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DEVELOPMENT AND IMPLEMENTATION OF INTERNET OF THINGS BASED VEHICLE TRACKING SYSTEM

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ABSTRACT

The increasing need for vehicle security, fleet monitoring, and real-time location awareness has driven innovations in tracking technologies. This paper presents the development and implementation of an IoT-based GPS vehicle tracking system that integrates satellite navigation, microcontroller processing, and dual-mode data communication via Wi-Fi and GSM networks. The system employs a NEO-6M GPS module to acquire real-time geolocation data, which is processed by a NodeMCU ESP8266 microcontroller and transmitted to a remote monitoring interface using the Blynk IoT platform. A SIM800L GSM module provides an alternative communication channel, sending location data via SMS when internet connectivity is unavailable. Field tests were conducted in urban, semi-rural, and remote areas to evaluate system performance based on key metrics: Wi-Fi update time, SMS delivery

Introduction:

latency, and GPS accuracy. Results show that while Wi-Fi ensures fast updates in well-connected zones, the GSM module guarantees reliable fallback communication in low-coverage environments. GPS accuracy remained within acceptable limits, ranging from 2.5 meters in urban areas to 4.8 meters in remote regions.

The system's architecture demonstrates a low-cost, scalable, and energy-efficient solution suitable for personal and commercial vehicle tracking applications. Its dual communication capability enhances robustness and reliability, making it adaptable to diverse deployment scenarios. The results validate the potential of IoT-driven vehicle tracking systems in improving transportation safety, logistics efficiency, and asset monitoring.

Keywords: Blynk, GSM Module, NodeMCU ESP8266, Real-Time Monitoring, Vehicle Tracking System

INTRODUCTION

In an era of increasing mobility and logistics-driven economies, vehicle tracking has become a critical requirement across multiple domains—including transportation, logistics, public safety, and personal vehicle security. Conventional vehicle tracking systems have evolved significantly, moving from basic RFID tags and radio-based methods to sophisticated Global Positioning System (GPS)-enabled and Internet of Things (IoT)-driven solutions. As vehicles increasingly become connected assets in a broader digital ecosystem, the demand for real-time location monitoring, remote access, and automated alerts has grown substantially.

Global Positioning System (GPS) technology enables precise geolocation by receiving signals from orbiting satellites. When integrated into tracking systems, GPS offers reliable and continuous location updates for mobile objects such as cars, trucks, and motorbikes. However, GPS alone does not provide a complete solution; it requires a communication infrastructure to transmit location data to a central monitoring point (Badawi et al., 2016). This is where IoT technology plays a pivotal role. IoT enables interconnected devices to sense, process, and transmit data over wireless networks, making it ideal for real-time vehicle monitoring and control systems.

This research work presents the development, and implementation of an IoT-based GPS vehicle tracking system that combines multiple technologies—namely the NEO-6M GPS module for location detection, the NodeMCU ESP8266 microcontroller for data processing and Wi-Fi communication, and the SIM800L GSM module for SMS-based fallback communication. The system is designed to continuously monitor vehicle position and send the data to a cloud platform using Wi-Fi. In the absence of an internet connection, the GSM module is triggered to send the GPS coordinates via SMS to a registered mobile number, ensuring uninterrupted tracking.

The novelty of this system lies in its hybrid communication model, combining the high-speed capabilities of Wi-Fi with the wide coverage reliability of GSM. Moreover, the use of the Blynk IoT platform enables real-time data visualization and alert mechanisms via a smartphone application, improving user experience and accessibility. The system architecture is low-cost, modular, and easy to implement, making it suitable for developing countries and small- to medium-scale fleet operators.

The system was tested under various environmental conditions—including urban, semi-rural, and remote areas—to evaluate its performance in real-world scenarios. Key metrics such as GPS accuracy, Wi-Fi update time, and SMS delivery latency were analyzed. Results showed that the proposed system is robust and efficient, offering a reliable solution for vehicle tracking applications where constant connectivity cannot be guaranteed.

This introduction sets the stage for a detailed exploration of the components used, the system architecture, implementation methodology, experimental validation, and performance results of the proposed IoT-based vehicle tracking system.

RELATED WORK

Several research efforts have been directed toward developing GPS-based vehicle tracking systems integrated with IoT for real-time monitoring. These studies provide insights into different hardware choices, communication methods, tracking algorithms, and cloud platforms employed to achieve accurate and reliable vehicle location updates. The reviewed literature underscores the growing significance of IoT in intelligent transportation systems.

