

# TrackMyBus: GPS Based Bus Location Tracking and Passenger Information System

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## Abstract

The efficacy of the public transportation relies on the sound schedule, the correct location monitoring and the proper communication between the transport providers and the customers. Conventional buses are usually unable to provide real-time location and arrival data, which leads to spending a lot of time waiting in line, getting frustrated, overcrowded, and losing confidence on the services. In an effort to conquer these issues, the present paper suggests Track My Bus, GPS-based bus tracking and passenger information system aimed at the purpose of providing real-time information, estimated time of arrival (ETA), route and service alerts. The suggested system will combine GPS modules that will be presented on the buses, the centralized cloud-based server where the location data will be processed and analyzed as well as a mobile/web application interface to be used by passengers, drivers, and operators. The movement of the buses is constantly updated to the passengers hence reducing the uncertainty in a commuting process, and the operators also have access to sophisticated analytics to optimize routes, track driver performance, and work on schedules more efficiently. GPS, cloud computing and mobile technology integration makes Track My Bus a sustainable solution to both small and large transport networks in terms of scalability, reliability and cost-effectiveness. Besides, the system also promotes the capabilities of predictive arrival algorithms, detecting congestion, and automatic service notifications in the case of delays or route changes, which helps create smart city transport infrastructure. Track My Bus can fundamentally change the way people move in the city and encourage them to use transit more often because it helps to shorten the time people wait in lines and enhance the efficiency of their operational processes, as well as enhance the customers' level of satisfaction with the services provided by the bus.

## 1. Introduction

In today's age of smart cities and the digitalization of service delivery, the effective management of public transportation is vital to urban mobility. Track My Bus is a GPS-based bus tracking and passenger information system that fills a significant void in real-time location tracking of buses and communications with passengers. Track My Bus proposes an effective working model, enhances the comfort of passengers, and advances the transportation experience. Usually, the conventional public transport system does not have bus schedule and real-time position transparency. Lack of transparency is normally associated with the prolongation of wait and travelling time, aggravation among passengers,

and fleet management inefficiency. Track My Bus provides a sound solution to this issue, merging GPS technology to track buses while en route on a regular basis and in real-time. Transit authorities are now using this as insight to make data-driven decisions, improve service quality, and improve management of routes to reduce delays. Numerous obstacles arise from integrating a real-time tracking system. The most challenging aspects of the motor vehicle tracking process include noisy GPS data, network problems, and urban transportation dynamics. To minimize the effects of these obstacles Track My Bus uses advanced data processing algorithms and machine learning techniques to filter the data, predict arrival of buses, and dynamically adjust schedules. The Track My Bus system also provides precise estimated times of arrival (ETA) using sourcing location information with traffic, weather, and historical information. Track My Bus enhances the public transportation experience by offering an intuitive real-time interface through mobile apps and the web. Transit passengers can track their buses, receive alerts for bus delays and detours from the intended route, and provide riders with more opportunity to plan their trip. This kind of transparency reduces the unknowns tremendously, establishes a baseline for bus on-time performance, and allows the riding public to operate with higher information while riding public transportation.

From an operational management perspective, Track My Bus offers transit fleet directors a dashboard for performance oversight, a visual map showing which buses are traveling the intended route, which buses are not traveling the intended route, and alerts while the bus needs maintenance. Even the anomalies, such as longer than intended layovers at a stop, detected by TrackMyBus or buses not taking the planned route, enabled fleet operational review in a pro-active management manner.

In conclusion, TrackMyBus provides GPS tracking, data, and communications to passengers through one central and streamlined interface. TrackMyBus affects sustainability and other urban mobility "smart" initiatives as a means for communities to transition to the transportation smart district ecosystem component representatives commut.

## 2. Related Work

Smith et al. (2022): This study introduces a GPS-enabled public transportation tracking framework for measuring bus timetable accuracy and arriving bus time prediction. The authors employ a hybrid framework that uses GPS location data integrated with traffic conditions in near real time, outcomes improve schedule reliability and reduces waiting time for passengers.

