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Design and Development of an IoT-Based Automatic Vehicle Security and Tracking System Using ESP3

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ABSTRACT

Vehicle security is an important concern that requires practical and accessible monitoring solutions. Conventional vehicle security systems may have limitations in providing remote location information, making Internet of Things (IoT) technology a potential approach to improve vehicle tracking. This study aims to design and develop an IoT-based automatic vehicle security and tracking system using the ESP32 microcontroller and NEO-6M Global Positioning System (GPS) module. The research employed a Research and Development (R&D) approach consisting of literature study, system design, hardware and software implementation, system testing, and result analysis. The hardware integrates the ESP32 microcontroller with the NEO-6M GPS module through a UART serial interface, while Wi-Fi connectivity enables communication with the Telegram Bot API. The system was programmed using Arduino IDE to acquire GPS coordinates, process user commands, validate GPS status, and transmit vehicle location information through Telegram, including Google Maps links. Functional testing covered nine aspects: Wi-Fi connectivity, GPS initialization, GPS data acquisition, Telegram connection, command reception, GPS status validation, location transmission, message delivery, and user identification updates. Based on the results documented in the research report, all nine functional test items were recorded as passed according to their predefined test scenarios. These findings demonstrate that the developed prototype can integrate GPS positioning and Telegram-based communication for vehicle location monitoring. However, quantitative GPS accuracy, response time, power consumption, and long-term reliability were not measured in the reported tests. Further research is therefore needed to evaluate these performance parameters and improve the system's reliability under different environmental and network conditions.

INTRODUCTION

The development of information and communication technology in the era of the Fourth Industrial Revolution has significantly influenced various aspects of human life, including the management, monitoring, and security of physical assets. One of the rapidly developing technologies is the Internet of Things (IoT), which enables physical devices to connect and exchange data through internet networks. IoT technology supports automated data collection, processing, and transmission, making it applicable to vehicle monitoring and security systems (Abdullah et al., 2023). One relevant application is vehicle tracking using the Global Positioning System (GPS), which determines geographical positions based on latitude and longitude coordinates. Such systems can improve vehicle security and facilitate remote monitoring (Aditya et al., 2025).

Although GPS-based vehicle tracking devices are increasingly used, their implementation still faces challenges related to device integration, network connectivity, and the accessibility of location information. Conventional vehicle security systems may rely on manual supervision, which can limit the ability to monitor vehicles remotely. Previous research has explored IoT-based vehicle security systems incorporating GPS tracking, web monitoring, and automatic electrical control to improve vehicle protection (Hidayat & Ardiani, 2023). Therefore, a practical tracking system is needed to acquire vehicle coordinates and transmit location information to users through an accessible digital platform.

Previous studies have investigated the integration of microcontrollers, GPS modules, and IoT technology for vehicle security. Maldini et al. (2022) examined a motorcycle security system using a NodeMCU ESP8266 V3 and ESP32-CAM, while Hamsir et al. (2023) developed an IoT-based GPS tracking system for rental vehicles using the NodeMCU ESP-32. In addition, Isyanto et al. (2022) integrated GPS tracking with Telegram Messenger to support remote vehicle monitoring. These studies demonstrate the potential of combining location tracking, microcontroller technology, and digital communication. However, the integration of these components still requires functional evaluation to determine whether location data can be acquired and delivered according to the intended system requirements.

Based on these issues, this study aims to design and develop an IoT-based automatic vehicle security and

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tracking system using the ESP32 microcontroller. The proposed system integrates the ESP32 as the main controller, the NEO-6M GPS module to obtain vehicle coordinates, and Wi-Fi connectivity to transmit data through an internet-based communication service. Telegram is used to enable users to request location information and receive GPS coordinates through Google Maps links. This approach is intended to facilitate remote vehicle monitoring without requiring users to access the tracking device directly.

The main contribution of this study is the development and functional evaluation of a vehicle tracking prototype integrating the ESP32, NEO-6M GPS module, Wi-Fi, and Telegram. System testing covers Wi-Fi connectivity, GPS initialization and data acquisition, Telegram communication, command reception, GPS status validation, and location coordinate transmission. The results documented in the research report indicate that all tested functions were recorded as successful according to the predefined test scenarios. This study provides a practical foundation for IoT-based vehicle tracking development, while further evaluation is needed to measure GPS positioning accuracy, communication response time, and long-term reliability.

