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GNSS Based Automated Toll Collection System

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Abstract
The increasing number of vehicles on roads has exposed the limitations of traditional toll collection systems, which cause traffic congestion, delays, fuel wastage, and environmental pollution due to vehicles stopping at toll plazas. To address these issues, this project proposes a GNSS-based automated toll collection system that enables seamless, contactless, and distance-based tolling without requiring vehicles to stop.
The system uses the Global Navigation Satellite System (GNSS) to track the real-time position of vehicles using latitude and longitude coordinates. A GNSS module installed in the vehicle continuously provides location data, which is processed by an Arduino Uno microcontroller. The system detects entry and exit points of toll zones and calculates the distance travelled. Based on this distance, the toll amount is computed, ensuring fair and transparent charging.
The proposed system integrates both hardware and software components. The hardware includes a GNSS module, Arduino Uno, GSM module, and LCD display. The software, developed using Embedded C in Arduino IDE, processes location data, performs toll calculation, and manages communication. The GSM module enables automatic toll deduction through digital payment systems, while the LCD display provides real-time user information.
This system eliminates the need for physical toll booths, reduces traffic congestion, saves fuel, and lowers emissions. It also supports real-time data collection for better traffic management and infrastructure planning. Although challenges such as signal dependency and initial cost exist, the system offers significant long-term benefits.
Overall, the GNSS-based toll collection system provides an efficient, reliable, and scalable solution for modern transportation, supporting the development of smart cities and intelligent transportation systems.

Keywords: *GNSS, Automated Toll Collection, Intelligent Transportation Systems (ITS), GPS, Arduino Uno, GSM Communication, Distance-Based Tolling, Smart Transportation, IoT, Traffic Management*

Introduction

The rapid development of road transportation and the increasing number of vehicles on highways have made toll collection an essential part of infrastructure management, but traditional toll collection methods, where vehicles are required to stop at toll plazas and pay manually, have created several serious problems such as long waiting lines, heavy traffic congestion, fuel wastage, increased travel time, and inconvenience to drivers, especially during peak hours and festive seasons, and to overcome these challenges, modern technology has introduced the GNSS-based automated toll collection system, where GNSS stands for Global Navigation Satellite System, a satellite-based navigation system that helps in determining the exact location of a vehicle anywhere on Earth in real time, and a commonly used example of this technology is GPS, which is widely used in smartphones and navigation devices, and the main aim of this advanced toll collection system is to provide a seamless, efficient, and contactless method of collecting toll charges without requiring vehicles to stop, thereby improving the overall transportation experience and making road travel faster, smoother, and more convenient for users.

Automation is also a key objective of the GNSS-based toll collection system. The system automatically tracks the route of each vehicle using satellite signals and calculates the toll charges accordingly. The amount is then deducted from a prepaid account or linked digital payment system without any manual intervention. This eliminates the need for human involvement in toll collection, reducing errors and increasing efficiency. It also ensures that the entire process is fast, reliable, and convenient for users.

Ensuring fairness and accuracy in toll collection is another major aim of this system. In traditional systems, vehicles are charged a fixed amount at toll plazas regardless of how much distance they travel. This may not always be fair to users who travel shorter distances. The GNSS-based system solves this problem by charging toll fees based on the actual distance travelled by the vehicle. This distance-based charging method ensures that users pay only for what they use, making the system more transparent and equitable.

Literature Survey

The rapid advancement of intelligent transportation systems has significantly transformed traditional toll collection mechanisms, leading to the development of automated and satellite-based solutions. Conventional manual toll collection systems required vehicles to stop at toll plazas for cash transactions, resulting in increased traffic congestion, longer waiting times, and higher fuel consumption. To mitigate these limitations, Electronic Toll Collection (ETC) systems based on RFID technology were introduced, enabling faster and partially automated toll payments. However, RFID-based systems still rely on fixed infrastructure and require vehicles to slow down at toll points, thereby limiting their efficiency in high-density traffic environments.

Recent research has focused on Global Navigation Satellite System (GNSS)-based toll collection, which enables distance-based charging without the need for physical toll plazas. Jain *et al.* [1] proposed a GNSS-based electronic toll collection system that tracks vehicle location in real time using GPS and onboard units (OBUs). Their approach demonstrates improved scalability and flexibility compared to traditional toll systems, while significantly reducing congestion and travel delays. Nevertheless, the study assumes uninterrupted satellite connectivity and does not adequately address issues such as signal degradation and infrastructure cost.

