iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** I **Month of publication:** January 2025

DOI: https://doi.org/10.22214/ijraset.2025.66765

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue I Jan 2025- Available at www.ijraset.com

Enhancing Roadway Efficiency with GPS Based Toll System

Kalpesh Vilas Gangurde[1], Pratik Dattatray Hule[2], Shivraj Gorakhnath Gawali[3], Ms. Kalyani Akhade[4]
[1, 2, 3]Student, [4]Professor, Computer Science Engineering Sinhgad Institute Of Tech & Science Pune

Abstract: The traditional systems for toll collection are plagued with various problems, including traffic buildup at toll booths, long waiting time on users, and administrative costs. This research proposes a GPS-Based Toll Collection System that would help to solve these problems by using better location-based technologies for the automatic tolling of vehicles. This system consists of a combination of a GPS receiver, a microprocessor, and a battery inside the vehicle. It can track the vehicle's course in real-time and the position where the vehicle enters or exits the toll road zone is automatically detected and the toll amount calculated per distance traveled using pre-defined rates or dynamic pricing models.

The user-friendly web interface allows vehicle owners to register their vehicles, maintain a digital wallet, and view transaction histories. The deducting toll is automatic without the need for any toll booth physical interaction, efficiently accelerating the toll collection process, thereby causing less traffic congestion, more throughput, and substantial operational cost reduction in staff and manual handling.

Apart from better user convenience and operational benefits, the automated, highly accurate, and transparent toll collection system assures equal opportunities for all persons entering the national highways by way of toll. This paper discusses the architecture of this system, major components, critical challenges faced during its implementation, and its potential impact on the transport sector. Comparison of the proposed GPS-based system with traditional tolling methods reveals advantages such as lower maintenance costs, improved scalability, and real-time data processing. It also examines security protocols employed to ensure data privacy and fraud prevention. Lastly, the study concludes with an account of the proposed improvements and the possibility of the wide-scale deployment of the system in furtherance of smarter and more sustainable transportation infrastructure development.

Keywords: GPS-based toll system, Toll collection automation, Location-based technology, Digital wallet, Microprocessor integration, Traffic congestion reduction,Vehicle registration, Dynamic pricing, Cost reduction

I. INTRODUCTION

A toll collection system from the modern world has grown in frequency and complexity to stand as an irreplaceable tool for a range of operations. While original toll systems have often proved inadequately slow in collecting sums due to traffic congestion at toll booths, long waiting for vehicle processing, and toll collection procedures that vary depending on the diligence of the human worker, these systems, as demanded by growing motor traffic, have become far too inefficient. In the longer run, therefore, the systems increase operational costs and have a poor user experience.

While GPS technology is certainly showing some promise in moving to an automated style of the toll queue process, leveraging GPS and the Internet, the entire tolling process can also be automated and work quicker, more accurately, and without the friction now associated with most transactions. The system puts forward a GPS-Based Toll Collection System, which implements location tracking devices on vehicles and facilitates the collection of toll via a web-based user interface.

It targets abolishing conventional toll booths, using the NeverStop specification of measurement process for automatic toll deduction at various points of exit, and thus conditional or variable tolling may cushion the induced demand by precipitating bonded travel times. Toll calculation based on vehicle position is performed in real-time, and deduction from the linked digital wallet is done automatically. Directly interfacing with this system shall relieve congestion and eliminate errors, but most importantly, significant operational efficiency occurs due to the saved amount of human effort along with lower capital cost to operate it on-line. In addition, the Web application provides vehicle dialog options, transaction history discussion, and enhanced topping off of particulars; that is to say, how to make your wallet work best for you.

The paper describes the design and implementation for the GPS based toll system, addressing hardware and software concerns, problems encountered during application implementation, and leading benefits over the traditional methods of toll collection.

The investigation of this research explores the security concerns, the nuances of scalability, and the big-picture outcomes created by building road network systems.

II. LITERATURE REVIEW

The primary intention of the GPS-based toll system is the efficient and automatic solution without a manual toll collection process using the GPS tracking system. This chapter helps to have an in-depth understanding about the project, as various research papers regarding the GPS-based toll collection have been analyzed. There are several ways for implementing the GPS-based toll system, including: satellite tracking mobile app integration vehicle tag recognition, among others, a proposed survey gives us an idea to research and develop the same.