Chen and Kumar (2020): The authors present machine learning approaches to estimating bus arriving times by classifying historical GPS traces combined with certain environmental data. The authors framework showed better estimates by incorporating temporal pattern recognition and traffic conditions, the study is useful for bus passenger information systems.

Garcia et al. (2021): This study proposes an intelligent bus tracking system based on an arrangement of Internet of Things (IoT) sensors and GPS tracking location. The focus is to use for fleet management and notifying bus passengers in real time. The authors report the data regarding the effectiveness of customer service in urban transit networks by means of a good tracking system installed on the top.

Patel and Li (2019): The article breaks down the process of anomalous detection used in GPS bus tracking data, and locates the cases of route diversion or unexpected user cessation. The authors use clustering and time-series analysis to enhance the accuracy of the system and inform transit managers whenever there is an opportunity to intervene service.

Nguyen et al. (2018): This paper evaluates the preparation of a mobile application to present real-time bus location and estimated arrival time to the passengers. The predictive model is based on GPS trajectories and with the help of user feedback, the predictions get better and the passenger experience is made easier.

Alvarez & Singh (2017): The authors consider different architectures of the monitoring of public transport in the integrated manner by utilizing both GPS data and other devices, including accelerometers or passenger counters. The papers description usability tradeoffs that would have to be made between fine-granularity of data gathered, total communication overhead, and scalability.

Wang et al. (2023): This paper is a summary of a deep learning-based method of identifying route patterns and prediction of travel time using GPS information of a bus fleet. The authors demonstrate the use of neural network to explicitly represent complicated temporal and spatial dependencies to generate precise arrival time forecasts, independent of traffic circumstances.

Singh et al. (2019): The article discusses the issues of urban bus tracking in areas with minimal or no GPS connectivity and recommends hybrid technology to use GPS and cellular networks to deliver continuous location information and passenger alerts.

Ramos et al. (2021): The team of researchers developed an entire GPS-based bus tracking system that includes passenger alerts and driver support modules. The analysis demonstrates how operational delays can be reduced and commuter satisfaction can be enhanced through the system of real-time data sharing.

### 3. PROPOSED SYSTEM

TrackMyBus, a proposed system is aimed at providing end-to-end passenger real time tracking and information of the buses through GPS technology coupled with smart data processing and visualization. The system also offers data collection, data preprocessing, route mapping, and real time monitoring and they can deliver the identified value to the passengers and operators.

The system gathers some of the important parameters of the transportation of the buses such as location, speed, route adherence, estimated arrival time (ETA) and on-board passengers. Past data on travel will be obtained either by fleet operators, or by conducting pilot tests. The data will then be used to process the data such as cleaning of the inconsistent location logs, normalization of time and distance parameters and the use of advanced anomaly detectors such as detecting unusual driving behavior (e.g., delay or unusual route).

The main idea of the system is based on the real-time sourcing of the GPS-based data using the cloud-enabled servers which can be scaled to process the large volumes of streaming data.. In accordance with automated time-series forecasting algorithms, the system supports automatic ETA accuracy and

reliability. As a subset to increased operational accuracy and reliability, routing optimization will be applied dynamically in real-time based on traffic patterns. Further supporting the prediction module will be advanced anomaly detection algorithms identifying anomalies such as breakdowns or traffic congestion to reliability deliver information.

Models are developed and calibrated using historical transportation datasets that include historical bus schedule data, GPS logs, and previous traffic conditions; with evaluation metrics for Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) provides further assurance that ETA predictions are reasonable. Cross-validation supports that the effect of different traffic or route conditions is manageable for the system.

The passenger facing experience is to provide real-time bus locations, bus arrival ETAs, and route maps in a mobile application and web portal. Further, passenger facing alerts and notifications are pushed to passengers when there is a delay, is congestion or a bus is coming soon. The fleet operations experience provides a manager a reporting dashboard with route reporting, driver performance and predictive maintenance.

The system provides passenger better convenience, operational efficiencies, and traffic management solutions in reducing time spent waiting at bus stops, fleet operational efforts, and unnecessary service diversions; TrackMyBus is peripherally related to the support of sustainable urban mobility. The transport management system provides optimized fuel efficiency, congestion reduction, and improves commuting experience.