Similarly, Kumar *et al.* [2] developed a smart toll collection framework integrating GPS and GSM technologies to facilitate automatic toll deduction. The system enhances user convenience through cashless transactions and continuous vehicle movement. However, its dependence on mobile network availability introduces reliability concerns, particularly in remote or signal-deprived regions.

To improve system robustness, Sharma *et al.* [3] proposed a hybrid approach combining RFID and GNSS technologies. In this model, RFID ensures accurate vehicle identification, while GNSS enables dynamic distance-based toll calculation. Although the hybrid system improves performance and reliability under varying traffic conditions, it increases system complexity and deployment cost due to the requirement of dual infrastructure.

Verma *et al.* [4] introduced a fully satellite-based toll collection system that eliminates the need for physical toll booths. Their study highlights key advantages such as improved traffic flow, reduced operational costs, and enhanced transparency in toll calculation. However, continuous vehicle tracking raises significant concerns regarding data privacy and security, which remain critical challenges for large-scale implementation.

In another study, Singh *et al.* [5] explored the integration of GNSS with IoT and cloud computing within an Intelligent Transportation System (ITS) framework. Their system enables real-time monitoring, efficient toll management, and advanced functionalities such as traffic analysis and route optimization. Despite these benefits, the system faces challenges related to cybersecurity, system reliability, and the necessity for uninterrupted internet connectivity.

Reddy *et al.* [6] proposed a GPS-based toll collection system aimed at minimizing travel delays and fuel consumption. The system automatically calculates toll charges based on vehicle position and facilitates seamless payment processing. While the results indicate improved efficiency, GPS accuracy issues in urban environments with signal obstructions may affect system reliability.

Ahmed *et al.* [7] presented an IoT-enabled toll collection system integrated with GNSS for enhanced automation and monitoring. The system supports real-time communication between vehicles and centralized servers, enabling efficient toll processing. However, the increased system complexity, maintenance requirements, and the need for secure data handling mechanisms pose significant implementation challenges.

Overall, the reviewed literature indicates that GNSS-based toll collection systems offer substantial improvements over traditional and RFID-based approaches in terms of efficiency, scalability, and user convenience. However, challenges such as signal reliability, data security, infrastructure cost, and dependency on communication networks remain key areas for further research and development.

GNSS Technology and Fundamentals

Global Navigation Satellite System (GNSS) is a satellite-based navigation system that provides location and time information anywhere on Earth, in all weather conditions, 24 hours a day. GNSS technology has revolutionized navigation, positioning, and timing applications across various sectors including transportation, agriculture, aviation, maritime, surveying, and telecommunications.

The most commonly used GNSS is the Global Positioning System (GPS) developed by the United States Department of Defense. GPS became fully operational in 1995 and was originally

designed for military applications. However, it was made available for civilian use in the 1980s, leading to an explosion of navigation and location-based services.

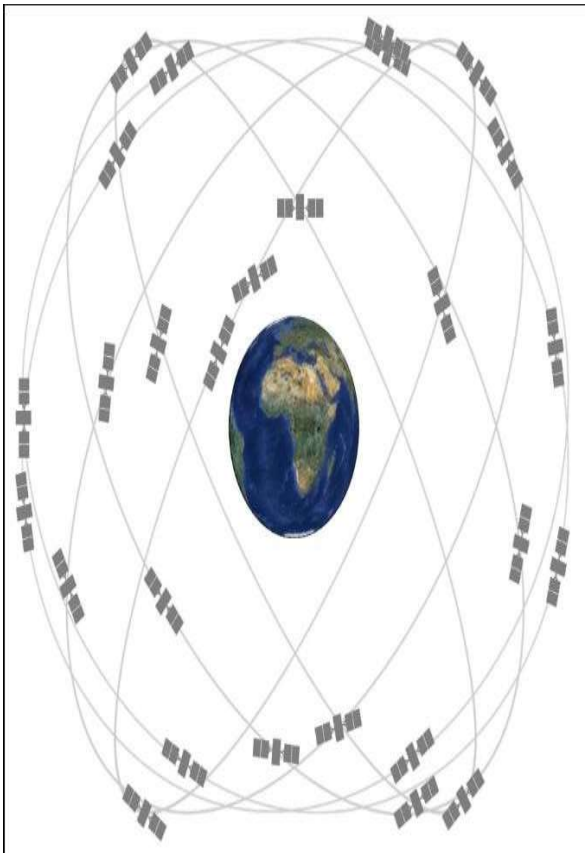

Figure 1: GNSS Satellite Constellation

Other GNSS systems include:

- GLONASS (Russia) - Global Navigation Satellite System, restored to full operation in 2011
- Galileo (European Union) - Europe's global navigation system, declared operational in 2016
- BeiDou (China) - BeiDou Navigation Satellite System, completed in 2020 with 35 satellites
- NavIC (India) - Navigation with Indian Constellation, a regional system covering India and surrounding areas (up to 1500 km)

The availability of multiple GNSS systems provides significant benefits for positioning applications. In the context of toll collection, GNSS technology plays a crucial role by enabling real-time vehicle tracking without requiring physical infrastructure such as toll booths or roadside readers. A GNSS receiver installed in the vehicle continuously receives signals from multiple satellites and calculates its precise position in terms of latitude, longitude, and altitude.

GNSS-Based Toll Collection System Design

The Global Navigation Satellite System (GNSS)-based toll collection system is a modern and efficient solution developed to overcome the limitations of traditional toll collection methods. With the rapid increase in the number of vehicles, conventional toll booths often lead to heavy traffic congestion, long waiting times, and increased fuel consumption. This system aims to eliminate the need for physical toll plazas by using satellite-based tracking technology to monitor vehicle movement and automatically calculate toll charges.

In this system, GNSS technology is used to determine the real-time position of a vehicle as it travels across different toll zones. A microcontroller such as the Arduino Uno processes the location data received from the GNSS module and identifies when the vehicle enters or exits a predefined toll area. Based on the distance travelled or the zone crossed, the system calculates the toll amount automatically without requiring the vehicle to stop.

To enable seamless communication and payment processing, a GSM Module is integrated into the system. This module helps in transmitting the toll data to a central server or user account for automatic deduction. Additionally, an LCD display is used to show important information such as system status, toll amount, and initialization messages, making the system user-friendly and transparent.

Overall, the GNSS-based toll collection system offers a smart, contactless, and efficient approach to toll management. It reduces traffic congestion, minimizes fuel wastage, and improves travel time. This system is highly suitable for future smart cities and intelligent transportation systems, where automation and real-time data processing play a crucial role in enhancing efficiency and sustainability. reduces traffic congestion, minimizes fuel wastage, and improves travel time. This system is highly suitable for future smart cities and intelligent transportation systems, where automation and real-time data processing play a crucial role in enhancing. This system is highly suitable for future smart cities and intelligent transportation systems.

Proposed System

The proposed system is a GNSS-based automated toll collection system designed to overcome the limitations of traditional toll collection methods such as manual, RFID, and smart card-based systems. The main objective of the system is to enable seamless, contactless, and distance-based toll collection without requiring vehicles to stop at toll plazas, thereby improving traffic flow and reducing congestion.

