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Real Time Bus Tracking System

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ABSTRACT—The Real-time bus tracking system is a crucial innovation in the field of transportation as it offers accurate information about the location and arrival time of buses. Transportation systems in general fail to update passengers on time, and as a result, there can be many inconveniences. Thanks to recent innovations in the areas of GPS technology, web-based technologies, and real-time communication, there are opportunities to enhance the efficiency and effectiveness of bus tracking systems. In this paper, a real-time bus tracking system is proposed that will allow users to monitor bus locations, see their routes and have access to updated bus information. The proposed system works through a web-based application and utilizes Express.js framework for the development of its backend architecture and MongoDB Atlas for the storage of bus and routes information.

KEYWORD-Real-Time Bus Tracking, GPS, Express.js, MongoDB Atlas, Node.js, Web Application, Bus Location Tracking, Public Transportation, Socket.IO.

I.INTRODUCTION

Public transportation plays an integral role in everyday activities. The passengers may experience some challenges because of the non-availability of real-time information about the bus locations, delays, and unpredictability of arrival times.

The conventional approaches to tracking bus locations have their drawbacks in providing reliable and accurate updates. The modern technologies like GPS, web apps, and real-time communication can help in solving this problem. The proposed project includes a Real-Time Bus Tracking System, which allows passengers to monitor bus locations and get the latest information about buses via a web app. The suggested system implements the following tools for software development: Node.js, Express.js (back-end), MongoDB Atlas (database), and Socket.IO (real-time communication).

II. LITERATURE REVIEW

The advancement of the real-time bus tracking system is an evolution from the traditional methods used to track buses to the current systems that incorporate GPS technology and internet-based transportation systems. In early systems, there was the use of fixed schedule and manual tracking [1], [2] that lacked the accurate real-time information. Currently, GPS enables the live tracking of bus movement, and digital maps assist passengers in understanding where the buses are going [3], [4]. Cloud computing and data analysis have also advanced the storage of the tracking information and prediction of bus arrivals [5], [6].

A. Foundational Concepts

Current studies have emphasized the application of GPS technology, web-based applications, and passenger information services. Smart transportation systems have incorporated the real-time tracking and the route management to make the process efficient [7], [8]. Current approaches have also embraced the use of geofencing in order to create location-based alerts and multilingual interfaces [9], [10]. This gives an overview of creating a real-time bus tracking system that gives information about bus locations and routes.

A. Comparative Analysis

In this section, there is a comparative analysis of technologies and methodologies used in real-time bus tracking systems. This comparison has been made in terms of the applications of various technologies/methodologies and their respective advantages.

Table I Comparative Analysis of Real-Time Bus Tracking Systems

Year	Model/Technique	Domain	Key Metric
2019 [1]	Traditional Tracking	Bus Scheduling	Basic information about buses
2020 [3]	GPS-Based Tracking	Location Monitoring	Real-time location
2021 [5]	Cloud Computing	Data Management	Storage and access of data
2022 [7]	Smart Transportation System	Public Transportation	Enhanced Efficiency
2023 [9]	Geofencing Technology	Passenger Alerting	Locationspecific alerts

III. SYSTEM ARCHITECTURE

A. Architecture Overview

The proposed Real-Time Bus Tracking System follows a clientserver architecture. The frontend provides an interface for passengers to view live bus locations, routes, and estimated arrival times. The backend processes bus location data received through GPS and provides real-time updates. A database stores bus details, route information, stops, and location records. Interactive maps display bus movements, while geofencing and notifications alert passengers when buses approach their selected stops.

This architecture separates the frontend, backend, GPS tracking, and database components, allowing each component to be maintained and improved independently. It provides a foundation for reliable bus tracking, efficient data management, and improved passenger convenience.

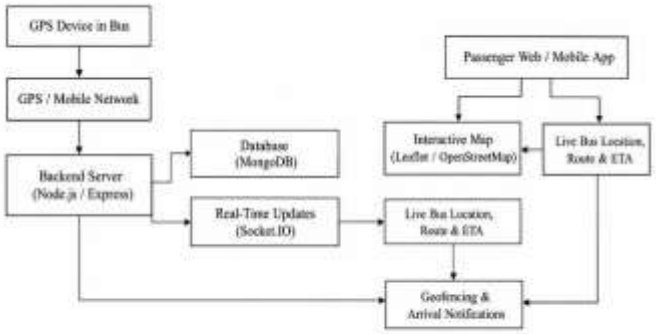


Fig. 1. System architecture of the proposed real-time bus tracking system.

B. Major Modules

The major modules of the Real-Time Bus Tracking System include the User Module, GPS Tracking Module, Bus and Route Information Module, Live Map Module, Estimated
Arrival Time Module, and Notification Module. The User Module allows passengers to search for buses and select destination stops, while the GPS Tracking Module collects live bus location data. The Bus and Route Information Module manages bus details, routes, and stop information. The Live
Map Module displays bus locations, and the Estimated Arrival Time Module calculates expected arrival times. The Notification Module provides geofencing-based alerts and push notifications, while the Web Interface Module offers multilingual access to bus services across Karnataka.

C. Data Flow

The data flow begins when the bus GPS device or driver's mobile device captures the current bus location. The backend receives the GPS coordinates, validates the data, and updates the bus location in the database. The updated location is processed and transmitted to the frontend, where the bus is displayed on an interactive map. The system retrieves bus routes, current stops, next stops, speed, and estimated arrival times for passenger access.

When a passenger selects a destination stop, the system monitors the bus location and checks its proximity to the selected stop using geofencing. When the bus enters the defined geofence, an arrival notification is triggered, subject to device and browser permissions. This flow separates GPS data collection, backend processing, database storage, map visualization, and notification services to provide timely and accessible bus information.