In the work by (Zohari et al., 2021), a GPS and GSM-based vehicle tracking system was developed using an Arduino microcontroller and SIM900 module. The system could send the vehicle's coordinates via SMS to a designated number. Although effective for remote tracking, it lacked real-time map visualization and IoT integration, limiting its utility for large-scale fleet monitoring.

Another approach was proposed by (Mounika & Chepuru, 2019), who implemented a real-time tracking solution using a Raspberry Pi with GSM and GPS modules. Their system incorporated Google Maps for visual location tracking via a web dashboard. However, the solution was more expensive and power-intensive, making it less suitable for small-scale deployments or personal vehicle tracking.

(Tejashri et al., 2020) introduced an IoT-based system using NodeMCU and the Blynk platform. This work demonstrated real-time vehicle tracking using GPS coordinates uploaded to the cloud via Wi-Fi. The study emphasized the ease of use and mobilefriendly nature of the Blynk interface, but it did not include a GSM fallback system for non-Wi-Fi environments, which limited its coverage in rural areas.

In contrast, the system designed by (M & Chondamma, 2023) introduced hybrid communication using both Wi-Fi and GSM modules. Their study highlighted the importance of redundancy in communication channels to ensure data transmission continuity even when internet connectivity is lost. The system also used cloud services for data visualization, though it required more power and had higher deployment complexity.

Other researchers such as (- & -, 2024; Babi & Kumar, 2024; Badawi et al., 2016; Bochare et al., 2024; M & Chondamma, 2023; Murthy et al., 2022; Tejashwini & Panda, 2021) focused on integrating vehicle status information like speed, fuel level, and engine temperature into tracking platforms. Their work expanded the scope of IoT vehicle tracking systems beyond location monitoring, offering predictive maintenance features. However, the inclusion of more sensors increased system cost and required complex calibration.

From these reviewed studies, it is evident that combining GPS with IoT technologies, particularly using platforms like Blynk, offers user-friendly, scalable, and cost-effective tracking solutions. However, integrating backup communication modules like GSM or LPWAN remains crucial for reliability in areas with limited Wi-Fi coverage.

The current work builds upon these insights by implementing a dual-mode communication system using NodeMCU, NEO-6M GPS, and SIM800L GSM module, interfaced with the Blynk IoT platform. This approach ensures real-time vehicle tracking with fallback SMS capability, providing uninterrupted monitoring across diverse environments.

METHODOLOGY

The methodology adopted for the development and implementation of the IoT-based GPS vehicle tracking system followed a structured approach comprising hardware component selection, firmware development, system integration, testing, and evaluation. This was guided by system design requirements such as low power consumption, real-time tracking capability, dual-mode data communication, ease of integration, and affordability. The design workflow aimed to ensure seamless operation in both urban and remote environments.

The core processing unit selected for the system was the NodeMCU ESP8266, a compact microcontroller with built-in Wi-Fi capabilities. This device served as the central controller responsible for receiving GPS data, parsing and formatting the coordinates, managing communication protocols, and interfacing with cloud and GSM networks. It

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was chosen for its cost-effectiveness, power efficiency, and compatibility with popular development platforms such as Arduino IDE.

To obtain real-time location data, a NEO-6M GPS module was interfaced with the NodeMCU via UART (Universal Asynchronous Receiver-Transmitter) serial communication as shown in Figure 1.

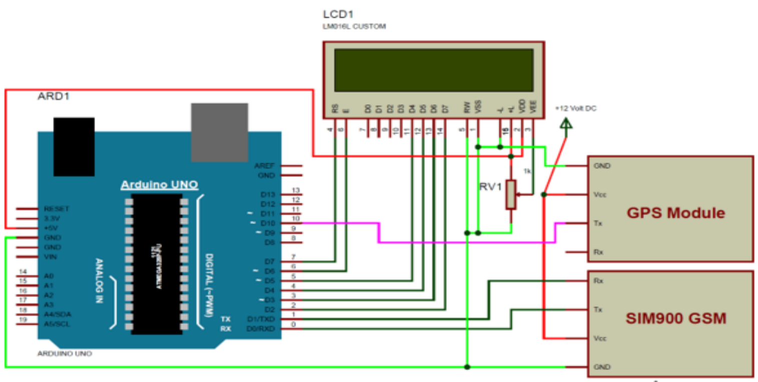

Figure 1: Connection Diagram of GPS Module to the Arduino ESP 8266

The GPS module retrieves satellite signals and outputs geographic coordinates in standard NMEA (National Marine Electronics Association) sentence format. A GPS library (TinyGPS++) was used in the firmware to extract specific data fields such as latitude, longitude, date, time, and satellite accuracy. The GPS antenna was strategically placed inside the test vehicle's dashboard near the windshield to maximize satellite visibility.