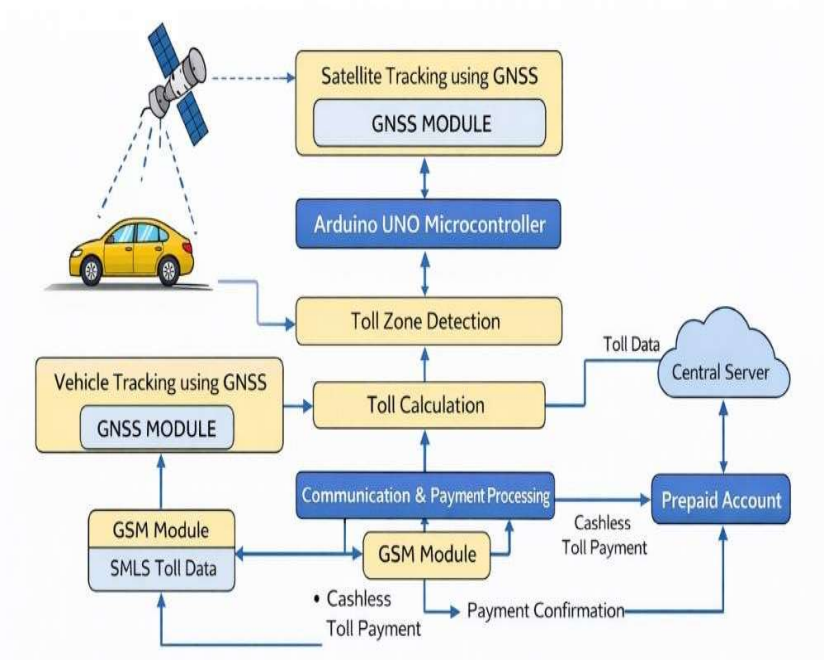

Fig 2 Block Diagram of Proposed System

Results and Discussion

The result of GNSS-based toll collection is a significant improvement in the efficiency of transportation systems. By removing the need for physical toll booths, vehicles can travel without stopping, which ensures smooth traffic flow on highways and urban roads. This helps in reducing travel delays and makes journeys faster and more convenient for users. The elimination of bottlenecks at toll plazas also improves overall road capacity and reduces traffic congestion, especially during peak hours and festive seasons.

Another important outcome is the reduction in fuel consumption and environmental impact. Since vehicles do not need to stop and start frequently at toll plazas, fuel usage is minimized, leading to lower emissions of harmful gases such as carbon dioxide and nitrogen oxides. This contributes to a cleaner and more sustainable environment while also reducing operating costs for vehicle owners. Additionally, reduced idling time decreases engine wear and improves vehicle lifespan.

GNSS-based toll collection also provides accurate and fair tolling by charging users based on the actual distance travelled rather than fixed toll points. This increases transparency and user trust in the system. The use of real-time positioning ensures precise toll calculation, minimizing billing errors. Furthermore, digital payment integration enables secure and cashless transactions, improving convenience and reducing revenue leakage.

Another key result is enhanced data collection and traffic management. The system continuously gathers real-time data about vehicle movement, travel patterns, and road usage. This data can be analysed by authorities to optimize traffic flow, improve infrastructure planning, and identify high-density traffic zones. It also supports dynamic toll pricing and better policy decisions for transportation systems. This data can be analysed by authorities to optimize traffic flow, improve infrastructure planning.

Finally, the system supports the development of smart transportation and smart city initiatives. It reduces the need for manual toll collection, lowering operational costs and human errors. With automation, real-time tracking, and integration with intelligent transportation systems, it enhances overall road safety, improves efficiency, and creates a more advanced and user-friendly transport infrastructure. The system is also scalable and can be extended to future technologies such as connected vehicles, IoT-based transport systems, and nationwide tolling networks.

Discussion

GNSS-based toll collection is an advanced and modern approach that uses satellite technology to calculate toll charges based on the distance travelled by a vehicle. Unlike traditional toll systems that require physical toll plazas, this system allows vehicles to move freely without stopping, improving

traffic flow and reducing congestion. It plays a key role in transforming conventional transportation into a more efficient and intelligent system.

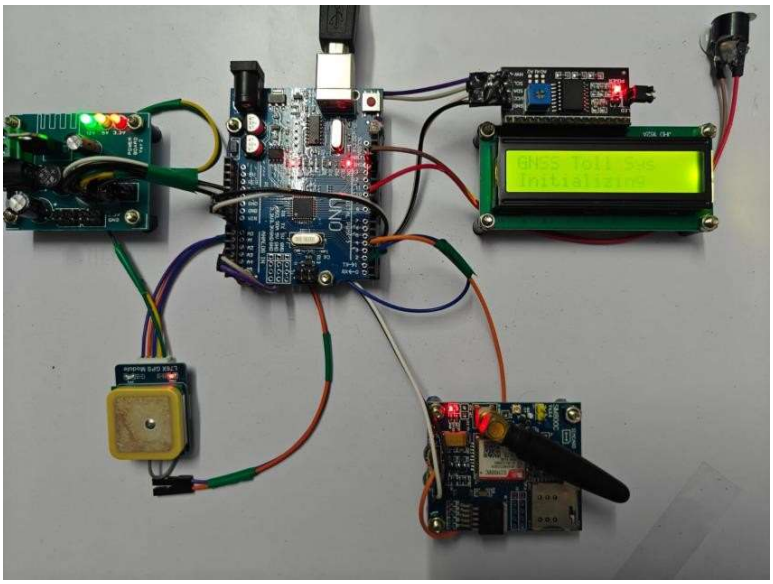

Fig 3 Hardware Setup of GNSS-Based Toll Collection System

The above figure shows the complete hardware setup of the GNSS-based toll collection system. The system consists of an Arduino Uno microcontroller, GNSS module, GSM module, LCD display, and power supply unit, all interconnected to perform real-time toll collection operations.

