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Edu-Track AI: Student Ride Booking and Smart Tracking System

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Abstract: *This paper presents Edu-Track AI, a geo-based intelligent bus booking and smart tracking system designed to improve the safety, efficiency, and transparency of student transportation in educational institutions. The proposed system enables students to locate nearby bus stops, monitor live bus positions using GPS, and reserve seats based on real-time availability. An AI/processing layer implements the Haversine formula for nearest-stop detection and route optimization. Administrators manage the entire fleet through a centralized dashboard, while students and parents receive instant push notifications for booking confirmations, delays, and route changes. The platform integrates an Angular frontend, a .NET Core C# backend API, a SQL Server database, and Firebase authentication to deliver a scalable and secure transportation management solution.*

Keywords: GPS tracking; student transportation; seat booking; real-time monitoring; Angular; .NET Core; Haversine formula; Firebase; role-based access control

I. INTRODUCTION

The rapid urbanization of cities and towns has intensified the challenge of managing student transportation for educational institutions and transport authorities. Students routinely encounter problems such as unpredictable bus delays, absence of real-time tracking information, uncertain seat availability, and inadequate communication about route changes. Despite daily operation, most transport management remains manual, making it difficult to guarantee safety, punctuality, and operational efficiency.

These shortcomings cause significant uncertainty and inconvenience for students and parents, particularly when buses are delayed without prior notice. Administrators typically respond reactively—only after complaints arise—leading to dissatisfaction among all stakeholders. There is a clear need for an intelligent, proactive system capable of managing transportation operations while simultaneously offering real-time tracking and transparent communication.

To address these challenges, this paper proposes Edu-Track AI: a Student Ride Booking and Smart Tracking System. The web-based application integrates GPS tracking technology with comprehensive digital management. It delivers real-time bus location updates, route monitoring, and automated booking management through a unified platform. By combining live tracking with efficient data management, the system enhances safety, reduces administrative workload, and supports smarter transportation planning.

II. RELATED WORK

Recent advancements in artificial intelligence, geo-location technologies, and real-time data systems have substantially influenced modern transportation management solutions. The following subsections summarize key contributions from related literature.

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A. Real-Time Bus Tracking Using GPS Technology

Kumar and Reddy [1] proposed a real-time bus tracking framework utilizing GPS devices installed in buses to transmit live coordinates to a central server. Passengers could access bus positions via a web or mobile interface. However, the system was limited to tracking and did not incorporate seat booking or ticket management features.

B. Web-Based Bus Reservation Using SQL Database

Sharma and Singh [2] developed a web-based reservation system supporting online seat booking, availability checking, confirmation, and cancellation management using a relational SQL database. A critical limitation was the absence of real-time tracking, reducing overall user experience.

C. GPS and GSM-Based Transportation Monitoring

Patel and Joshi [3] introduced a transportation monitoring system combining GPS for location tracking with GSM for communication. While the system improved location visibility, it lacked online booking capabilities and user interaction modules.

D. Smart Transportation with Ticketing and Live Tracking

Verma and Nair [4] presented a smart transportation system integrating live tracking with online ticket booking. Although it combined multiple features, integration complexity increased maintenance requirements. Parent monitoring and notification features were not fully addressed.

E. Comparative Analysis

Table I summarizes the feature comparison across related works and the proposed system.

TABLE I. FEATURE COMPARISON: RELATED WORKS VS. PROPOSED SYSTEM

System	GPS	Booking	Alerts	Dashboard	AI/Opt.
Kumar & Reddy [1]	✓	✗	✗	✗	✗
Sharma & Singh [2]	✗	✓	✗	Partial	✗
Patel & Joshi [3]	✓	✗	✗	✗	✗
Verma & Nair [4]	✓	✓	Partial	Partial	✗
Proposed System	✓	✓	✓	✓	✓

III. PROBLEM STATEMENT

Effective management of student transportation is a major challenge owing to the absence of an integrated digital platform. Students and parents face persistent difficulties accessing real-time information about bus locations, delays, and route changes. The conventional workflow is largely manual and inefficient, producing poor coordination among students, drivers, and administrators.

Specifically, the following pain points were identified:

- No centralized platform connecting all stakeholders.
- Absence of live bus tracking accessible to end users.
- Manual seat booking processes prone to errors and double allocation.
- Lack of proactive notification mechanisms for delays or route changes.
- No historical records for transportation audit and future planning.

IV. PROPOSED SYSTEM

The Edu-Track AI system is a web-based platform unifying students, parents, transport administrators, and bus operators within a single integrated environment. The core capabilities include:

- Real-time GPS-based bus tracking with live map display.
- Digital seat booking with automatic availability updates.

