Automated Bus Scheduling and Route Management System for Smart Campus Transportation with Real-Time Tracking

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Abstract: *Transport coordination within educational institutions is often managed manually, which leads to scheduling conflicts, miscommunication, and inefficient resource utilization. To overcome these challenges, this study presents an Automated Bus Scheduling and Route Management System (ABSRMS) designed to streamline the daily and special transportation needs of colleges and universities. The system automates bus and driver assignments based on route and time availability while ensuring every scheduled stop is covered. Developed using a Flask-based backend and a MySQL database, it provides a robust administrative web interface built with React and mobile applications developed in Flutter for students and drivers. Key modules include route management, scheduling automation, real-time GPS tracking via OpenStreetMap, push notifications using Firebase Cloud Messaging (FCM), and special-trip scheduling for events such as industrial visits. The implementation demonstrates improved accuracy in scheduling, reduced administrative workload, and enhanced communication between students, drivers, and transport administrators. The proposed system offers a cost- effective, open-source solution suitable for scalable adoption across educational institutions.*

Keywords*: Bus scheduling, Route management, Flask, MySQL, React, Flutter, Firebase, Transport automation, educational institutions*

I. INTRODUCTION

Most educational institutions rely on dedicated bus transport systems to provide safe and timely commuting for students and faculty members. Traditionally, the scheduling of buses, assignment of drivers, and route planning are performed manually, often using spreadsheets or paper records. This manual process is prone to human error, resulting in overlapping assignments, incomplete coverage of routes, and poor communication in the event of delays or breakdowns.

The Automated Bus Scheduling and Route Management System (ABSRMS) addresses these challenges by introducing automation and digitization into institutional transport management. The system is specifically tailored for campus buses that follow fixed pickup and drop-off routes. Unlike public transport optimization, this approach ensures all predefined stops are retained while optimizing resource usage, such as assigning drivers and buses based on their availability and maintenance status.

This paper discusses the design, architecture, and implementation of the ABSRMS. The system leverages open- source technologies for backend processing, data management, and cross-platform interface development, ensuring affordability and adaptability for institutions with limited technical resources.

II. LITERATURE REVIEW AND EXISTING SYSTEM

Previous research on transport management systems primarily focuses on large-scale city transportation optimization using complex algorithms such as Genetic Algorithms (GA) or Ant Colony Optimization (ACO). However, these methods are impractical for educational institutions where routes and stops are predefined and consistent.

The existing manual systems in colleges often fail to update real-time information, lack centralized management, and depend heavily on human intervention. Communication between the transport department, drivers, and students is typically reactive and inefficient.

The proposed ABSRMS bridges this gap by introducing a structured, modular system specifically designed for institutional bus management. It simplifies the tasks of scheduling, driver assignment, and student communication without altering fixed routes.

Objectives and Scope
Objectives:

- To develop an automated and intelligent bus scheduling and management system with GPS integration.
- Send real-time notifications using Firebase through mobile apps for drivers and students and provide a scalable and user-friendly transport management solution.
- Special trip management without any conflicts.

Scope:

The system is intended for colleges or universities with dedicated bus fleets operating on fixed routes. It supports recurring daily schedules (morning, afternoon, evening) as well as special ad-hoc trips. The architecture is fully modular, allowing institutions to scale the system as their fleet grows.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

The ABSRMS follows a client–server architecture built entirely on open-source technologies. The backend, developed using Flask (Python), handles data processing, scheduling logic, and API management. The data layer is managed by MySQL, ensuring efficient storage and retrieval of route, driver, and bus details.

The administrative dashboard, built with React, allows authorized users to perform CRUD (Create, Read, Update, Delete) operations on routes, buses, and drivers.

Students and drivers interact with the system through Flutter-based mobile applications, enabling real-time notifications and updates.

Communication between components occurs through RESTful APIs. Notifications are handled via Firebase Cloud Messaging (FCM), while maps and live tracking use OpenStreetMap integrated through Leaflet.js.

