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Real Time Bus Tracking System for Small Cities

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Abstract
The rapid growth of smart transportation systems has increased the demand for efficient and secure vehicle tracking solutions. Traditional bus monitoring systems mainly depend on manual communication methods, which often create delays and lack transparency. This paper presents an IoT-based real-time bus tracking system developed using GPS, ESP32, Firebase, and Flutter technology. The proposed system provides live bus location tracking with role-based modules for Admin, Driver, and User operations. The driver's live GPS location is continuously updated to Firebase Firestore, allowing users to monitor bus movement on a live map interface. Firebase Authentication ensures secure access control and real-time synchronization between all modules. The system improves transportation management, passenger safety, communication efficiency, and tracking accuracy. Experimental implementation results demonstrate reliable live location updates and effective real-time monitoring performance.

Keywords: *Bus tracking system; ESP32; Firebase; Flutter; Internet of things.*

1. Introduction
Transportation management has become an important part of modern educational institutions and public transportation systems. In many schools, colleges, and organizations, bus transportation still depends on manual communication methods between drivers, administrators, parents, and passengers. These traditional systems often create confusion, delays, lack of transparency, and difficulties in monitoring the exact location of buses in real time. With the rapid growth of Internet of Things (IoT) technology, smart transportation solutions are becoming more efficient and reliable. IoT enables devices to communicate and exchange data through the internet, allowing real-time monitoring and automation. GPS technology further improves transportation systems by providing accurate live location tracking of vehicles. Combining IoT, GPS, and cloud computing technologies can significantly improve transportation safety, management, and communication efficiency. The proposed IoT-Based Bus Tracking System is designed to provide a smart and secure real-time bus monitoring solution using GPS, ESP32, Firebase, and Flutter technologies. The system continuously tracks the live location of buses and updates the information to a cloud database in real time. The system follows a role-based architecture consisting of Admin, Driver, and User modules. The Admin manages buses, routes, and driver assignments through a centralized dashboard. Drivers can automatically share GPS location updates, while users can track buses live using the mobile application. Firebase Authentication and Firestore Database are used to ensure secure login, real-time synchronization, and efficient data management. The main objective of the system is to improve transportation transparency, reduce communication gaps, increase passenger safety, and provide an efficient smart transportation management platform. The proposed solution offers a scalable and user-friendly approach for modern transportation systems and can be extended further with advanced smart city and artificial intelligence features [1-5].

1.1. System Architecture and Workflow
The system architecture of the proposed IoT-Based

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Bus Tracking System is designed to provide real-time vehicle monitoring and efficient data communication between hardware devices, cloud services, and mobile applications [6-10]. The architecture integrates GPS technology, IoT devices, Firebase cloud services, and Flutter applications to create a secure and scalable transportation management system Shown in Figure 1.

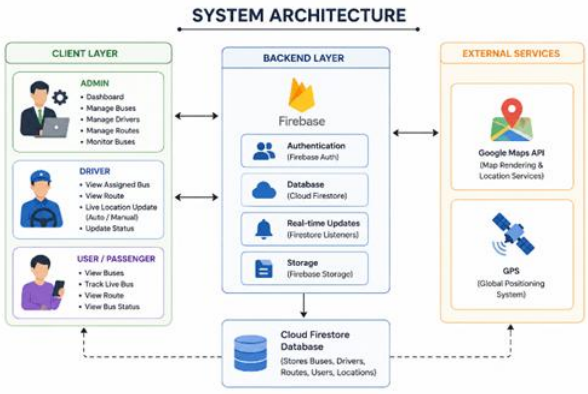

Figure 1 System Architecture Diagram

The overall architecture flow of the system is as follows:

GPS Module → ESP32 → Firebase Firestore → Flutter User Application

In this architecture, the GPS module continuously captures the current latitude and longitude coordinates of the bus. The collected location data is transferred to the ESP32 microcontroller for processing. The ESP32 acts as the central IoT device responsible for reading GPS coordinates and uploading them to the Firebase Firestore cloud database using internet connectivity.