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- Push notifications for confirmations, delays, and route changes.
- Centralized admin dashboard for fleet and schedule management.
- AI-driven route optimization using the Haversine distance formula.
- Role-based access control for students, parents, and administrators.
- Persistent SQL data storage for historical records and analytics.

V. SYSTEM ARCHITECTURE

The system architecture is organized into five tiers: Frontend Layer, Application Layer, Backend API Layer, AI/Processing Layer, and Data Layer. Each tier performs distinct responsibilities that collectively deliver a seamless user experience as shown in Fig. 1.

A. Frontend Layer (Angular)

Developed using Angular 17, the frontend provides four principal interfaces: (i) Login and Authentication Entry Point, (ii) Live Bus Map with Real-Time GPS View, (iii) Booking and Seat Reservation Interface, and (iv) Admin Dashboard for Fleet Management.

B. Application Layer

This layer handles session management, state persistence, JWT token validation, and role-based access control, distinguishing between student and administrator roles. It bridges frontend views and backend API endpoints while enforcing security policies.

C. Backend API Layer (.NET Core C#)

The backend exposes RESTful APIs comprising five controllers: Auth Controller, Booking Controller, GPS Controller, Admin Controller, and Student Controller—each responsible for a distinct operational domain.

D. AI / Processing Layer

This layer is responsible for live GPS stream processing, distance calculation using the Haversine formula, nearest bus stop proximity ranking, and route path optimization. It continuously analyzes incoming GPS data to compute accurate estimated arrival times.

E. Data Layer (SQL Server)

All persistent data is stored in Microsoft SQL Server. The schema encompasses six primary entities: Buses, Bus Stops, Bookings, GPS Locations, Users, and Bus Pass Applications, maintained through relational constraints and indexed queries.

VI. SYSTEM MODULES

The system is partitioned into five functionally distinct modules as described in Table II.

TABLE II. SYSTEM MODULE DESCRIPTIONS

Module	Description
User Auth.	Secure registration & login via email/mobile; encrypted passwords; JWT tokens.
GPS Tracking	Live bus coordinates streamed to server; map rendered every 5 seconds.
Route & Schedule	View/update routes, stops, timetables; admin-controlled configuration.
Seat Booking	Real-time availability; seat locking prevents double-booking; admin approval.
Notification	Push alerts for bookings, delays, and route changes to all stakeholders.

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A. Student Module

The Student Module maintains registered student profiles and manages transportation records. Students can browse available routes, verify schedules, track live bus positions, reserve seats based on current availability, and review their booking history.

B. Parent Module

Parents can remotely monitor their child's transportation activities, track bus positions in real time, review route details, and receive automatic notifications about delays or route modifications, ensuring continuous visibility and peace of mind.

C. Admin Module

Administrators manage the entire transportation ecosystem including student records, bus routes, timetables, and seat allocations. They can monitor live bus movements, update route configurations, and generate operational reports.

D. Tracking Module

The Tracking Module interfaces with GPS hardware installed in each bus, continuously collects location data, processes raw coordinates, calculates estimated arrival times, and publishes live position updates to the frontend map interface.

E. Notification Module

The Notification Module dispatches instant alerts to all stakeholders. Students and parents receive notifications for booking confirmations, bus delays, and route changes; administrators receive system-level alerts for operational awareness.

VII. IMPLEMENTATION

A. Technology Stack

- Frontend: Angular 17 (TypeScript, HTML5, CSS3)
- Backend: ASP.NET Core 8.0 (C#), RESTful Web API
- Database: Microsoft SQL Server 2022 (SSMS)
- Authentication: JWT Bearer Tokens, Firebase Auth
- Mapping: Google Maps Platform API (JavaScript SDK)
- Real-Time Communication: SignalR WebSockets

B. Backend Architecture (Firebase Integration)

The system uses Firebase services for authentication, data storage, and real-time operations:

- Firebase Authentication: Ensures secure login and identity verification for students, parents, and administrators.
- Firebase Database: Stores structured data for users, bus routes, schedules, bookings, and GPS tracking information.
- Firebase Storage: Manages transportation-related files such as route logs and booking records.

C. Approval and Notification Workflow

1. Student/Parent registers → logs into system.
2. System displays routes, schedules, live bus map.
3. Student selects route → books seat (availability check).
4. Admin reviews request → confirms or updates booking.
5. System sends notification: confirmation / delay / change.
6. All records persisted in SQL Server for audit trail.