IV. METHODOLOGY

A. Data Preparation

GPS technology is used to determine the geographical position of a moving bus. The driver's mobile device accesses location services and periodically captures latitude and longitude coordinates. The coordinates are transmitted to the backend server, where they are associated with the corresponding bus and trip. The latest location is stored and made available to passengers through the web application. The location update process enables continuous monitoring of bus movements during an active journey.

B. Distance Calculation and Estimated Arrival Time

The system calculates the geographical distance between the current bus location and the passenger's selected destination stop using GPS coordinates. The Haversine formula is used to estimate the distance between two geographical points

$$a = \sin^2\left(\frac{\Delta\phi}{2}\right) + \cos\phi_1 \cos\phi_2 \sin^2\left(\frac{\Delta\lambda}{2}\right)$$

$$d = 2R \arcsin(\sqrt{a})$$

where d represents the distance between two points, R is the Earth's mean radius, φ represents latitude, and λ represents longitude. The estimated arrival time is calculated using the distance and average bus speed:

$$ETA = \frac{d}{v}$$

Where ν represents the average speed of the bus. When distance is expressed in kilometres and speed in kilometres per hour, the result is obtained in hours and can be converted into minutes. The estimated arrival time may vary depending on traffic conditions, road conditions, and unexpected delays.

C. Geofencing and Push Notifications

Geofencing is deployed to detect the moment when the bus reaches the destination bus stop that the passenger has chosen. The geographic radius is set around the destination, and the system checks the bus' current coordinates against the destination's coordinates. As soon as the bus crosses the set radius, an arrival notification may be sent. With push notifications, it is possible for the passengers to get an immediate notification without visiting the tracking website continuously.

D.Passenger Interface and Multilingual Support The interface of the passenger enables the users to find buses, choose routes, select destinations, and even view the locations of the buses. Information like bus number, bus current stoppage, next bus stoppage, speed of bus, and bus expected arrival time is displayed depending on availability of data. The solution has been developed keeping in mind the Karnataka transport companies like KSRTC, BMTC, NWKRTC, and KKRTC. The use of multilingual functionality makes it easier for the users to access bus information.

E. Overall System Workflow

The whole process flow involves the following steps: 1) the driver turns on the bus tracking service and provides GPS functionality; 2) the device gets the coordinates of the current bus position; 3) the server processes and saves the obtained information about location; 4) the new coordinates are sent to the front end; 5) the customer sees the bus position on the interactive map; 6) the estimated time of arrival is calculated based on geographical distance and speed; 7) the geofencing function starts the alarm when the bus reaches the chosen stop; and 8) the passengers track their ride with the help of the web app. This approach makes it possible to divide such processes as collecting information about

location, processing, storing, visualizing, and delivering notifications, which forms a basis for future development.

V. IMPLEMENTATION

Frontend implementation involves React and Vite frameworks that offer an interactive web interface for real-time bus tracking. Backend implementation uses Node.js and Express to enable REST-like backend services as well as handle application requests. The database chosen is MongoDB Atlas, which stores bus information, route details, and location logs.

GPS technology is used to get the current locations of buses, while the maps show their location on an interactive map. Communication between the front and back ends uses HTTP/JSON protocol. Location information about the buses will be collected by the backend services and then stored in the MongoDB Atlas, and the updated information is sent to the frontend to show the location of the buses and their arrival times.

The modularity enables the implementation of user interaction, backend services, location tracking, maps visualization, and database management in a modular manner. The system can easily be extended to include arrival times prediction based on traffic, notifications for passengers, and optimization of routes.

VI. RESULTS AND DISCUSSION

The constructed prototype shows how the real-time tracking works, from acquiring the bus locations up to displaying the bus locations and routes on the interactive map. In addition, it can be used to view the bus details and estimate their arrival times.

The real-time tracking approach is considered a feasible way for passengers to track buses' movements and plan their travel. Nonetheless, the accuracy of tracking is affected by GPS availability and the Internet connection.

The existing prototype has some problems when it comes to making accurate prediction of the arrival times in case of congestion and network interruption. Further evaluations need to be made using appropriate measurements. Such measurements include the accuracy of location, response time, update frequency, and users' satisfaction. There is no need to
provide any value since they are not determined yet

VII. FUTURE ENHANCEMENTS

Future Future enhancements will include enhancing the realtime bus tracking system by using advanced GPS tracking technology in order to increase bus location precision. Predictions based on traffic awareness could be implemented for better estimation of arrival times.

The system could use real-time traffic data to increase the precision of predictions. Passenger alerts could be incorporated into the system in order to alert users regarding bus arrival, delays, and other information related to the route.

Route optimization and analysis of historical travel data could be implemented within the tracking system to enhance transportation efficiency. Testing on a large dataset is needed in order to evaluate tracking precision and response time.

VIII. CONCLUSION

In this paper, the authors propose a system of real-time bus tracking which integrates a web app with GPS-based location tracking. For the architecture of the proposed solution, the following tools were used: React/Vite, Node.js with Express, MongoDB Atlas.

This system allows tracking of the location of buses, accessing information about routes, and viewing their estimated arrival times. Integration of the frontend and backend services helps to ensure the work of communication between the system components and displaying bus tracking information, whereas MongoDB Atlas helps to store information about buses, routes, and locations.

Modular architecture serves as a basis for further improvements such as integration of real-time traffic, enhancement of the algorithm of arrival time estimation, notifications of passengers, and optimization of routes. In addition, the existing prototype allows demonstrating the workflow of bus tracking; however, additional testing under various conditions is necessary.

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