Real-Time GPS-Based Bus Tracking System to Improve Public Transportation in Sri Lanka

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1. Introduction

Public transportation systems play a crucial role in urban mobility, enabling the daily movement of millions of passengers. However, inefficiencies such as delays and a lack of real-time information often led to passenger dissatisfaction. Traditional bus services generally lack real-time tracking capabilities, causing unpredictable wait times and limited communication between passengers and service providers. The advent of Information Technology and the Internet of Things (IoT) offers promising solutions to address these issues.

This project aims to develop a real-time bus tracking system that utilizes Global Positioning System (GPS) technology to provide passengers with accurate Estimated Time of Arrival (ETA) information. By harnessing real-time data, the system is designed to enhance the efficiency of bus services, reduce waiting times, and improve communication among passengers, drivers, and bus operators.

The primary objectives of this project include developing:

- A data collection module to monitor buses' real-time location and speed,
- Mobile applications for passengers, drivers, and bus operators, and
- A smart bus halt display that shows the estimated arrival time of the next bus.

This system is intended to not only enhance the passenger experience but also provide valuable insights for bus operators, contributing to a more efficient public transportation system.

2. Materials and Methods

The methodology for this study includes a structured data collection process, machine learning model development, and deployment of a GPS-enabled prediction system to improve the reliability and efficiency of bus services along the Colombo 15 route.

Data Collection:

- **Route Selection:** The Colombo 15 bus route was selected as the sample route due to its high passenger volume and significance within the urban public transportation network.
- **Data Points**: Data was collected at every bus stop and major halt along the Colombo 15 route, with arrival times for each bus.
- **Scheduled Time Retrieval**: Scheduled arrival time was obtained from the local bus depot, providing a reference for comparing actual arrival times.
- **Delay Calculation**: Using the scheduled times and actual arrival times, the delay at each bus stop was calculated. This information forms the core dataset, providing insight into typical delays and variability along the route.

Data Processing:

- **Cleaning and Preprocessing**: Collected data was cleaned to remove any inconsistencies, and missing values were handled. Additionally, timestamps were standardized to ensure accuracy in calculating delays and ETA predictions.
- **Feature Engineering**: Key features such as delay patterns, time of day, day of the week, and location were identified and created to enhance the model's predictive capabilities.

These features help the model learn patterns in bus travel times and delays more effectively.

Machine Learning Model Development:

- **Model Selection and Training**: Using data mining concepts, a machine learning model was developed to predict the Estimated Time of Arrival (ETA) for each bus stop.
- **Training and Testing**: The model was trained using historical data from the bus route, focusing on learning the relationship between scheduled times, delays, and actual arrival times. A portion of the data was held out for testing to validate the model's predictive accuracy.
- **Performance Evaluation**: The model was evaluated based on prediction accuracy, used to ensure reliable ETA predictions.

System Deployment:

- **GPS Module Integration**: The trained model was deployed on a GPS-enabled device installed on each bus. The GPS module tracks the real-time location of the bus and transmits this data to a centralized database.
- **Real-Time Data Update**: The GPS data is continuously updated in the database, allowing the model to adjust ETA predictions in real-time based on the bus's current position and speed.

Output and User Interface:

- **Mobile Application**: The predicted ETA for each bus stop is displayed to passengers via a mobile application, offering real-time information on bus arrival times.
- **Smart Bus Halt Displays**: The ETA is also displayed at smart bus halts along the route, providing passengers at bus stops with accurate and real-time information on the next bus's arrival.

Ongoing Data Collection and Model Refinement:

- **Continuous Data Collection:** As the system operates, it collects ongoing data on bus performance, delays, and ETAs, which are stored in the database.
- **Model Updates**: The collected data is periodically used to retrain and improve the model, ensuring it adapts to new patterns and continues to provide accurate predictions as traffic conditions and other factors change.

This methodology ensures a robust, real-time bus tracking system, which enhances passenger experience and operational efficiency in public transportation along the Colombo 15 route.

3. Results and Discussion

The pilot test conducted on a selected bus equipped with the real-time tracking system yielded promising results, demonstrating the system's accuracy and reliability in predicting Estimated Time of Arrival (ETA). Key observations from the test are as follows:

Accuracy of ETA Predictions:

- The system achieved high accuracy in predicting ETAs, with minimal deviation from the actual arrival times recorded at each bus stop.
- On average, the ETA predictions varied by less than 2 minutes from the actual arrival times, confirming the model's ability to account for dynamic variables such as traffic conditions and speed variations effectively.

System Reliability:

- The GPS module and data processing algorithms functioned smoothly throughout the pilot test, providing consistent real-time location data.

- The ETA predictions were updated in real-time as the bus progressed along its route, demonstrating the system's ability to adapt to real-time conditions and deliver reliable information to users.

Potential Impact on Waiting Time:

- The preliminary data suggest that implementing this system across all buses could help reduce average waiting times by up to 30%, leading to improved time management.

The pilot test demonstrated that the real-time bus tracking system is both accurate and reliable in predicting ETAs, with minimal deviation from actual arrival times. This technology has strong potential to address passenger frustrations related to unpredictable waiting times by offering live arrival information, enabling better planning and reducing average wait times.

Implementing this system across all buses in Sri Lanka could significantly enhance passenger satisfaction and increase the appeal of public transportation by improving reliability. The initial success of this pilot suggests that the system can be scaled up to create a more efficient, dependable public transit network in Sri Lanka, benefiting both passengers and operators.

4. Conclusion

This research demonstrates the potential of a real-time bus tracking system, utilizing GPS technology and machine learning, to improve the reliability and efficiency of public transportation in Sri Lanka. The pilot test on the Colombo 15 route revealed that the system can accurately predict the Estimated Time of Arrival (ETA), providing timely and reliable information that reduces passenger wait times and enhances overall user satisfaction.

By scaling this system across the entire bus network, Sri Lanka's public transportation infrastructure can address long-standing issues of unpredictability and passenger dissatisfaction. The success of this pilot not only validates the effectiveness of integrating IoT with data-driven models but also underscores the feasibility of using such systems to modernize urban transit. Future work should focus on expanding the system to additional routes, refining prediction accuracy, and integrating with other transportation systems to further elevate the standard of public transportation in Sri Lanka.

5. Keywords

Estimated Time of Arrival, GPS, IoT, Machine Learning

6. References

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