REAL-TIME BUS TRACKING AND PASSENGER OCCUPANCY INFORMATION SYSTEM

Project Reference No.: *49S_BE_0612*

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Keywords:

GPS-Based Real-Time Vehicle Tracking, Firebase Realtime Database, WebSocket Data Synchronization, Google Maps JavaScript API, Estimated Time of Arrival (ETA).

Introduction:

The growing dependence on institutional transportation has made it increasingly important for colleges to provide students with timely, accurate information about bus availability and arrival. Traditional bus systems operate on fixed timetables that fail to account for real-world variables such as traffic congestion, route delays, and driver-side disruptions, leaving students with little clarity on when their bus will actually arrive. This paper presents a Real-Time Bus Tracking and ETA Prediction System developed for Vidyavardhaka College of Engineering (VVCE), designed as a web-based platform to bridge this communication gap between bus drivers and student commuters. The system leverages the browser-native Geolocation API to capture live GPS coordinates from driver devices, which are then streamed to a Firebase Realtime Database at three-second intervals using a persistent WebSocket connection. These location updates are instantly propagated to student-facing dashboards without any manual polling, ensuring near-instantaneous data delivery across all connected users. An interactive Google Maps interface renders the live bus position along with predefined route polylines, providing students with spatial awareness of bus movement. The Estimated Time of Arrival is dynamically calculated on the client side using the Haversine formula, which derives great-circle distance between the bus and the nearest stop and divides it by average speed. Firebase Authentication manages secure, role-separated login flows for drivers and students, ensuring that location write access is restricted to authorized driver accounts. Built using React.js and deployed on Vercel, the application requires no native mobile installation and is accessible across all modern browsers, making it a practical and scalable solution for campus transportation management.

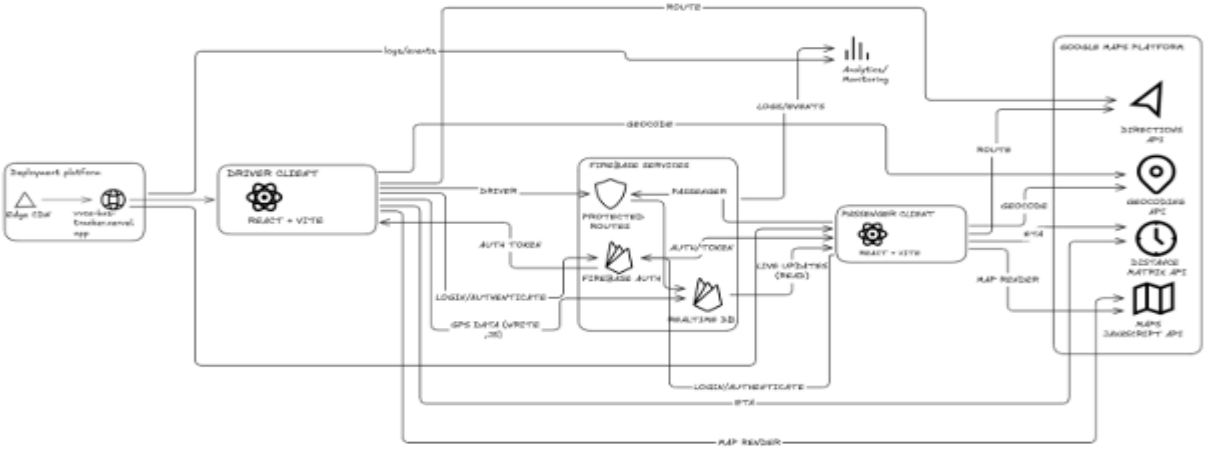

Figure 1: System Architecture of Real-Time Bus Tacking

Objectives:

1. Real-Time Bus Location Tracking: Continuously track bus location using GPS and display the live position on an interactive map for students.
2. ETA Prediction for Students: Calculate and display the estimated bus arrival time based on the bus's current location and distance to the stop.
3. Secure Role-Based Login System: Provide separate login access for drivers and students, ensuring only authorized drivers can share their location.
4. Live Map Interface with Route Display: Offer students a simple, browser-based dashboard to view the bus on a map along with the planned route and stops.

Methodology:

1. The proposed system follows a three-tier architecture consisting of a driver client, a Firebase cloud backend, and a student-facing passenger client. Upon authentication through the Firebase Email/Password sign-in module, the driver accesses a dedicated dashboard where location broadcasting is initiated by clicking the "Start Tracking" control. Once activated, the browser invokes navigator.geolocation.watchPosition(), which continuously captures the device's GPS coordinates at three-second intervals alongside speed and timestamp metadata. These values are written in real time to a structured node in the Firebase Realtime Database under the path /buses/{busId}/location, uniquely keyed to the assigned bus identifier to support multi-bus fleet operation.
2. On the passenger side, students select their assigned bus from the dashboard, which triggers a React useEffect hook to subscribe to the corresponding Firebase database node using the onValue() listener. Firebase maintains a persistent WebSocket connection, ensuring that every driver-side location update is pushed instantly to all connected student clients without any manual polling. The received coordinates are used to update a live marker on a Google Maps JavaScript API canvas, which also renders predefined route polylines and stop positions loaded from the Firebase Realtime Database. The Estimated Time of Arrival is computed client-side using the Haversine formula, which calculates the great-circle distance between the bus's current position and the nearest upcoming stop, then divides it by an assumed average speed to yield an arrival estimate in minutes. The entire application is built

using React.js with Vite as the build tool and deployed on Vercel's edge network, enabling global accessibility through any modern web browser without requiring native application installation.

Result and Conclusion:

In conclusion, the Real-Time Bus Tracking and ETA Prediction System was tested within the campus environment of Vidyavardhaka College of Engineering and demonstrated consistent, reliable performance across multiple bus routes. The system maintained a location refresh interval of approximately three seconds, with Firebase's WebSocket connection delivering updates to student dashboards in under 100 milliseconds under standard network conditions. ETA estimates computed using the Haversine formula remained within an acceptable margin of error, providing students with dependable arrival predictions that noticeably reduced uncertainty during peak commuting hours. The role-based login system functioned as intended, with drivers and students accessing their respective interfaces without any cross-role conflicts, and the Google Maps integration rendered route polylines and live bus markers smoothly across all tested browsers. Since the system operates entirely through a web browser using the device's built-in GPS, no additional hardware investment was required, making it a genuinely low-cost and practical alternative to dedicated IoT-based tracking setups. By bringing together Firebase, Google Maps API, and React.js into a single cohesive platform, the system achieves a level of responsiveness and accessibility well-suited to institutional transport environments.

References:

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Future Scope:

The future scope of this project includes:

1. Native Mobile Application: A dedicated Android and iOS app can be developed to utilize hardware GPS sensors for improved location accuracy and to enable background tracking, which is currently limited in browser-based environments.
2. Traffic-Aware ETA and Push Notifications: Integrating real-time traffic data from the Google Maps Directions API can improve ETA accuracy beyond the current distance-based formula, while Firebase Cloud Messaging can deliver instant arrival alerts to students without requiring them to keep the app open.
3. Multi-Bus Fleet Management Dashboard: The system can be expanded to support a larger number of buses with a centralized admin panel, allowing transport coordinators to monitor all active buses simultaneously and manage route assignments dynamically.