LITERATURE REVIEW

Internet of Things for Vehicle Tracking Systems

The Internet of Things (IoT) enables physical devices to exchange data through network connectivity, supporting the development of automated monitoring and security systems. In vehicle tracking applications, IoT can be integrated with the Global Positioning System (GPS) and microcontrollers to obtain vehicle location coordinates and transmit them to remote monitoring platforms. Previous research has explored the use of IoT technology for vehicle monitoring, location tracking, and security enhancement. Abdullah et al. (2023) discussed an IoT-based vehicle security system, while Isyanto et al. (2022) investigated a vehicle security system that integrates GPS, Telegram, and Google Maps for remote monitoring. These studies demonstrate the relevance of connected devices in supporting vehicle security and location monitoring.

However, the effectiveness of an IoT-based tracking system depends on the integration of hardware, communication networks, and software applications. Network availability and the ability to transmit location information are important factors in ensuring that users can access vehicle tracking data. Therefore, developing a practical tracking system requires an appropriate combination of microcontroller technology, GPS positioning, and internet-based communication.

GPS and Microcontroller Integration

GPS technology is widely used to determine geographical positions based on latitude and longitude coordinates. When integrated with a microcontroller, a GPS module can provide location data that can subsequently be processed and transmitted to a monitoring application. Several studies have investigated GPS-based vehicle tracking and positioning systems. Hamsir et al. (2023) developed an IoT-based GPS tracker for rental vehicles using the NodeMCU ESP32, while Maldini et al. (2022) examined a motorcycle security system using the NodeMCU ESP8266 and ESP32-CAM. These studies illustrate the application of microcontrollers and connected devices in developing vehicle security and tracking systems.

In this research, the ESP32 microcontroller is integrated with the NEO-6M GPS module to obtain vehicle location coordinates. The ESP32 serves as the central controller responsible for processing GPS data and managing communication with the internet-based monitoring service. This architecture provides a foundation for developing a compact tracking prototype. Nevertheless, system operation must be evaluated through GPS initialization, coordinate acquisition, and location data transmission tests to determine whether the device operates according to the intended specifications.

IoT Communication and Remote Monitoring

Communication technology is a fundamental component of IoT-based vehicle tracking systems because location data must be delivered from the tracking device to the user. Previous studies have explored different communication platforms and remote monitoring approaches. Isyanto et al. (2022) integrated Telegram and Google Maps into a vehicle security system to facilitate access to GPS location information. Similarly, Hamsir et al. (2023) investigated GPS tracking for rental vehicles using IoT technology. These studies provide relevant examples of how network connectivity and software applications can support remote vehicle monitoring.

Building on these approaches, this study uses Wi-Fi connectivity to connect the ESP32 to the internet and Telegram as the user communication platform. Telegram enables users to request vehicle location information through commands and receive responses containing tracking data. The system also includes GPS status validation to indicate whether the GPS module has acquired a satellite signal. These features are intended to facilitate remote monitoring through an accessible communication interface. However, system operation remains dependent on internet availability and successful GPS signal acquisition.

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Research Gap and Research Contribution

Previous studies have explored vehicle security systems, microcontroller-based tracking devices, GPS positioning, and IoT-enabled monitoring applications (Abdullah et al., 2023; Hamsir et al., 2023; Isyanto et al., 2022; Maldini et al., 2022). These studies provide a foundation for developing vehicle tracking systems that support remote access to location information. However, based on the literature reviewed for this study, further evaluation is needed to document the functional integration of the ESP32, NEO-6M GPS module, Wi-Fi connectivity, and Telegram within the proposed prototype. The available references do not provide sufficient comparative evidence to establish that this combination is entirely novel or superior to existing solutions.

Accordingly, this study focuses on the implementation and functional evaluation of an integrated vehicle tracking prototype using these components. The evaluation covers Wi-Fi connectivity, GPS initialization and coordinate acquisition, Telegram communication, command reception, GPS status validation, and location data transmission. The contribution of this study lies in documenting the integration of the selected components and evaluating their operation through predefined test scenarios. The resulting prototype is intended to provide a practical basis for further development of IoT-based vehicle security systems, including potential improvements in location monitoring, communication reliability, and additional security features.