In the paper [3] Traditional toll collection systems involve physical toll booths where vehicles are required to stop for manual or electronic payments. These systems contribute significantly to traffic congestion, delays, and increased fuel consumption.

In the paper [7] the author has proposed ETC systems, like RFID-based solutions, These systems have been widely adopted to reduce congestion at toll booths. A study indicates that although these systems have improved toll processing times, they still rely on physical infrastructure, and their performance is limited by technical issues such as faulty RFID tags and scanners. These limitations hinder scalability and do not completely eliminate traffic slowdowns at toll points.

GPS-based tolling is a more advanced system that calculates tolls based on movement and distance covered without physical toll booths. Priyanka (2024) reports that GPS-based systems can adjust the toll charges in real-time depending on the real-time traffic condition and usage of roads, thereby reducing congestion significantly and enhancing efficiency. These are more flexible and scalable and decrease operational costs as compared to RFID-based toll collection.

Dynamic models of pricing, as researched by Jude and Navya (2023), allow toll prices to fluctuate about specific variables such as the time of day, traffic density, or type of vehicle. The dynamic pricing balance ensures optimal flow of traffic at peak hours and enforces an incentive for off-peak travel in order to achieve an optimal usage of road infrastructure. GPS-based toll systems have no problems with these dynamic models of pricing because their mode of collection is real-time.

Multiple studies, including Sonali, Kushal and Digvijay (2023), have noted the environmental benefits of GPS-based toll systems. By eliminating the need for toll booths and reducing stop-and-go traffic, fuel consumption and vehicle emissions are significantly lowered. From an economic perspective, GPS-based systems reduce the need for costly toll infrastructure maintenance and save time for commuters, contributing to higher overall productivity.

The literature review points to a progression of the toll collection systems, From traditional manual methods to modern GPS-based solutions, the impetus is driven by efficiency, cost reduction, and improved traffic flow. Traditional toll booths require vehicles to stop for manual or RFID-based payments, which significantly contribute to traffic congestion, especially during peak hours. Studies show that this leads to increased fuel consumption, extended travel times, and environmental concerns due to excessive emissions caused by idling vehicles.

One of the benefits of GPS-based tolling is dynamic pricing models, which vary the rates at which tolls are charged according to various drivers such as traffic density, time of day, and road conditions. Studies note that dynamic pricing tends to control road usage better than static models because it encourages off-peak travel and reduces congestion during rush hours. There is thus more control over patterns of movement in traffic and optimal use of infrastructure for the road network.

III. PROBLEM STATEMENT OR OBJECTIVES

The present-day tolling systems commonly create traffic bottlenecks and rely on a human for management. This generates higher operating costs for toll collecting. Thus, an efficient electronic toll collection mechanism without physical booths to better manage and enhance traffic circulation is in requirement..

The objectives of this research are to develop a GPS-based toll collection system that automates toll payments using real-time location tracking for smoothened user experience and reduction of operational inefficiencies.

IV. METHODOLOGY

The methodology of the GPS-based toll collection system consists of the general design, hardware and software integration, and steps in implementation and testing. The description of the methodology used in the project is explained in detail as below , Firstly in System Configuration

The proposed system is an integration of hardware and software into an automated toll collection system. The concept of the system design includes three key components: a GPS device, a microprocessor, and a battery-all mounted in the vehicles to track location.

The GPS device continuously reports the location being traveled. This data is processed by the microprocessor, which calculates the distance and identifies the toll zones. The microprocessor completes the processing using the battery as its power source.

The backend is implemented in Python , offering high performance and resource optimization. The web interface is developed using JavaScript for dynamic user interactions

MySQL is used to manage the database, storing user details, vehicle information, toll rates, and transaction history .The system uses PHP for backend server operations, handling data processing and user requests. The communication between the vehicle's hardware and the server is facilitated using HTTP protocols and real-time APIs.