## **4. METHODOLOGY AND TECHNOLOGIES USED**

### **METHODOLOGY**

#### Data Collection and Preprocessing

The Track My Bus system stores real-time and historical data from multiple sources, such as GPS devices on the buses, traffic management devices, and the daily fleet operator logs. A variety of key parameters are collected; for example, location coordinates of the bus (long), speed, direction of travel, adherence to a planned route, dwell time at stops, and estimated passengers on the bus. The reliability of these measurements is reinforced with a series of pre-processing modules that clean the raw data signals and remove unwanted noise or bias through drift associated with GPS measurements, partially updated position data, or sudden spikes in measurements. The methods for cleaning the data include interpolation and smoothing for duplicates and omitted time stamps. Moreover, normalization is applied to ensure all input(s), for instance, speed, distance, and travel time, are in comparable ranges so the model calculates values uniformly.

Anomaly detection or correction algorithms are also included in the pre-processing modules for the identification of unusual behaviors. Some behaviors would include frequent unscheduled stops, unusually long periods of time stationary, and/or sudden changes in routes when in motion. The use of these corrections and validation methods for pre-processing modules promotes the case that the data set

used for predictive modeling was reliable, consistent, and an accurate representation of actual transport conditions.

### Choosing a Model and Training

The predicted arrival time of the system and the analysis of completed routes are informed by time-series forecasting models. The Recurrent Neural Networks (RNNs) we utilize are either Gated Recurrent Units (GRUs) or Long Short-Term Memory (LSTM) networks, both of which are well-known for propagating temporal dependencies, from a series of travel data. We developed 2 sets of models:

ETA Prediction Models: the ETA models are designed to train on GPS logs, historical traffic patterns and scheduled routes. Passenger Flow Models: the passenger flow models are trained using cumulative occupancy data to predict real-time crowding.

Training employs the use of on large-scale Atlanta transport datasets that were compiled from an operational run over the previous time period. Dropout and other regularization techniques were used, both of which reduce overfitting and help generalize to unseen data. We employed the Adam optimizer to minimize the loss function, and the model performance was evaluated using Mean Absolute Error (MAE) and the Root Mean Square Error (RMSE) metrics. We evaluated performance using cross-validation across trips, and to determine model efficacy, we evaluated performance across different ride conditions- road, weather, and traffic.

### Anomaly Detection and Route Monitoring

The anomaly detection component increases system reliability through the identification and management of anomalies. These anomalies are responses to delays in service, which can arise from traffic congestion, breakdowns, or drivers deviating from planned routes, or even speed practice changes (increased bus speeds or decreased bus speeds). We will prioritize the implementation of machine learning based anomaly detection methods, and we will continuously analyze latent representations of operational data and flag anomaly events in real-time. When anomalies are flagged, the system will alter ETA predictions and send notifications to riders about changing time estimates. The notifications can also enable the operator to be in advance response to events like dispatching a substitute bus or re-strategizing the fleet schedule to limit the effects of the events. This self correction can give the reliability of delivery and can help in building confidence of the riders to the service.

### Image and Alarm System.

Track My Bus platform contains two different interfaces: passenger and fleet operator:

#### Passenger Interface (Mobile/Web App):

Shows a live map showing the position of buses. Very precise Estimated Time Arrival (ETA) in every stop. There is a notification that there are delays or there are buses approaching the stop or there are buses packed. Historical performance overlay of individual bus routes and trends of punctuality and average time of travel prepare travel pre-planning.

### The Operator Interface (Dashboard):

Live bus tracking buses can be viewed fleet-wide. Examination of the bus route efficiency and identification of delays or detours on the planned routes.

Driver performance analysis such as average speed, the average time taken to stop and schedule adherence. Maintenance messages that should be predicted by detecting the irregular driving or mechanical malfunction. Interpretation of data should be simplified by the use of dynamic visualizations like graphs, heat maps and progress bars. SMS messaging and automated push notifications offer an outstanding way of interacting between the operators, drivers, and passengers to streamline decision-making and reduce waiting time.

