoring of vehicle location and transmits coordinates via SMS to the user [17]. Although effective in tracking, these systems lack real-time control features such as engine immobilization. Several studies have explored IoT-enabled vehicle security systems that combine multiple sensors such as vibration, motion, and ultrasonic sensors to detect unauthorized activities. These systems send real-time alerts and store data on cloud platforms for monitoring and analysis [18]. While they enhance detection accuracy, they often increase system complexity and cost.

Advanced anti-theft systems integrating GPS, GSM, RFID, and IoT technologies have been proposed to provide multi-layered security. These systems offer real-time tracking, user authentication, and remote monitoring capabilities, significantly improving vehicle safety [19]. However, their implementation requires careful integration of multiple components and protocols. Another approach includes combining theft detection with accident monitoring using GPS and GSM modules. These systems not only track stolen vehicles but also provide emergency notifications in case of accidents, reducing response time and improving safety [20]. Despite their advantages, such systems may require additional sensors and processing power.

Low-cost IoT-based vehicle tracking systems using cloud platforms such as ThingSpeak have also been developed. These systems store vehicle data remotely and allow users to access real-time information through web or mobile applications [21]. The main advantage is affordability and scalability, but they depend on stable internet connectivity.

Research has also explored biometric-based vehicle security systems using fingerprint recognition, facial detection, and OTP verification. These systems provide enhanced authentication and prevent unauthorized ignition access [22]. However, biometric systems may face challenges such as higher cost and environmental limitations. Modern IoT-based vehicle security solutions incorporate vibration sensors, ignition monitoring, and accelerometers to detect intrusion or abnormal movement. These systems send alerts and allow remote engine disabling through GSM or internet-based commands [23]. Such systems provide a balanced combination of detection, tracking, and control.

Recent studies emphasize the importance of real-time monitoring and remote engine locking mechanisms. Systems integrating GSM, GPS, and relay-based engine control allow users to immobilize vehicles remotely, preventing further misuse after theft [24]. These solutions significantly improve response time and recovery chances. Furthermore, IoT-based vehicle security systems have evolved to include anomaly detection techniques and intelligent decision-making using sensor data. These systems aim to improve detection accuracy and reduce false alarms, enhancing overall system reliability [25].

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From the above literature, it is evident that while existing systems provide effective tracking and notification, there is still a need for an integrated solution that combines real-time detection, instant notification, and remote engine control with cost efficiency. The proposed system addresses these gaps by utilizing ESP32, SIM808 module, vibration sensor, and web-based control for enhanced vehicle security.

III. PROPOSED METHODOLOGY

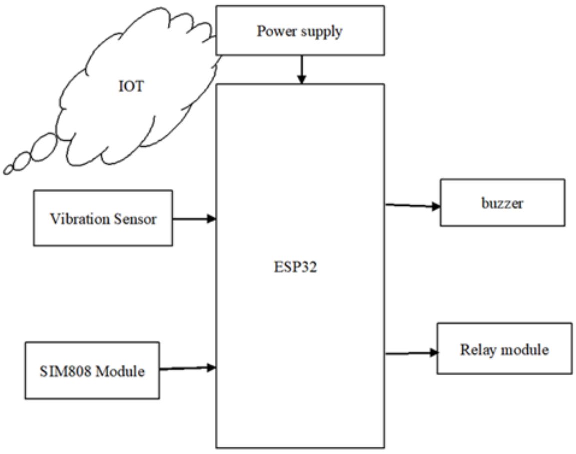

Fig1: Block Diagram

The proposed system is an IoT-enabled vehicle anti-theft solution that integrates detection, tracking, alert notification, and remote engine immobilization. The system is built around the ESP32 microcontroller, which acts as the central processing unit, interfacing with a vibration sensor, SIM808 GSM/GPS module, relay module, buzzer, and a web-based control interface. The overall architecture ensures real-time monitoring and rapid response to unauthorized vehicle access.

1. System Initialization and Power Management

The system is powered using dual 18650 Li-ion batteries connected in series, providing a nominal voltage of 7.4V. A voltage regulation circuit ensures stable power supply to the ESP32 and peripheral modules. Upon powering ON, the ESP32 initializes all connected components, including the vibration sensor, GSM/GPS module, relay module, and buzzer. It also establishes a network connection for IoT-based communication through Wi-Fi.

2. Continuous Monitoring Using Vibration Sensor

A vibration sensor is mounted on the vehicle body to detect unauthorized movement or tampering. The ESP32 continuously reads the sensor output. Under normal conditions, the sensor remains inactive. When abnormal vibrations are detected (such as forced movement or ignition tampering), the sensor sends a signal to the ESP32, triggering the alert mechanism.