1.1.1. Frontend Layer (Flutter App)

This layer provides the user interface for bus tracking and transportation management. It is developed using Flutter and allows users to view live bus locations, route information, and tracking updates through an easy-to-use mobile application. The app displays real-time bus movement using Google Maps integration

1.1.2. Backend Layer (ESP32 Controller + Firebase Services)

The backend manages data processing and communication between hardware devices and cloud services. The ESP32 microcontroller receives GPS coordinates, processes the data, and sends it to Firebase through internet connectivity. It handles continuous data transmission for real-time tracking. Services include:

- GPS data processing
- Data transmission management
- Real-time cloud communication

1.1.3. Data Layer

This layer is responsible for secure storage and synchronization of system information. The system uses:

- **Firebase Firestore:** Stores live GPS coordinates, bus details, route information, and user records.
- **Firebase Authentication:** Manages user accounts, secure login, and role-based access control.

1.1.4. External APIs

The system integrates external services to improve functionality:

- **Google Maps API:** Used for displaying live bus locations and route visualization.
- **GPS Satellite Service:** Provides real-time geographical coordinates for accurate tracking.

This architecture makes the system efficient, scalable, secure, and suitable for real-time transportation monitoring.

1.2. Workflow of the System

The working process of the proposed IoT-Based Bus Tracking System follows a continuous real-time data flow to ensure accurate monitoring and tracking of buses.

- **Step 1:** GPS Data Collection

The GPS module installed in the bus captures live latitude and longitude coordinates.

- **Step 2:** Data Processing

The ESP32 microcontroller processes the GPS data into a suitable format.

- **Step 3:** Data Upload to Cloud

Processed data is uploaded to Firebase Firestore through internet connectivity.

- **Step 4:** Real Time Synchronization

Firebase updates and synchronizes the latest bus location in real time.

- **Step 5:** User Authentication

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Firebase Authentication provides secure role-based access for Admin, Driver, and User modules.

- **Step 6:** Live Bus Tracking

The Flutter application fetches live data from Firebase and displays the bus location on Google Maps [11-15].

- **Step 7:** Admin Verification

The system continuously updates and monitors bus movement for uninterrupted real-time tracking.

2. Results and Discussion

2.1. Results

The proposed IoT - Based Bus Tracking System was successfully implemented and tested to evaluate its performance in providing accurate real-time bus location tracking and transportation monitoring. During testing, the GPS module successfully captured live geographical coordinates of the bus and transmitted them to the ESP32 microcontroller. The ESP32 processed the received data and uploaded it to Firebase Firestore using internet connectivity. The cloud database efficiently stored and synchronized the tracking information without significant delay. The system maintained continuous updates of bus location data, ensuring reliable real-time communication between hardware devices and the mobile application. Overall, the system demonstrated stable performance, accurate location tracking, and efficient real-time data synchronization Shown in Figure 2 - 5.