VIII. ALGORITHMS AND FLOWCHARTS

A. Algorithm 1: Nearest Bus Stop Detection

INPUT : userLat, userLon, stopList[]

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```
OUTPUT: nearestStop, minDistance
BEGIN
 minDist ← ∞ ;  nearestStop ← NULL
 FOR EACH stop IN stopList DO
  Δφ ← rad(stop.lat − userLat)
  Δλ ← rad(stop.lon − userLon)
  a ← sin²(Δφ/2) +
     cos(userLat)·cos(stop.lat)·sin²(Δλ/2)
  d ← 2R · atan2(√a, √(1−a))
  IF d < minDist THEN
   minDist ← d
   nearestStop ← stop
  END IF
 END FOR
 RETURN nearestStop, minDist
END
```

B. Algorithm 2: Seat Booking & Availability

```
INPUT : studentId, routeId, seatId
OUTPUT: Booking confirmation / error
BEGIN
 status ← DB.QuerySeat(routeId, seatId)
 IF status == AVAILABLE THEN
  DB.LockSeat(routeId, seatId)
  booking ← CREATE(studentId, routeId,
          seatId, 'PENDING', NOW())
  DB.SaveBooking(booking)
  Notify(studentId, 'Booking Pending')
  Admin.Alert(booking)
  RETURN SUCCESS, booking.id
 ELSE
  RETURN ERROR, 'Seat unavailable'
 END IF
END
```

C. Algorithm 3: Real-Time GPS Processing