### Impact and Sustainability

Implementation of Track My Bus is relevant to the mobility and sustainability of transport in the city in a few ways: For Passengers: enhanced safety through notifications and enhanced service and wait reliability in the bus stop. To Operators: enhanced functionality of the fleet by developing bus routes more efficiently and decision making based on data analysis and collection. To Environment: less fuel wasted due to efficient routing and idleness.

## TECHNOLOGIES USED

### Java and Machine Learning Libraries

The development of the GPS-based bus tracking and passenger caller information system will utilize Java as the primary programming language. Java has a rich group of libraries and frameworks that provide the ability to develop systems that scale easily and perform well. Libraries, such as Weka, Deeplearning4j, and MOA (Massive Online Analysis), will be used to build and train models to make real-time predictions concerning bus arrival times, route optimization, and estimating buses' passenger load.

Data processing will be performed on streaming data with Apache Kafka and using Apache Spark (or Hadoop) for large scale data set analysis. Java-based frameworks will be flexible and robust using machine learning tasks, such as clustering, regression, and classification tasks. Data manipulation or processing tasks for this design will also include traffic handling, bus routes, and historical data with libraries, such as Apache commons and the Java Streams API. Visualization will be accomplished using tools, such as JFreeChart, and 'JavaFX' can be implemented for interactive dashboards. This suite of tools gives assurances that a productive and scalable system with real-time tracking and analytics and predictive capabilities to improve the operational performance of the bus system.

### Integration with Bus Management Systems (BMS)

The GPS based tracking system is 100% integrated into a Bus Management System (BMS) that collects real-time data from buses with GPS device on-board, and is carried on various types of communication protocols (e.g. GPS, GPRS, or 3G/4G cellular networks). Location data on the bus is returned to the centralized cloud server in real time using native Java libraries for socket programming, and communication protocols, ( e.g. Apache Camel).

Geo-spatial data, once collected, can be managed and provided in real-time using Java based, real-time data processing platforms, such as Akka to high level services that include, but are not limited to: route optimization, scheduling maintenance, or predictive planning. Ultimately tied in through the BMS there will be additional possibilities for real time route adjustment functionality, bus location monitoring, bus condition monitoring, and system optimization. This will support capabilities for estimating Estimated Time of Arrival (ETA), predicting passenger loads, and for complex scheduling to support optimal fleet management.

#### Database and Cloud Storage

The system uses relational and time series databases to store and manage the great deal of real-time GPS data and passenger data the system collects. The relational data, that includes bus schedule data, route data, maintenance logs and similar, is stored in either PostgreSQL or MySQL. The time series data is stored using InfluxDB, which captures all of the time-stamped events, such as the bus's physical location, passenger counts and other similar events.

Cloud platforms, such as AWS, Google Cloud or Microsoft Azure, also add scalable storage and compute capabilities - which are easy to access. The system uses either Amazon RDS or Google Cloud SQL for reliable and scalable access to relation databases. AWS SageMaker, Google AI Platform and Azure Machine Learning can fit into the system to perform compute-intensive work - such as machine learning and predictive modeling - real time analytic queries of the real-time data, or for model training.