The first step entailed mounting the GPS module, the microprocessor, and the battery inside a unit so small it fit easily in an automobile. Such hardware was evaluated to track location very accurately and send relevant data. The first step included the assembly of the GPS module, microprocessor, and battery into a unit suitable for automobile mounting. The hardware accurately tracks a location and its capability to forward the same relevant data.The GPS hardware was configured with a server that would receive real-time data from the hardware. In the backend, it was programmed to calculate the toll based on how far the vehicle had traveled in a toll zone. It implemented an algorithm to subtract the calculated amount of toll from the user's digital wallet. A web interface was developed with an interactive interface for the user. It includes features of user registration, wallet management, addition of vehicles, and tracking the history of transactions. It gets connected to the backend to retrieve real-time data and updates.In such a system, the complete functionality was tested for a range of scenarios: vehicles entering and exiting toll zones, network disruption, and simultaneous use by multiple vehicles. Testing ensured functionality, accuracy, and reliability in the system.

V. SYSTEM ARCHITECTURE

The architecture of the GPS-based toll collection system is designed to ensure scalability, reliability, and seamless communication between different components. It is structured to handle the efficient processing of real-time location data, toll calculation, and transaction management. The architecture is divided into several key layers, each of which plays a crucial role in the system's operation.The hardware layer of the system consists of the GPS unit, microprocessor, and the communication module that is installed within the vehicle. The GPS unit is constantly reading location data that it sends over to the microprocessor for processing. The microprocessor, using the vehicle's coordinates, will decide whether it is entering or exiting a toll zone and will compare the latter with the previously set toll zone boundaries, which are stored in the system's database. The communication module, normally GSM or GPRS-based, transmits location data of the vehicle to the central server in real-time. Once the location data is transmitted, it enters the server layer. The server is where all the data processing takes place. The server compares the received coordinates with the boundaries of toll zones in the database upon receiving the data from the vehicle. If the vehicle is within a toll zone, the server computes the toll fee based on the distance traveled and the predefined rates for that particular zone. This calculation is done automatically so that users pay only for the distance covered. The server layer deals with user account and transaction history maintenance.