METHOD

Research Design

This study employed the Research and Development (R&D) method to design, develop, and test an IoT-based automatic vehicle security and tracking system using the ESP32 microcontroller. The research focused on developing a functional prototype that integrates GPS positioning, internet connectivity, and Telegram communication to support remote vehicle location monitoring. The research stages consisted of literature study, system design, hardware and software implementation, system testing, and result analysis. This approach was selected to ensure that the developed system could be evaluated according to its functional requirements and predefined test scenarios.

Research Procedure

The research procedure was organized into several sequential stages, beginning with a literature study and ending with the analysis of testing results. Each stage was conducted to ensure that the hardware and software components could operate as an integrated vehicle tracking system.

The literature study was conducted to identify problems related to vehicle security, GPS-based tracking, and IoT implementation. The system design stage involved determining the hardware components, communication architecture, and software requirements. The implementation stage involved assembling the ESP32 microcontroller and NEO-6M GPS module, developing the program using Arduino IDE, and configuring Telegram communication. Subsequently, system testing was conducted to evaluate the functionality of the implemented components, followed by an analysis of the results to determine whether the system met the expected requirements.

The overall research procedure is illustrated in Figure 1.

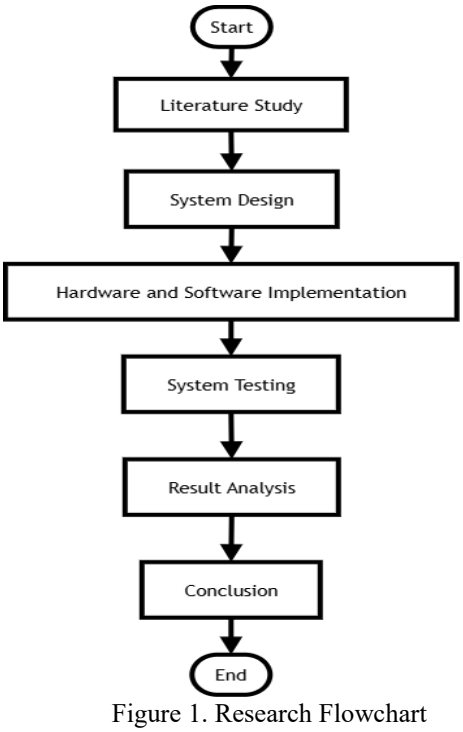


Figure 1. Research Flowchart

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Hardware Design

The hardware architecture consisted of an ESP32 microcontroller and a NEO-6M GPS module. The ESP32 functioned as the main controller responsible for processing GPS data and managing communication with the internet. The NEO-6M GPS module was used to acquire geographical coordinates in the form of latitude and longitude. Wi-Fi connectivity on the ESP32 enabled the transmission of location information to the Telegram communication platform.

The GPS module was connected to the ESP32 through a Universal Asynchronous Receiver-Transmitter (UART) serial interface. Based on the hardware configuration documented in this study, the GPS module's VCC pin was connected to the ESP32 3.3 V pin, and the GND pin was connected to GND. The GPS TX pin was connected to GPIO 18 on the ESP32 to transmit GPS data to the microcontroller, while the GPS RX pin was connected to GPIO 19 for receiving data from the ESP32.