Conclusion and Future Scope

Conclusion

GNSS-based toll collection is an advanced technology that significantly enhances the efficiency of transportation systems by introducing automation and real-time vehicle tracking. By eliminating the need for physical toll plazas, it allows vehicles to move freely without stopping, resulting in smoother traffic flow and reduced travel time. This not only improves driving comfort but also reduces traffic congestion, especially on busy highways and urban roads. The system enables seamless travel across long distances, making road transportation faster, more reliable, and user-friendly. Another key benefit is the reduction in fuel consumption and environmental impact.

The system also ensures accurate and fair toll collection by charging users based on the actual distance travelled rather than fixed toll points. This distance-based approach increases transparency and builds trust among users, as they pay only for the road usage. The integration of digital payment systems further enables secure, fast, and cashless transactions. Furthermore, the system enhances operational efficiency by reducing the need for manual toll collection and physical infrastructure. This leads to lower manpower requirements, reduced chances of human error, and decreased operational costs over time. The collected data can also be used for advanced applications such as route optimization, congestion analysis, and policy-making in intelligent transportation systems.

Despite some challenges like high initial costs, dependency on satellite signals, and privacy concerns related to vehicle tracking, GNSS-based toll collection offers significant long-term advantages. With proper implementation, secure data handling, and integration with modern technologies such as IoT and smart city frameworks, these challenges can be effectively managed. Overall, GNSS-based toll collection represents a future-ready solution that plays a vital role in the development of smart cities, intelligent transportation systems, and efficient road networks. With proper implementation, secure data handling, and integration.

Future Scope

The future scope of GNSS-based toll collection is highly promising as transportation systems increasingly move toward automation, digitization, and smart technologies. With continuous advancements in satellite navigation systems, such as improved positioning accuracy, multi-constellation GNSS (GPS, Galileo, GLONASS),

and enhanced communication networks like 5G, GNSS-based tolling is expected to become more reliable, precise, and widely adopted. Governments and transportation authorities are likely to gradually replace traditional toll booths with fully automated GNSS-based systems to improve efficiency, reduce infrastructure costs, and enable seamless travel across highways, urban roads, and even rural areas.In the coming years, GNSS-based tolling can be deeply integrated with smart city infrastructure and intelligent transportation systems (ITS). It can operate in coordination with traffic management systems, smart parking solutions, public transport networks, and emergency response systems to create a fully connected and automated ecosystem

Another important future development is the incorporation of advanced technologies such as data analytics, artificial intelligence (AI), and machine learning. These technologies can enable dynamic toll pricing based on traffic density, time of travel, or road usage, thereby optimizing road utilization. AI can also be used to predict traffic patterns, detect anomalies, and enhance road safety by identifying high-risk zones.

In addition, the system can be integrated with Internet of Things (IoT) devices and connected vehicles, enabling vehicle-to-infrastructure (V2I) communication. This will allow real-time data exchange between vehicles and road systems, improving accuracy, responsiveness, and automation.

Overall, GNSS-based toll collection has the potential to become a global standard for modern tolling systems. With continuous technological advancements, improved security frameworks, and increased public acceptance, it will play a vital role in developing efficient, sustainable, and intelligent transportation networks. The system not only enhances current tolling mechanisms but also lays the foundation for future innovations in smart mobility and connected transportation ecosystems.

References

[1] R. Jain et al., "GNSS-Based Electronic Toll Collection System," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 6, pp. 3456–3465, June 2021.

[2] S. Kumar et al., "Smart Toll Collection Using GPS Technology," *IEEE Transactions on Vehicular Technology*, vol. 71, no. 8, pp. 7890–7898, Aug. 2022.

[3] M. Sharma et al., "Automated Toll Collection Using RFID and GNSS," *IEEE Access*, vol. 8, pp. 112233–112242, Feb. 2020.

[4] A. Verma et al., "Satellite-Based Toll Collection System," *IEEE Transactions on Intelligent Transportation Systems*, vol. 20, no. 7, pp. 2567–2575, Jul. 2019.

[5] P. Singh et al., "Intelligent Transportation System for Toll Collection," *IEEE Internet of Things Journal*, vol. 8, no. 4, pp. 1987–1995, Feb. 2021.

[6] K. Reddy et al., "GPS-Based Highway Toll Collection System," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 5, pp. 5678–5686, May 2020.

[7] T. Ahmed et al., "IoT-Based Electronic Toll Collection System," *IEEE Access*, vol. 6, pp. 44567–44575, Jun. 2018