3. Theft Detection and Alert Generation

Once the vibration threshold is exceeded, the ESP32 identifies it as a potential theft attempt. Immediately, the system activates the buzzer to provide a local audible alert. Simultaneously, the ESP32 communicates with the SIM808 module to initiate GSM-based notification. An alert message is generated and sent to the registered user's mobile number.

4. Real-Time Location Tracking Using GPS

The SIM808 module includes a GPS receiver that continuously acquires satellite signals to determine the vehicle's real-time location. When theft is detected, the GPS coordinates (latitude and longitude) are extracted and embedded in the alert message. This allows the vehicle owner to track the exact position of the vehicle in real time.

5. GSM Communication for Notification

The GSM functionality of the SIM808 module is used to send SMS alerts to the vehicle owner. The message typically includes a warning notification along with a Google Maps link containing the vehicle's live location. This ensures that the user receives immediate and actionable information regardless of internet availability.

6. IoT-Based Remote Monitoring and Control

The ESP32 hosts a lightweight web server that enables remote access to the system via a smartphone or computer. Through this interface, the user can monitor the vehicle status and send control commands. The IoT framework allows real-time interaction with the vehicle system over the internet.

7. Remote Engine Locking Mechanism

Upon receiving a command from the user via the web interface, the ESP32 processes the request and activates the relay module. The relay is connected to the vehicle's ignition system (represented by a DC motor in the prototype). When triggered, the relay interrupts the ignition circuit, effectively immobilizing the vehicle and preventing further movement.

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8. System Safety and Reliability

The system is designed to ensure safe operation during engine locking. The relay mechanism is activated in a controlled manner to avoid abrupt stoppage, especially in real-world implementations. The use of reliable communication modules and stable power supply enhances system robustness and ensures continuous operation.

IV.WORKING PROCESS & RESULTS

4.1 WORKING PROCESS

The proposed system is designed to detect unauthorized access to a vehicle, send alerts to the owner, track the vehicle location using GPS, and remotely lock the engine through a web-based interface. The system integrates components such as ESP32, SIM808 (GSM + GPS), vibration sensor, relay module, buzzer, RPM BO motor, and battery power supply to ensure efficient vehicle security and operation.

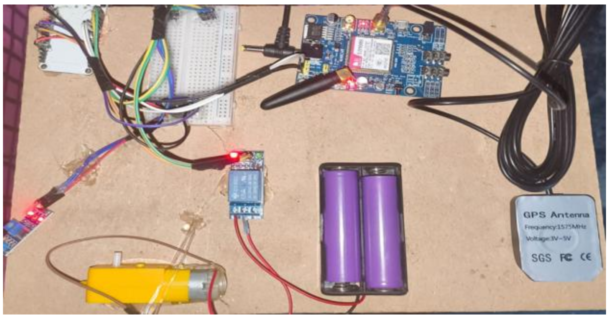

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Fig 2: Hardware kit

Step 1: Power Supply Initialization

The system is powered using batteries, which provide the required voltage to all components. A regulated power supply ensures stable voltage for the ESP32, SIM808 module, sensors, relay, and motor. Proper power management is important since the SIM808 requires high current during operation.

Step 2: System Initialization

Once powered ON, the ESP32 initializes all components including the SIM808 module, GPS, vibration sensor, buzzer, and relay module. The SIM808 registers on the GSM network and activates GPS for tracking. The system enters standby monitoring mode.

Step 3: Continuous Monitoring

The vibration sensor continuously monitors the vehicle for any movement or disturbance. During normal conditions, the system remains idle while checking sensor signals.

Step 4: Theft Detection

If any abnormal vibration or tampering is detected, the vibration sensor sends a signal to the ESP32. This indicates a possible theft attempt.

Step 5: Alert Generation

Upon detection:

- The ESP32 activates the buzzer to alert nearby people.
- The SIM808 module sends an SMS alert to the owner about the theft attempt.

Step 6: GPS Location Tracking

The GPS feature of the SIM808 retrieves real-time location data (latitude and longitude). This information is sent to the user via SMS or can be accessed through the web interface.

Step 7: Communication via GSM

The ESP32 communicates with the SIM808 using UART and sends AT commands. The SIM808 transmits alerts and location data over the GSM network to the user's mobile phone.

Step 8: Web Page Monitoring

The ESP32 connects to Wi-Fi and updates the system status on a web page. The user can monitor alerts and control the system remotely through this interface.

Step 9: Remote Engine Locking

If theft is confirmed, the user sends a command through the web page to stop the vehicle. The ESP32 receives this command and activates the relay module.

Step 10: Engine Control using Relay and Motor

The relay module acts as a switch controlling the power supply to the motor (engine prototype). When activated:

- The relay cuts off power from the battery to the motor

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- The motor stops running, thereby locking the engine

Step 11: System Reset

After handling the situation, the system can be reset. The ESP32 returns to monitoring mode for continuous protection.