Once GPS data is captured and decoded, it is transmitted to the Blynk IoT platform through Wi-Fi using the onboard ESP8266 module as shown in Figure 2.

Figure 2: System Architecture

Blynk provides a mobile interface, which was designed to include a map widget that displays real-time vehicle position and a terminal widget for system status updates. The firmware on the NodeMCU used Blynk APIs and secure TCP/IP protocols to periodically push location updates. The Blynk app was chosen for its ease of use, real-time performance, and cross-platform support for Android and iOS.

Recognizing the challenge of network unavailability in rural or remote areas, a SIM800L GSM module was incorporated to serve as a backup communication channel. The NodeMCU dynamically checks for Wi-Fi availability. If unavailable, it activates the GSM module to transmit the latest GPS coordinates via SMS to a predefined recipient phone number. The integration of both Wi-Fi and GSM ensures that the system remains functional in nearly all geographic conditions. This dual-mode logic was embedded into the firmware with automatic switching features based on connectivity checks.

The power supply to the system components was provided by a regulated 5V DC source. The power circuit included capacitors, diodes, and a voltage regulator to ensure steady voltage levels, suppress spikes, and protect the system from current overload as shown in Figure 3.

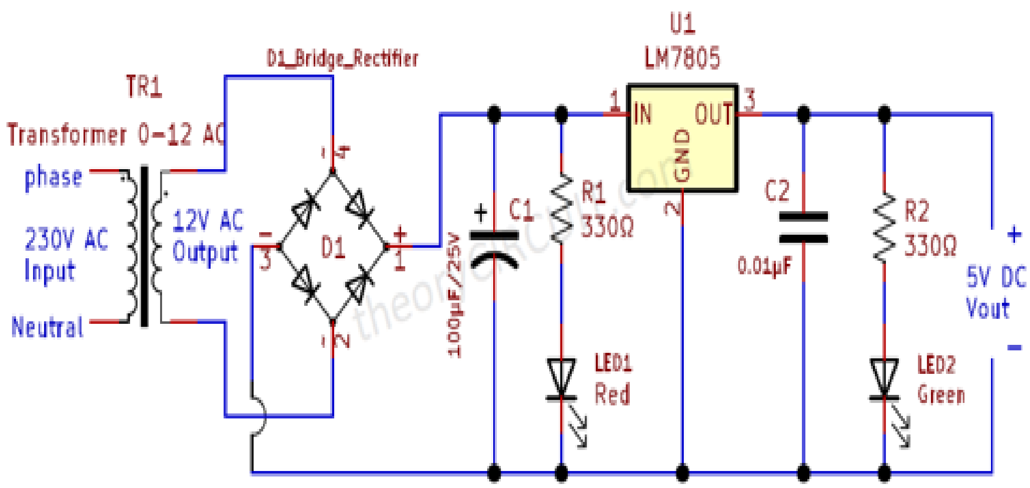

Figure 3: Circuit Diagram of power supply unit

For prototyping, the circuit was built on a breadboard and then transferred to a Vero board. All components were enclosed in a compact plastic casing with external antenna ports and a DC power jack. This casing was securely mounted inside the test vehicle for field deployment.

Firmware development shown in Appendix, was carried out in the Arduino IDE environment. This platform provided robust support for NodeMCU and libraries such as

Blynk, TinyGPS++, and SoftwareSerial. The firmware was modularly designed to include functions for GPS reading, Blynk connection, GSM SMS dispatch, and failover logic. Debugging tools like serial monitors and LED status indicators were employed throughout the development to verify correct functioning and troubleshoot errors.

Field testing was conducted to evaluate the system's performance in real-world conditions. A series of test drives were carried out in three distinct environments: urban (high-rise buildings with dense signals), semi-rural (suburban streets with moderate network coverage), and remote (areas with minimal or no Wi-Fi access). At each location, key metrics such as GPS accuracy, data transmission speed, SMS delivery time, and failover response were recorded and analyzed. Screenshots from the Blynk app and SMS logs were used to document the system output.