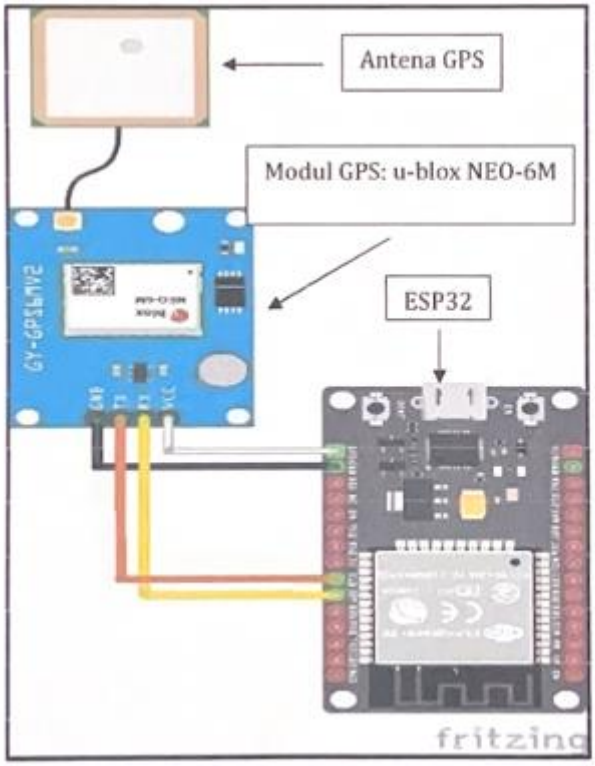


Figure 2. Hardware Configuration of the ESP32 and NEO-6M GPS Module

Software Implementation

The software was developed using Arduino IDE. The program was designed to initialize the ESP32, establish a Wi-Fi connection, communicate with the NEO-6M GPS module, process GPS information, and interact with the Telegram Bot API. The implementation consisted of several functional stages.

First, the ESP32 was configured to connect to a Wi-Fi network using the specified network credentials. Second, the GPS module was initialized to receive and process location data through the UART interface. Third, the system evaluated GPS data availability and satellite lock status to determine whether valid location information could be obtained. Finally, the ESP32 processed user commands received through Telegram and transmitted the requested location information when the required data were available.

Telegram was used as the communication interface between the user and the tracking device. The system supported command reception, location information delivery, and user identification through a chat ID. The program also included an update mechanism to prevent repeated processing of the same user identifier.

System Testing

System testing was conducted to evaluate whether the developed prototype operated according to the predefined functional requirements. The testing procedures covered Wi-Fi connectivity, GPS initialization, GPS data acquisition, Telegram connectivity, command reception, GPS lock status validation, location coordinate transmission, message delivery, and user identification updates.

The Wi-Fi connectivity test evaluated whether the ESP32 could connect to the configured network. The GPS initialization and data acquisition tests examined whether the GPS module could communicate with the ESP32 and provide location coordinates. Telegram communication tests evaluated the connection between the device and the Telegram Bot API, including the reception of user commands and the delivery of responses. The GPS lock status test

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examined whether the system could identify the availability of satellite positioning information. Finally, the location transmission test evaluated whether the system could send vehicle coordinates that could be accessed through Google Maps.

The test results were recorded according to the expected outcomes and the actual system responses. Each test was classified as successful or unsuccessful based on whether the observed behavior matched the predefined testing criteria.

Data Analysis

The collected testing data were analyzed descriptively by comparing the expected outcomes with the actual results obtained during system testing. Each functional component was evaluated to identify whether it operated according to the system requirements. The analysis focused on connectivity, GPS data acquisition, command processing, and location information delivery.

The evaluation was based on the functional testing results documented in the research report. This analysis was intended to determine the operational feasibility of the developed prototype and identify aspects that could be improved in future development. The results were then used as the basis for drawing conclusions regarding the implementation of the ESP32-based IoT vehicle tracking system.

RESULT

In this section, the researcher will explain the results of the research obtained. Researchers can also use images, tables, and curves to explain the results of the study. These results should present the raw data or the results after applying the techniques outlined in the methods section. The results are simply results; they do not conclude.

System Testing Results

System testing was conducted to evaluate the functionality of the IoT-based vehicle tracking system using the ESP32 microcontroller, NEO-6M GPS module, Wi-Fi connectivity, and Telegram Bot API. The testing covered Wi-Fi connectivity, GPS initialization, GPS data acquisition, Telegram communication, command reception, GPS status validation, location transmission, message delivery, and user identification updates.