System Design
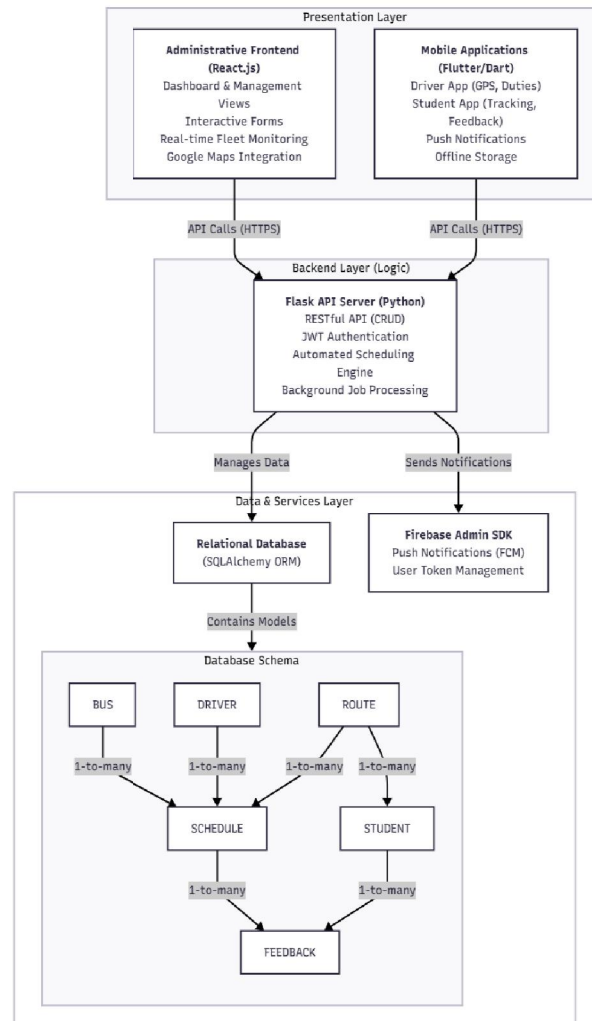
Key processes:
- Admin uploads or enters bus and route details into the system.
- The system automatically assigns drivers and buses based on availability.
- Drivers receive their assignment details via the mobile app.
- Students can view their assigned bus, stops, and expected times.
- Notifications are sent automatically for delays, driver changes, or special trips.

Modules Description

1. Admin Module:
- Create and manage routes, drivers, and bus details.
- Schedule trips (morning, evening, or special).
- Monitor live bus positions and performance reports.

2. Scheduling Module:
• Automates driver–bus assignments based on availability.
• Prevents overlapping or duplicate scheduling.
• Handles reassignments in case of breakdowns or driver absence.

3. Route Management Module:
• Stores route details including stop names, timings, and sequence.
• Displays route maps using OpenStreetMap.

4. Driver Module:
• Displays assigned routes and timings via mobile app.
• Allows location sharing for tracking.

5. Student Module:
• View route, bus, and driver details.
• Receive push notifications for delays or route changes.

6. Special Trips Module:
• Enables administrators to schedule one-time trips for events or industrial visits.
• Validates bus and driver availability before assignment.

7. Notification and Tracking Module:
• Uses Firebase Cloud Messaging for instant alerts.
• Integrates live GPS tracking for monitoring.

III. RESULTS AND DISCUSSION

The system was tested with sample datasets representing real institutional routes. Functional testing confirmed accurate scheduling, proper driver assignments, and reliable notifications. The system successfully prevented duplicate driver or bus assignments for overlapping trips.

Students received instant notifications regarding delays and driver updates. The admin dashboard provided clear visualization of bus locations and route coverage.

Operational efficiency improved notably, reducing manual workload by approximately 60% and enhancing communication accuracy.

IV. CONCLUSION

The Automated Bus Scheduling and Route Management System (ABSRMS) offers a reliable, open-source solution to automate and streamline transportation management within educational institutions. The integration of scheduling automation, live tracking, and push notifications significantly enhances operational efficiency, reduces human error, and improves user satisfaction. The modular nature of the system allows for future enhancements and adaptation to different institutional requirements.

Future Scope
• Integration of machine learning models to predict delays based on traffic and historical data.
• Addition of student attendance tracking via bus check-in.
• Implementation of analytics dashboards for performance insights.
• Integration with institutional ERP systems for unified data management.
• Expansion to cover multi-campus coordination.

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