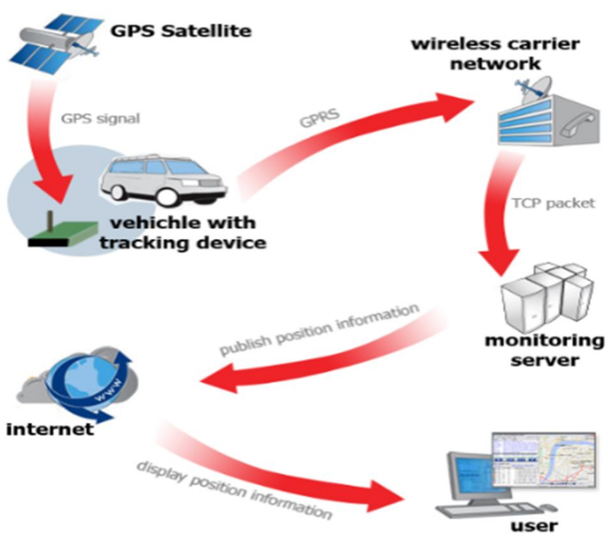

Fig. 1 Architecture

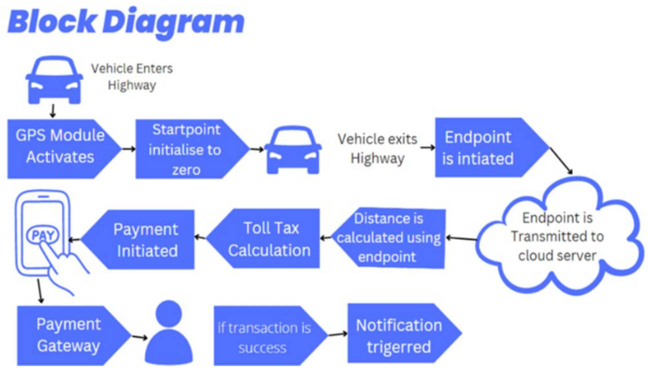

Fig. 2 Block Diagram

transaction histories are stored. The server queries the database to fetch such information and updates it after each toll transaction. A web application is given to the users in the frontend layer. The interface is developed for a web environment and is easy to use as well as interactive. The functionality provided here involves vehicle registration, wallet recharging, viewing transaction history, and checking account balances. This layer will be implemented by using HTML, CSS, and JavaScript for creating an engaging user experience. It uses PHP and RESTful APIs to connect to the backend server for direct communication and data updating at the web interface. The user can access his account details, get the amount of toll charges, and modify vehicle information from anywhere if there is internet access. At the communication layer, the system will use HTTP protocols with secure APIs to enable the real-time exchange of data between the vehicle hardware and the server. These protocols guarantee that the information transmitted is safe and correct, especially when it involves sensitive user information such as wallet balances and transaction records. In areas where network connectivity might be unreliable, the system is designed to store data temporarily and sync it with the server once a stable connection is re-established.

The last emphasis of architecture is scalability as well as robustness. So, the system may handle many vehicles and toll zones simultaneously because this would be one of the principles to reach large-scale deployment of the system across highways or along urban roads. Scalability as the user base grows will ensure high availability and responsiveness even in times of peak usage. Overall, the system architecture ensures that all components—hardware, software, communication protocols, and user interfaces—work harmoniously to provide a reliable, efficient, and user-friendly GPS-based toll collection solution. The integration of these components allows the system to automate toll collection, reduce traffic congestion, and enhance user convenience.

VI. RESULTS

The GPS-based toll collection system was implemented and tested under various conditions to evaluate its functionality, accuracy, and overall efficiency. The results showed that the system effectively addressed the challenges associated with traditional toll collection methods, such as traffic congestion, manual intervention, and inaccuracies in toll calculation. The integration of real-time GPS tracking, automated toll calculation, and digital wallet systems provided a seamless and user-friendly tolling experience. During the testing phase, vehicles fitted with the GPS hardware unit were taken through various toll zones of different distances and rates. The system constantly identified the entry and exit points of the vehicle in the toll zones by comparing real-time GPS coordinates with predefined boundaries stored in the database. The toll was deducted accurately by the distance travelled within each zone, and this amount would automatically be charged from the wallet provided without any manual payment. This reduced the time usually spent at a toll booth to tremendous proportions and reduced it to the minimum required for processing.

The system proved to be very accurate in identifying toll zones with a negligible error margin in tracking location. The accuracy was obtained by proper calibration of the GPS module and efficient processing algorithms. Moreover, communication between the GPS unit in the vehicle and the server was reliable even in areas with intermittent network connectivity due to the use of robust communication protocols and caching mechanisms for offline data storage. From a user's point of view, the web-based interface afforded a friendly environment for managing toll transactions. Users could register for their vehicles, recharge their wallets, or browse extensive histories of transactions. Satisfactory feedback collected from the test users indicated full satisfactory levels, as many users liked the transparency and automation of the system. Moreover, the facility of sending SMS or emailing toll deductions and wallet balances added a layer of convenience and trust to the system. The scalability of the system was verified for the simultaneous passage of several vehicles through different toll zones without a significant degradation in performance.

With respect to central data storage and retrieval, it performed very well, not even showing any lapse in real-time processing during peak times. This has a good possibility for implementation on higher scales such as national highways and urban toll roads.

Though the system has managed generally, there are some weaknesses that come forth:. For example, in areas where the visibility of GPS satellites is not excellent, such as in tunnels or heavily forested areas, the accuracy of GPS location tracking will not be optimal. In this regard, in the next versions, other alternative location tracking technologies could be added to supplement GPS data, like RFID and geofencing. Another challenge is ensuring consistent network connectivity in remote areas, which could be mitigated by integrating multiple communication technologies, such as LoRaWAN or satellite-based communication systems.

In summary, the findings prove the feasibility and efficacy of the GPS-based toll collection system as a modern substitute for traditional toll booths. It reduces congestion and operational costs but adds more convenience and transparency to users. Optimization and integration with complementary technologies will make this system scalable and reliable enough to be a pan-nation or global solution for management of tolls.