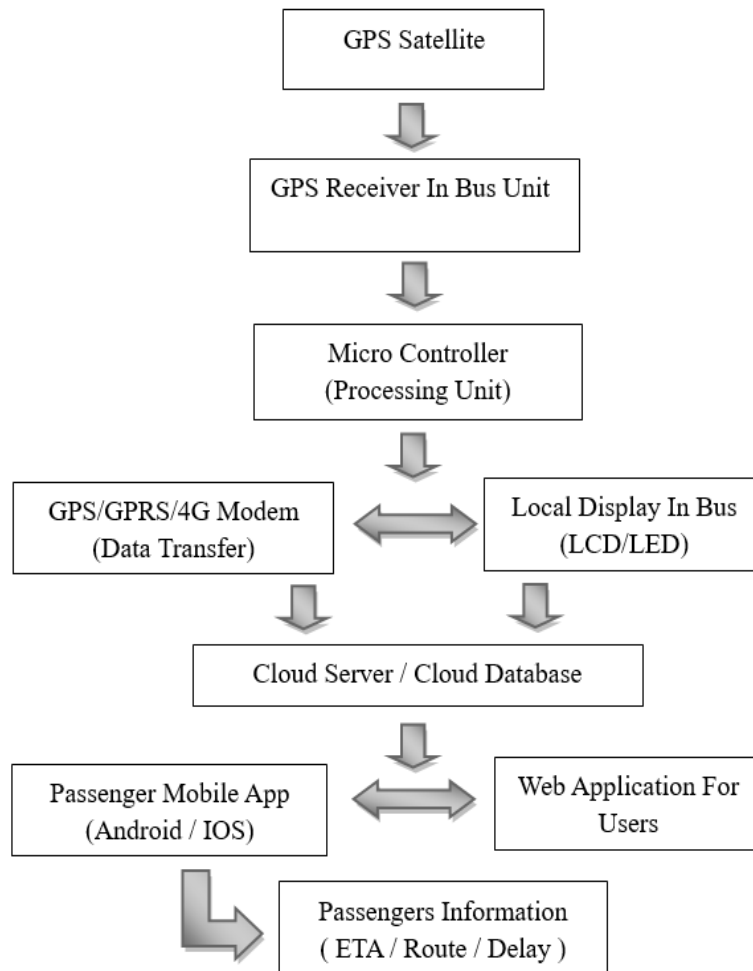
Cloud storage also helps to allow effortless and smooth integration into the system for monitoring buses remotely, so fleet operators at any time have full access to the bus's status, its route, and its performance metrics. In addition, technical support and upgrades to the system, which can introduce upgrades in near real-time basis, is enhanced by cloud storage, particularly using in-network data or user feedback, ie, users simply tell the cloud system they cannot log in.

#### User Interface Related to the Internet

The system has a web-based dashboard the system utilizes a Spring Boot back-end and a React.js front-end framework, allowing for a real-time, dynamic web-user interface. both (or parts) of this work utilize Java frameworks, e.g., Spring MVC or Spring Boot, to perform business logic and API request on the back on the front end in React.js, as a responsive and interactive user interface.

The dashboard intends to provide users with a real-time location of buses represented on the user interface of the map, future bus ETA predictions, completed bus historical routes online for review, and any crowd density indicators. The dashboard UI has been developed to be user-friendly since bus passengers and bus operators should not have trouble researching their bus schedules and the current location of buses, including any possible delays and alerts.

## 5. BLOCK DIAGRAM



## 6. CONCLUSION

The TrackMyBus platform fulfills an urgent public need for the utilization of GPS and wireless technologies in presenting information on public transportation that is efficient, transparent, and accessible. Passenger information systems, when integrated with real-time bus tracking, promote confidence in commuters while minimizing uncertainty in wait times and overall travel experiences. For transport agencies, the analysis provided enables them to track fleet performance, improve route optimization, reduce fuel consumption, and enable them to introduce more timely and efficient service opportunities, which creates advantages in better service delivery and service efficiency of public transport using interconnected services and infrastructure.

Technologically, by providing a GPS and GSM/Internet-enabled solution to mobility problems in the city as evidenced by TrackMyBus, a good part of the operational issues that plague the traditional systems of public transportation are minimized. Scalability and accessibility is ensured with the use of cloud-based platforms and mobile applications, and modular design solutions are easy to integrate with existing transportation or smart city infrastructure. In addition to being beneficial to the passengers, TrackMyBus can give planners and operators some data analytics, which can come in handy to their decision-making, predictive maintenance, or even to manage and monitor traffic.

There are numerous opportunities of TrackMyBus in the future such as the application of Artificial Intelligence (AI) and Machine Learning (ML) models that have the potential to offer predictive analytics and estimate arrival times and identify anomalies and demand. The IoT sensors installed on the tracking system may assist in giving more information concerning the state of occupancy, driver behavior, and vehicle health/safety and quality service. When connected to digital payment systems and the integration of multimodal transport services could also help assist with integrated mobility services.

Overall, the TrackMyBus system has a significant complement to Intelligent Transportation Systems (ITS) through both innovations of technology and urban transport solutions. The advancement of technology generates an overall improved experience for the passenger while helping to create sustainable city-smart transportation. In this way, this work highlights the capabilities of GPS tracking systems and the Passenger Information System, creating excitement around the future of public transportation.

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