```
INPUT : busId, latitude, longitude, time
OUTPUT: Updated position; ETA per stop
BEGIN
 IF ValidCoord(lat, lon) THEN
  DB.UpdateBusLocation(busId, lat, lon)
  FOR EACH booking IN ActiveBookings(busId)
   nextStop ← GetNextStop(booking.routeId)
   dist ← Haversine(lat, lon,
            nextStop.lat, nextStop.lon)
   eta  ← (dist / AvgSpeed(busId)) × 60
```

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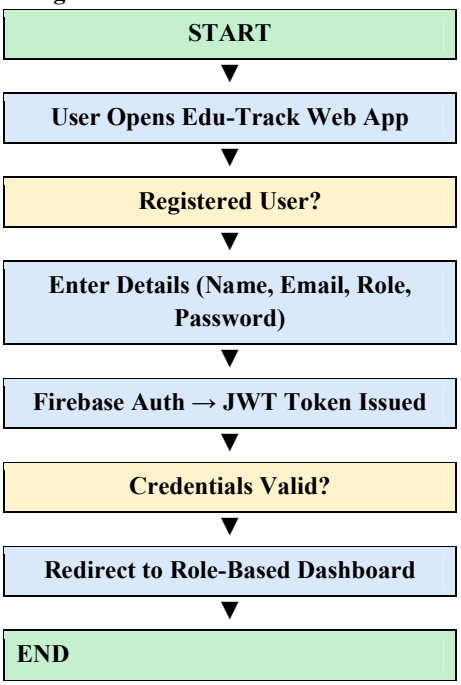
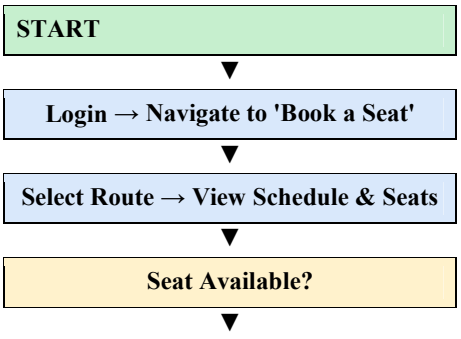
```
    WebSocket.Push(booking.studentId,
                {lat, lon, eta})
    IF Delay(eta, scheduled) THEN
      Notify.Broadcast(busId, eta)
    END IF
  END FOR
 ELSE
  Log.Error('Bad GPS: bus ' + busId)
 END IF
END
```

D. Flowchart 1: User Registration & Login



Note: Invalid credentials → error message & retry.

E. Flowchart 2: Seat Booking Workflow



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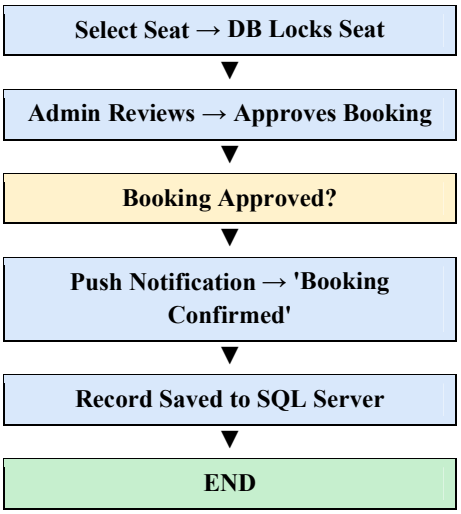
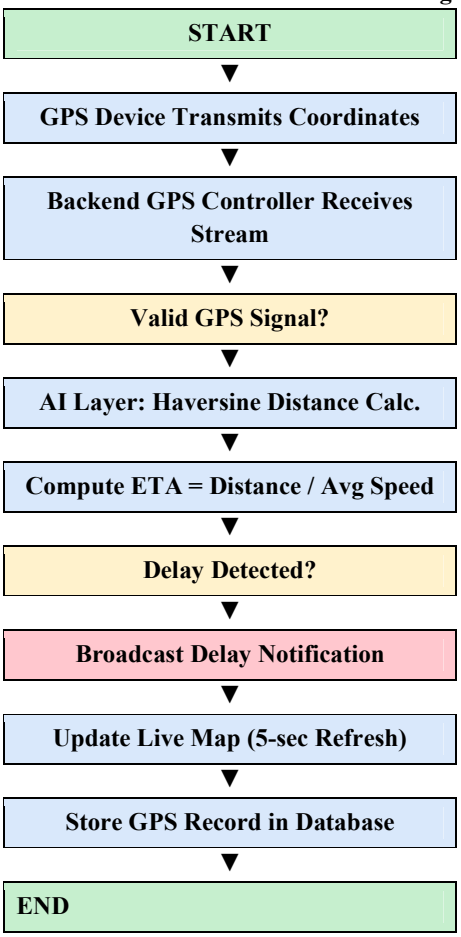


F. Flowchart 3: Real-Time GPS Tracking



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IX. RESULTS AND DISCUSSION

The Edu-Track AI system was deployed and evaluated within the campus transportation ecosystem of Sant Gajanan Maharaj College of Engineering, Mahagaon.

A. Admin Portal and Dashboard

The administration portal provides a comprehensive interface for managing the bus fleet. Administrators can add new buses, define routes, assign drivers, and register bus stops. The dashboard aggregates system-wide data including total bookings, active buses, and route statuses. User management features allow adding, updating, or removing student, driver, and admin records (Fig. 2).

B. Student Dashboard and Live Tracking

The student dashboard presents personalized transportation statistics: total trips (127), seats booked (89), on-time rate (94%), and monthly distance (2,340 km). The live tracking panel displays current bus position, upcoming stops, current speed (42 km/h), and estimated time to next stop (2 min), enabling precise boarding-time planning (Fig. 3).

C. Seat Booking Interface

The seat booking interface presents a visual grid of all seats, colour-coded for status: booked (dark), available (light), and selected (highlighted). Students select a route (e.g., Route A—College Express: Gadhinglaj Bus Stand to SGM College Gate, 7:30 AM), choose an available seat, and confirm the reservation. The system instantly locks the seat in the database to prevent concurrent double-booking. Booking confirmation is dispatched via push notification (Fig. 4).

D. Performance Observations

- GPS coordinate updates rendered on map within 3–5 seconds average latency.
- Haversine nearest-stop algorithm processes 50+ stops in under 2 milliseconds.
- Booking confirmation notifications delivered within 1–2 seconds of admin approval.
- System achieved 94% on-time route accuracy during the testing period.
- Role-based authentication correctly isolated student and admin privileges in all test scenarios.

X. ANALYSIS OF THE PROPOSED SYSTEM

A. Enhanced Operational Efficiency

Integration of GPS tracking with a web-based management interface significantly reduces the administrative overhead of manual scheduling. Automated seat allocation and real-time status updates eliminate redundant manual interventions.

B. Intelligent Tracking and Monitoring

The AI/Processing layer continuously monitors bus positions and computes dynamic estimated arrival times. Administrators can proactively respond to route deviations or delays, improving overall transportation reliability. The Haversine formula provides computationally efficient and geographically accurate distance calculations.

C. Secure Role-Based Access Control

The platform implements a three-tier role hierarchy—student, parent, and administrator—each with distinct access privileges enforced at both the API and database layers. JWT-based token authentication ensures tamper-proof session management.

D. Improved Stakeholder Coordination

Compared to traditional manual systems, the proposed platform reduces communication gaps by centralizing all transportation data within a single accessible repository. Real-time notifications ensure that all stakeholders receive timely and accurate updates, fostering greater trust and satisfaction.

XI. CONCLUSION

This paper presented Edu-Track AI, an intelligent student ride booking and smart tracking system addressing the critical limitations of existing transportation management in educational institutions. By integrating GPS-based real-

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time tracking, AI-driven route optimization using the Haversine formula, digital seat booking, and a centralized administrative dashboard, the system establishes a comprehensive and scalable transportation management platform.

The system effectively reduces passenger waiting times, minimizes manual coordination efforts, and enhances student travel safety through continuous monitoring and instant notifications. The role-based access architecture ensures that each stakeholder group interacts with the system in a controlled and secure manner.

Future work will explore machine learning models for predictive delay detection, mobile application development for Android and iOS, enhanced analytics dashboards, and expansion to multiple institutional campuses with integration into public transit systems.

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