4.2 RESULTS

The vehicle theft detection and notification system was successfully designed, implemented, and tested using ESP32, SIM808 module, GPS, vibration sensor, relay module, buzzer, and battery power supply. The system was evaluated under different operating conditions to verify its accuracy, response time, and reliability.

The ESP32 successfully connected to the available Wi-Fi network and dynamically generated an IP address using DHCP. This IP address was used to host a web-based interface, which acts as the main user interaction platform. The web page displayed the real-time engine status (ON/OFF) and allowed the user to remotely control the engine from a browser.

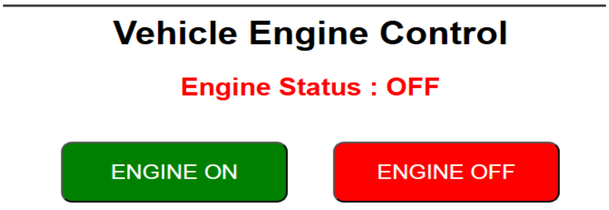

Fig 3: Vehicle Status

The communication between ESP32 and SIM808 module was established using UART protocol. AT commands were successfully transmitted and executed, enabling GSM communication and GPS data retrieval. The system maintained stable communication without significant delays or errors.

When a vibration was detected by the sensor, indicating a possible theft attempt, the ESP32 immediately triggered the buzzer to generate an audible alert. At the same time, the SIM808 module sent an SMS notification to the registered mobile number. The alert message was received without delay, confirming the effectiveness of GSM communication.

The GPS functionality of the SIM808 module was tested and found to be accurate. The module successfully acquired satellite signals and provided real-time location coordinates (latitude and longitude). These coordinates were sent to the user and could be used to track the vehicle's position

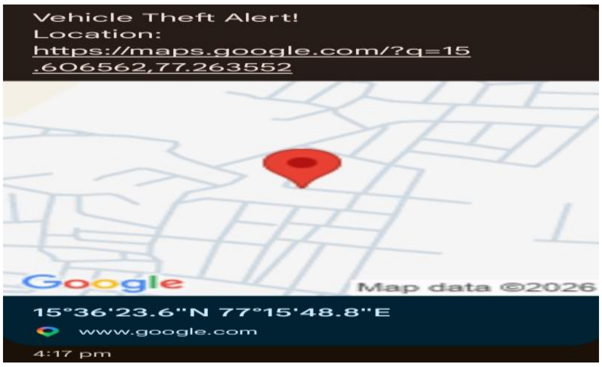

Fig 4.3 Alert Message

Fig 4.4 Location

The serial monitor output was used for debugging and system verification. It displayed important parameters such as network connection status, sensor readings, GSM responses, and command execution results. This helped in analyzing the system behavior during different stages of operation.

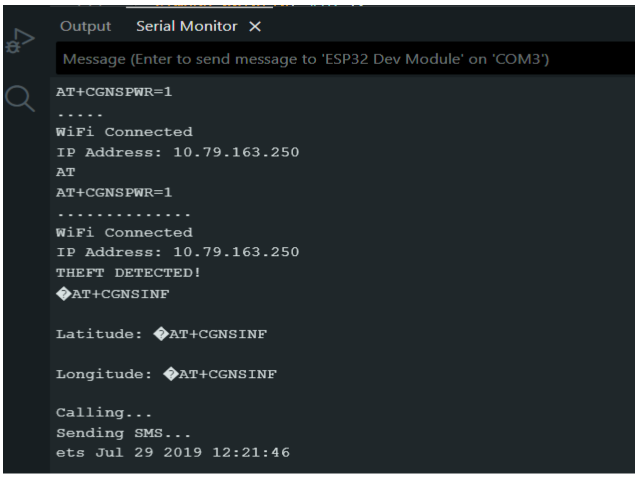

Fig 4.5 Serial Monitor

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V.CONCLUSION AND FUTURE SCOPE

The proposed IoT-enabled vehicle theft detection and notification system with remote engine locking using ESP32 demonstrates an effective and reliable approach to enhancing vehicle security. By integrating a vibration sensor for intrusion detection, a SIM808 GSM/GPS module for real-time tracking and alert notifications, and a relay-based engine immobilization mechanism, the system provides a comprehensive solution that addresses the limitations of conventional anti-theft systems. The use of IoT technology enables remote monitoring and control through a web interface, ensuring quick response and improved chances of vehicle recovery. The implementation is cost-effective, energy-efficient, and suitable for real-world applications. In future, the system can be further enhanced by incorporating features such as mobile application integration, biometric authentication, AI-based anomaly detection, geofencing alerts, and cloud-based data analytics to improve accuracy, automation, and scalability, making it more intelligent and adaptable to modern smart transportation systems.

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