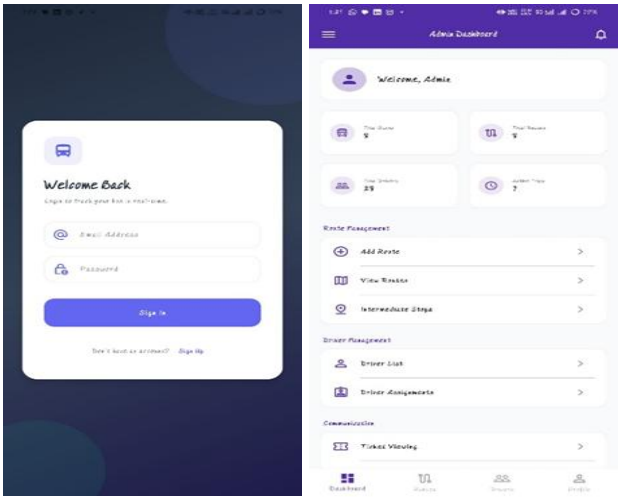

Figure 2 Home page & Admin Page

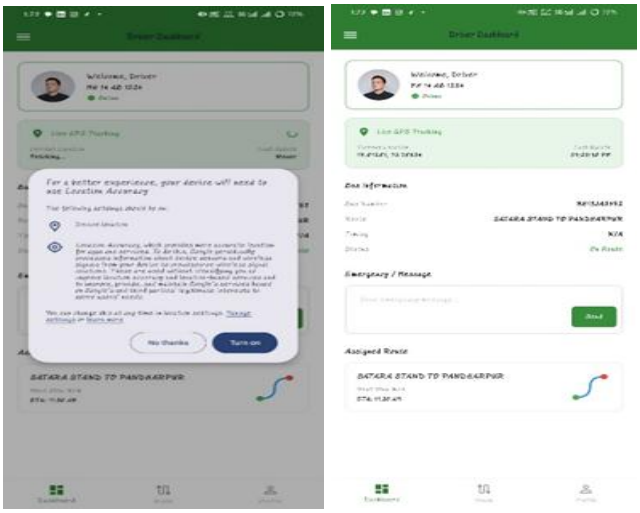

Figure 3 Driver Page

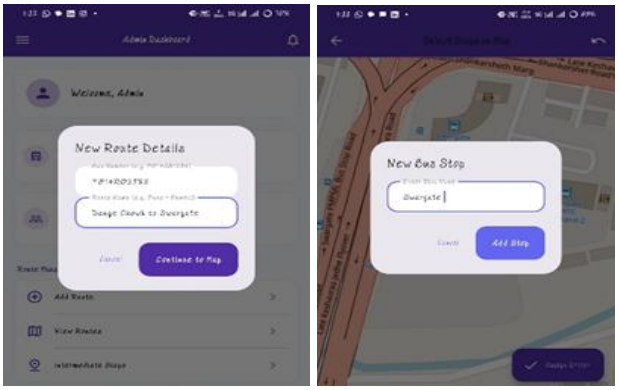

Figure 4 Admin Added Bus

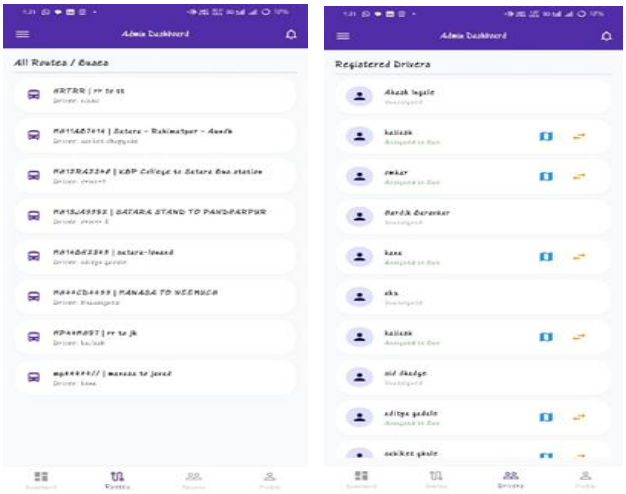

Figure 5 Student Details Dashboard Interface

2.2. Discussion

The obtained results indicate that the proposed system provides an effective solution for real-time

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transportation monitoring using IoT and cloud technologies. One major advantage of the system is real-time tracking capability. Users can monitor the live movement of buses through the mobile application, which helps reduce waiting time and improves travel planning. However, the system depends on stable internet connectivity for continuous operation. GPS signal interruptions or network failures may affect tracking accuracy in certain environments. Future improvements may include offline data buffering, predictive arrival estimation, and notification features for enhanced user experience. Overall, the proposed system provides a reliable, secure, and efficient approach for modern bus tracking and supports the development of smarter transportation systems.

Conclusion

The proposed IoT-Based Bus Tracking System provides an efficient and reliable solution for real-time bus monitoring using GPS, ESP32, Firebase, and Flutter technologies. The system enables continuous live location tracking, secure data synchronization, and role-based access management through a simple and user-friendly mobile application. The system improves transportation monitoring and communication efficiency while offering accurate real-time tracking. Although it depends on internet connectivity and GPS signal availability, it demonstrates effective performance for smart transportation applications. Future improvements such as arrival time prediction, notifications, and route optimization can further enhance the system.

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