Table 1. Vehicle Tracking System Testing Results

No.	Test Item	Expected Result	Test Result	Status
1	Wi-Fi Connection	ESP32 connects to the configured Wi-Fi network	ESP32 successfully connects to Wi-Fi	Passed
2	GPS Initialization	GPS module receives power and connects to ESP32	GPS data can be received by the ESP32	Passed
3	GPS Data Acquisition	ESP32 reads GPS data correctly	GPS coordinates are read correctly	Passed
4	Telegram Bot Connection	ESP32 connects to the Telegram server	ESP32 successfully connects to the Telegram Bot API	Passed
5	Telegram Command Reception	System receives user commands through Telegram	Commands are received and processed	Passed
6	GPS Status Validation	System provides information about GPS satellite lock status	System reports the GPS status through Telegram	Passed
7	GPS Location Transmission	System sends vehicle location information	Location information is transmitted through a Google Maps link	Passed
8	Telegram Message Delivery	System delivers messages to the user	Messages are received through Telegram	Passed
9	User ID Update	System updates the user ID without duplication	User ID is updated correctly	Passed

Table 1 shows that all nine functional test items were recorded as passed in the original research report. The ESP32 successfully established a Wi-Fi connection and communicated with the NEO-6M GPS module to obtain location data. The system also connected to the Telegram Bot API, received user commands, and transmitted location information through a Google Maps link.

The testing results further documented the operation of GPS status validation, Telegram message delivery, and user identification updates. These results describe the functional performance of the prototype according to the test scenarios presented in the original report. Quantitative measurements of GPS positioning accuracy, response time, and communication reliability were not included in the reported results.

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DISCUSSION

The testing results demonstrate that the ESP32-based vehicle tracking system can integrate Wi-Fi connectivity, GPS data acquisition, and Telegram communication within a single IoT-based prototype. All nine functional test items were recorded as passed in the original research report. These results indicate that the system operated according to the predefined test scenarios for connectivity, data acquisition, command processing, and location information delivery.

The successful Wi-Fi connection and GPS data acquisition indicate that the ESP32 can communicate with the NEO-6M GPS module and obtain vehicle location coordinates under the tested conditions. The integration of these components provides the basic functionality required for vehicle location monitoring. However, the reported results do not include quantitative measurements of positioning accuracy or GPS acquisition time. Therefore, the findings demonstrate functional operation rather than a verified level of location accuracy.

The integration of Telegram provides a communication interface through which users can send commands and receive location information. The successful Telegram connection, command reception, and message delivery tests indicate that the prototype can exchange information between the device and the user. Furthermore, the use of a Google Maps link allows the reported coordinates to be accessed through a mapping service. This approach offers a practical method of presenting location information without requiring a separate monitoring application.

The GPS status validation test is another important component of the system. According to the original testing report, the system could report GPS status through Telegram, including a condition in which the GPS had not acquired a satellite lock. This function provides information about the availability of positioning data. Nevertheless, further testing is needed to evaluate the system under different environmental conditions, particularly where satellite signals are limited.

Although all nine functional tests were recorded as passed, the results should be interpreted within the scope of the implemented test scenarios. The original report does not provide numerical data on GPS positioning error, communication latency, message delivery rate, power consumption, or long-term operational stability. Consequently, these aspects cannot yet be used to establish the overall performance of the system quantitatively.

Based on the reported findings, the integration of the ESP32, NEO-6M GPS module, Wi-Fi, and Telegram provides a functional foundation for IoT-based vehicle tracking. Further development should focus on quantitative GPS accuracy evaluation, repeated testing under different network conditions, and the implementation of additional security features to improve the system's practical applicability.

CONCLUSION

This study designed and developed an IoT-based vehicle security and tracking system using the ESP32 microcontroller and NEO-6M GPS module. The system integrates Wi-Fi connectivity and Telegram to support vehicle location monitoring, user command processing, and location information delivery through Google Maps links.

Based on the testing results documented in the research report, all nine functional test items were recorded as passed. The tested functions included Wi-Fi connectivity, GPS initialization, GPS data acquisition, Telegram communication, command reception, GPS status validation, location transmission, message delivery, and user identification updates. These results demonstrate that the system operated according to the predefined functional test scenarios.

However, the evaluation was limited to functional testing and did not establish quantitative GPS positioning accuracy, communication latency, power consumption, or long-term operational reliability. Future research should conduct repeated tests under different environmental and network conditions, measure GPS positioning errors, and evaluate communication performance. Additional features, such as geofencing, movement notifications, and alternative network connectivity, could also be developed to improve the functionality and practical applicability of the system.

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