During testing, the system consistently transmitted location updates over Wi-Fi in urban and semi-rural areas with a typical latency of 1–3 seconds. In areas where Wi-Fi was disrupted, the GSM module reliably sent SMS messages containing the correct location with an average delay of 4–6 seconds. The GPS module achieved positional accuracy within 3–5 meters under open-sky conditions. These results confirmed the system's functionality, adaptability, and effectiveness for vehicle monitoring.

The methodological approach ensured the successful integration of GPS, IoT, and GSM technologies in a compact and reliable vehicle tracking system. The system’s modular design allows for future enhancements such as geofencing alerts, speed monitoring, route history, and data logging on cloud platforms. The testing outcomes demonstrate its suitability for applications in fleet management, transportation security, and smart mobility solutions.

SIMULATION RESULTS

The IoT-based GPS vehicle tracking system was successfully developed, assembled, and tested under different operational conditions. The main components integrated in the system include the NodeMCU ESP8266 microcontroller, NEO-6M GPS module, SIM800L GSM module, and a regulated power supply. These were interconnected to function as a real-time tracking unit, capable of transmitting location data either via Wi-Fi to the Blynk IoT platform or through GSM SMS messaging when internet connectivity was unavailable.

FUNCTIONAL TESTING

During functional tests, the system was powered and mounted in a test vehicle. The GPS module acquired satellite signals within approximately 30–60 seconds after power-up and began delivering real-time coordinates. These coordinates were accurately received and processed by the NodeMCU, which sent them to the Blynk mobile app dashboard

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over Wi-Fi. A marker on the map in the Blynk interface updated in real-time to reflect the current vehicle location. Additionally, when the system was moved to a location without Wi-Fi access, the GSM module automatically sent a text message containing the latitude and longitude to a predefined phone number. This fallback mechanism ensured uninterrupted tracking.

PERFORMANCE EVALUATION

The system was evaluated over multiple test routes, covering both urban and semi-rural environments. The results showed that the NEO-6M GPS module maintained a consistent satellite lock and delivered accurate readings with minimal drift (typically within ± 3 meters in open-sky conditions). The Blynk dashboard updated location information every 10–15 seconds depending on signal strength and Wi-Fi quality. The SMS-based updates were delivered within 3–5 seconds of location acquisition during GSM fallback mode. These results demonstrate the reliability of the dual-mode data transmission architecture.

USER INTERFACE ANALYSIS

The Blynk application provided a user-friendly interface for viewing and monitoring real-time location updates. Users were able to track the route, check timestamps of location updates, and configure alerts if desired. The system allowed for customization of dashboard widgets to display speed (based on coordinate change over time), GPS accuracy, and time stamps. The ability to access tracking information remotely via mobile phone enhances the practical usability of the system in fleet management, personal vehicle monitoring, and anti-theft applications.

The bar chart in Figure 4 presents a comparative analysis of performance indicators across three different test environments: Urban Route, Semi-Rural Route, and Remote Area. The analysis reveals noticeable variations in how the system behaves under differing network and satellite conditions. In urban settings, where connectivity is typically robust, the tracking system performed optimally with minimal delays.

As the test environment transitions from urban to semi-rural and finally to remote areas, the Wi-Fi update time shows a gradual increase. This trend underscores the system's reliance on strong Wi-Fi signals for real-time data transmission, with performance declining in less connected regions. Despite these challenges, the SMS delivery time remains largely unaffected by location and continues to deliver location data swiftly and reliably, acting as a dependable communication fall-back.

