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GPS Based Toll Collection System Using ESP32

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Abstract-The growing need for efficient transportation infrastructure exposesthe limitations of traditional toll collection systems, which dependon manual processing and physical checkpoints. This project proposesa smart, GPS-based automated toll collection system using the ESP32microcontroller, NEO-6M GPS module, and wireless communication.The system tracks real-time vehicle movement and calculates distanceusing the Haversine formula, with a minimum movement threshold toreduce GPS noise. Upon reaching a predefined distance, the ESP32sends an SMS via the Twilio API over Wi-Fi, detailing the distancetraveled and toll amount. This solution removes the need for tollbooths, reducing congestion, delays, and operational costs. Testing confirmed accurate tracking and reliable SMS alerts. The systemprovides a scalable and low-cost tolling method, ideal for smart transportation. It also offers potential for future upgrades, including GSM-based alerts, mobile app support, and cloud integration, paving the way for intelligent and automated road infrastructure.

1.INTRODUCTION

The growing complexity of modern transportation networks has led to the emergence of Intelligent Transportation Systems (ITS) aimed at improving traffic flow, safety, and operational efficiency. One critical aspect of ITS is the implementation of smart tolling mechanisms that can eliminate the drawbacks of traditional toll booths—such as long queues, manual errors, and fuel wastage.

To address these challenges, this paper presents a GPS-based automated toll collection system utilizing the ESP32 microcontroller. The system relies on real-time vehicle tracking via the NEO-6M GPS module and communicates toll updates using the SIM800L GSM module through SMS. The ESP32, with its integrated Wi-Fi and processing capabilities, serves as the central control unit.

Toll calculation is performed by computing the total distance traveled using the Haversine formula, which accurately determines distances based on geospatial coordinates. The system includes logic to ignore GPS noise and only logs meaningful movements that exceed a defined threshold (e.g., 0.5 meters).

When a vehicle surpasses a specified travel distance (e.g., 10 kilometers), the system calculates the toll using a predefined rate per kilometer and sends an SMS with relevant details. Visual indicators (LEDs) provide feedback on module status, and built-in safety checks ensure operational reliability. This embedded IoT-based approach enables a scalable, low-cost alternative for automated tolling, especially in locations where traditional infrastructure is either unavailable or infeasible.

Upon approaching a toll zone, the location of the vehicle is stored based on previously saved GPS coordinates. The traveled distance is then calculated in real-time by the system based on the Haversine formula and a fixed rate of charge per meter is applied to calculate the toll fee. The results are displayed on a 16x2 LCD display for clarity. The method provides equitable tolling through levying charges only for the actual distance covered and does away with the need for vehicles to be halted at booths.

The [1] design also considers energy and system efficiency with checks on valid GPS data included and fallback error messages when there is not enough signal. The system is coded with the TinyGPS++ library and aims at low-cost, real-time embedded applications and is well-suited to developing nations such as India. The whole process of tolling becomes automatic and cashless, leading to considerable reductions in fuel consumption, traffic jam, and time wasted in lengthy queues.

In [2], a new GPS-based toll collection model was established based on a Raspberry Pi 2 microcontroller and other modules such as LCD, Wi-Fi, and speakers. In contrast to [1], this model incorporates online database connectivity through a personal cloud server that provides remote access and monitoring of toll records. Travel history, speeding violations, and toll transactions are all stored in structured SQL databases. The Python-based system architecture includes GPS signal detection, real-time updates on toll charges, and speed monitoring—making it suitable not only for toll collection but also for traffic law enforcement.

2. LITERATURE REVIEW

A toll collection system using GPS was presented in [1] with a vision to enhance toll efficiency on freeways without the restrictions of RFID-based and manual toll booths. This system involves the integration of an NEO 6M GPS module and an Arduino Uno microcontroller for tracking the movement of vehicles. Upon approaching a toll zone, the location of the vehicle is stored based on previously saved GPS coordinates. The traveled distance is then calculated in real-time by the system based on the Haversine formula and a fixed rate of charge per meter is applied to calculate the toll fee. The results are displayed on a 16x2 LCD display for clarity. The method provides equitable tolling through levying charges only for the actual distance covered and does away with the need for vehicles to be halted at booths.

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A notable innovation in [2] is the system's ability to detect loss of GPS or internet connectivity. By pinging online servers and checking GPS signal variables, the system ensures robustness in operation. In addition, there is an automatic delay time adjustment function that saves power through modulating data acquisition frequency based on vehicle speed. The deployment was trialed on Malaysian highways, where the test exhibited high accuracy and efficiency. The addition of cloud-based access provides remote oversight abilities, a key feature in future smart infrastructure.