VII. CONCLUSION

The modern, efficient, and scalable system concerning the challenges posed by conventional tolling methods is the GPS-based toll collection. Through the real-time tracking of a vehicle using GPS, automated calculation of tolls, and effective communication between a vehicle and its backend server, the system helps automate the toll collection process by avoiding the use of physical toll booths or manual intervention. This enables the reduction of traffic congestion and increases speed and accuracy in transactions. The system was implemented and tested under different conditions, showing its effectiveness in accurately calculating toll charges, managing user accounts, and ensuring real-time communication between vehicles and the server. The web-based interface gave users a convenient platform to manage their vehicles, monitor wallet balances, and track toll transactions, thus resulting in a high level of satisfaction.

However, there are areas that can be further optimized in the system. Especially, in areas with poor visibility of satellites, like tunnels or highly populated urban areas, the GPS accuracy may suffer. More technologies might be added in the future to include RFID and geofencing so that the system can be further strengthened to thrive in these types of environments. Another thing to expand the communication infrastructure by considering alternative technologies, such as satellite-based communication or LPWAN, could mitigate the issue of connectivity in remote areas. Overall, the GPS-based toll collection system represents a significant step forward in toll management. Its benefits include reduced operational costs, increased efficiency, and an enhanced user experience. Further development of this system with the integration of complementary technologies has the potential to be implemented on a large scale to improve highway, city roads, and other transportation networks. This innovative approach toward toll collection would be a benchmark for modern transportation infrastructure, paving the way for smart cities of the future.

VIII. ACKNOWLEDGMENT

We express our gratitude to my guide Ms.K.O.Akhade for her competent guidance and timely inspiration. It is our good fortune to complete our Project under her able competent guidance.This valuable guidance, suggestions, helpful constructive criticism, keeps interest in the problem during the course of presenting this Enhancing Roadway Efficiency With GPS-Based Toll System We would like to thank our Project Coordinator Ms.R.T.Waghmode and all the Teaching, Non-Teaching staff of our department. We are very much thankful to Dr.Geeta .Navale, Head, Department of Computer Engineering and also Dr.S.D. Markande, Principal, Dr.V.M.Rohokale, Vice principal, Sinhgad Institute of Technology and Science, Narhe for their unflinching help, support and cooperation during this project work. We would also like to thank the Sinhgad Technical Educational Society for providing access to the institutional facilities for our project work.

REFERENCES

[1] Priyanka Dudhe , Shreya Tembhurne, Abhishek Chaudhary Department of Computer Science and Engineering Department of Computer Science and Engineering India. "GPS – Enhanched Automated Toll Management System, " 2024.

[2] R. Subha, Jude Pinto, Navya Venugopal, Swasthik Singh † Computer Science Department — Federal University of Minas Gerais. "Smart Toll Collection: A GPS Based Automated System, " 2023.

[3] Sonali Patil, Shivam Desle, Khushal Chudhari, Digvijay Adusal a Department of Information Technology, Ramrao Adik Institute Of Technology,Navi Mumbai,400706,India. "Smart Toll Booth System Using Smart Contract)," 2023.

[4] Mohd Azlan Abu, Nurul Hazirah Indra1, Abdul Halim Abd Rahman, NorAmalia Sapiee "GPS Based Vehicle tracking System, " 2023.

[5] Richard Lincoln Paulraj; Santhosh Krishna B V; G. Vishnu Vardhan; K. Sai Pradeep; K. Hemanth; G. Bhavadeep Reddy Published in: 2022 International Conference on Advanced Computing Technologies and Applications (ICACTA) "A Detailed Approach on Vehicle Accident Recognition and Remote Alarm Device."

[6] Yu Yang; Xiaoyang Xie; Zhihan Fang; Fan Zhang; Yang Wang; Desheng Zhang ˇ , Published in: IEEE Transactions on Mobile Computing (Volume: 21, Issue: 7, 01 July 2022) " VeMo: Enable Transparent Vehicular Mobility Modeling at Individual Levels With Full Penetration."

[7] R. Shankar and A. V. Singh, 2019 4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO) (Trends and Future Directions), Noida, India, 2019.

[8] Allen Francis Antony, Anju P, Gautham Raj P, Keerthana M. S, Divya M. Menon , "Design of an Integrated Speed Tracking and Toll Management System for Express Highways," 2020.

[9] Danang Dismantoro; Istas Pratomo; Surya SumpenoFifth International Conference on Informatics and Computing (ICIC) "Minimizing Toll Payment Queue using GPS-Based Mobile Applications," 2020.