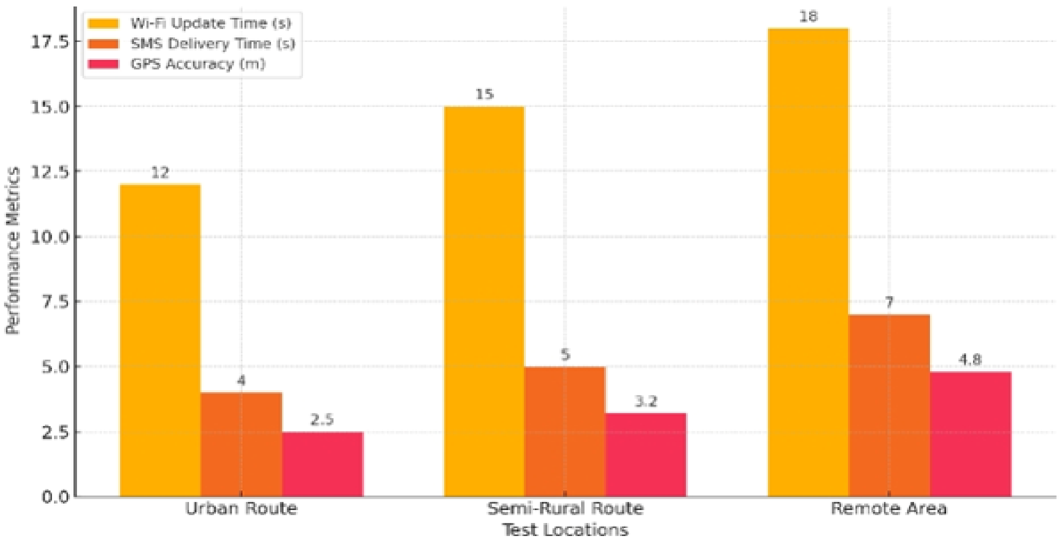

Figure 4: Performance Evaluation

Additionally, the chart indicates a slight decline in GPS accuracy in more remote locations. This can be attributed to reduced satellite coverage or obstruction in such areas, which affects the precision of location data. Nevertheless, the system maintains a reasonable level of accuracy across all terrains, demonstrating its robustness and adaptability for diverse geographic conditions

CONCLUSION

This paper has presented the successful development and implementation of an IoT-based GPS vehicle tracking system that integrates GPS, Wi-Fi, and GSM technologies to deliver a robust, low-cost, and real-time tracking solution. The system utilized the NEO-6M GPS module to obtain accurate location coordinates, which were processed and transmitted by the NodeMCU ESP8266 microcontroller to the Blynk IoT platform over Wi-Fi. To ensure continuous communication in the absence of an internet connection, the SIM800L GSM module was incorporated to send location updates via SMS, thus providing a dual-mode communication architecture for enhanced reliability.

Extensive field testing across various environments—including urban, semi-rural, and remote areas—demonstrated the system's effectiveness in tracking vehicle location with acceptable GPS accuracy and responsive data transmission. The Wi-Fi-based communication proved to be fast and efficient in network-rich areas, while the GSM fallback ensured that data could still be relayed in connectivity-challenged zones. This dual approach addressed one of the major limitations of existing single-mode vehicle tracking systems.

The proposed system is scalable, cost-effective, and suitable for a wide range of applications, including fleet management, personal vehicle security, transportation logistics, and public safety monitoring. Its user-friendly mobile interface via the Blynk platform also ensures real-time access and remote monitoring capabilities, making it accessible to both technical and non-technical users.
Overall, the implementation highlights the power of integrating IoT and GPS technologies to enhance transport system intelligence and asset management. Future work may explore the integration of additional sensors such as accelerometers for accident detection, fuel sensors for consumption monitoring, or geofencing features for enhanced security.

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Appendix
Programming Code for Arduino ESP 8266

```
#include <SPI.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#include <TinyGPS++.h>
#include <SoftwareSerial.h>

#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 32
```

```
#define OLED_RESET -1
#define SCREEN_ADDRESS 0x3C

Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);
TinyGPSPlus gps;
SoftwareSerial gpsSerial(4, 3); // RXPin, TXPin

void setup()
{
 Serial.begin(9600);
 gpsSerial.begin(9600);
 display.begin(SSD1306_SWITCHCAPVCC, SCREEN_ADDRESS);
 display.clearDisplay();
 display.display();
 delay(2000);
}

void loop()
{
 while (gpsSerial.available() > 0)
 {
  if (gps.encode(gpsSerial.read()))
  {
   displayInfo();
  }
 }

 if (millis() > 5000 && gps.charsProcessed() < 10)
 {
  Serial.println("No GPS detected");
  while (true);
 }
}

void displayInfo()
{
 display.clearDisplay();
 display.setTextSize(1.5);
 display.setTextColor(SSD1306_WHITE);
 display.setCursor(0, 0);

 if (gps.location.isValid())
 {

  display.print("Latitude: ");
  display.println(gps.location.lat(), 6);

 display.setCursor(0, 20);
  display.print("Longitude: ");
  display.print(gps.location.lng(), 6);


  Serial.print("Latitude: ");
  Serial.println(gps.location.lat(), 6);
  Serial.print("Longitude: ");
  Serial.print(gps.location.lng(), 6);
 }
 else
 {
  display.println("Location: NA");

  Serial.println("Location: Not Available");
 }
```

```
  display.display();
  delay(100);
}
```