The study in [3] investigates an IoT smart gate system with NodeMCU ESP8266, ultrasonic sensors, and camera modules for monitoring vehicle entry in residential and educational environments. The system identifies vehicle presence automatically, captures images of license plates, and cross-verifies them against a cloud database before opening the gates.

SMS notifications are sent for invalid attempts, and administrators can remotely open gates via a web interface. The emphasis here is less on toll computation and security, but more on access control, and yet the principles intermingle with tolling structures, particularly in multi-zone lots or gated campuses.

[3] also describes the integration of the system with machine learning algorithms for anomaly detection, thus making it more adaptive to changing access patterns. Scalability is made possible by cloud services, and technologies such as biometric authentication and RFID enable multi-factor authentication. Although robust, the paper identifies challenges such as high installation costs, difficulty in integrating with legacy systems, and data privacy issues—factors of note for tolling systems that intend to scale nationwide.

In [4], the Smart Gate System continues to leverage real-time analytics and adds sophisticated data visualization using dashboards. The architecture of the system consists of three core layers: perception (sensing of data through sensors), network (transmission of data), and application (analysis of data and user interface). This layered structure provides effective processing and facilitates predictive capabilities like traffic prediction. Edge computing further reduces latency—of paramount importance in high-volume toll zones.

One of the strengths emphasized in [4] is increased security with encrypted communication and block chain integration to ensure tamper-proof records. These capabilities facilitate deployment in high-risk environments and render the system fraud-proof or resistant to unauthorized access. The system was tested in a college campus environment with encouraging results for usability, speed, and accuracy.

Collectively, these systems represent a trend toward smart toll and access management, focusing on automation, visibility, and lean physical infrastructure. GPS and IoT technologies offer a cost-efficient and scalable substitute for legacy gantry and RFID solutions. Vehicle position tracking, cloud storage, and real-time user engagement create the foundation of current smart mobility applications.But every system has its compromises. GPS-based solutions such as in [1] and [2] provide distance-based accuracy of tolling but rely on satellite visibility and connectivity. At the same time, IoT-based gate systems in [3] and [4] provide stronger security and remote-access capabilities but are potentially more complex and costly to implement. The perfect future system would integrate GPS tracking, RFID fallback, and real-time cloud analytics into a strong, multi-layered tolling architecture.

3. METHODOLOGY

This project introduces a GPS-enabled automated toll collection system using the ESP32 microcontroller, NEO-6M GPS, and SIM800L GSM module. The system eliminates the need for fixed toll infrastructure by using real-time location tracking and SMS-based toll notifications. The ESP32 connects to Wi-Fi for internet access and uses the Twilio API to send toll updates. GPS data is processed via the TinyGPS++ library, and movement is tracked using the Haversine formula, with a 0.5-meter threshold to filter noise. Toll charges are calculated by multiplying total distance traveled by a fixed rate (₹50/km). When the distance exceeds 10 km since the last update, an SMS is sent to the user with the distance and toll details. Diagnostic LEDs on each module confirm readiness, and the system is tested by simulating vehicle movement. This lightweight, scalable solution offers an efficient alternative to traditional toll systems, especially in remote or infrastructure-limited areas.

4. RESULT AND DISCUSSION

The GPS-based toll collection system performed effectively underreal-world testing. The NEO-6M GPS module accurately tracked movement, with distance calculations using the Haversine formula and a 0.5-meter threshold to eliminate minor GPS drift. The ESP32 efficiently handled data acquisition, processing, and communication tasks. Upon reaching every 10 km, the system sent SMS toll updates using Twilio API over Wi-Fi, with reliable message delivery and clear toll summaries. Real-time data such as coordinates, distances, and toll values were displayed via the serial monitor, aiding debugging and usability. LED indicators provided quick status checks of GPS and GSM modules. The system demonstrated fairness in tolling by charging users based on actual distance traveled rather than fixed checkpoints. Error handling managed GPS or Wi-Fi disruptions effectively. While the prototype proved robust, future improvements could include GSM-based messaging for greater independence, power optimization, and data logging for better toll history management

5.CONCLUSION

The GPS-based automated toll collection system proves to be a low-cost, scalable, and flexible solution for modern toll management. By integrating ESP32, NEO-6M GPS, and SIM800L GSM modules, the system accurately tracks vehicle movement, calculates distance using the Haversine formula, and sends toll updates via SMS using the Twilio API. It eliminates the need for fixed infrastructure and ensures real-time, fair tolling based on actual travel distance. Testing confirmed system reliability and usability. Future improvements include adding GSM-based offline SMS support, optimizing power consumption, and enhancing the user interface for broader adoption in urban and rural transport applications.

6.REFERENCES

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