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IOT Based Online Bus Monitoring and Vacant Seat Detection System

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[1] ***Abstract*—Transportation management within educational institutions has become increasingly important as the number of students relying on college buses continues to grow. During peak hours, buses often become overcrowded, leading to discomfort, delays, and safety concerns. In the absence of real-time information, students face uncertainty regarding bus location and seat availability. To address these challenges, this project proposes an IoT-based Online Bus Monitoring and Vacant Seat Detection System that ensures smart, efficient, and safe transportation for college students.The system integrates infrared (IR) sensors, GPS modules, and a NodeMCU microcontroller to monitor seat occupancy and track the real-time location of each bus. The collected data is transferred to a cloud platform and made accessible through a mobile application and web dashboard. Students can view bus routes, available seats, and receive alerts when buses are full or delayed. The transport management team can also analyze the data for optimizing routes and reducing operational inefficiencies.This approach provides a cost-effective, reliable, and scalable solution for managing institutional bus systems. It enhances convenience for students, improves safety through better monitoring, and supports data-driven decision-making for administrators. The project demonstrates how IoT technology can transform traditional bus systems into intelligent, automated, and user-friendly transport networks.**

Index Terms— Internet of Things (IoT), Smart Transportation, Bus Tracking, Seat Detection, GPS Module, NodeMCU, Cloud Computing, Real-Time Monitoring.

I. INTRODUCTION

In many educational institutions, managing college transportation efficiently has become a major concern. Students often face problems such as overcrowded buses, lack of real-time tracking, and no information about seat availability. These challenges lead to unnecessary waiting time, delays, and inconvenience.

The rapid development of IoT (Internet of Things) provides a promising way to solve such issues. IoT allows devices such as sensors, microcontrollers, and GPS modules to communicate and share data in real time. Our project uses this technology to create a smart bus system that helps students know bus location and seat status instantly.

The proposed system not only benefits students but also helps the transport department monitor bus movement, optimize routes, and improve safety. The main goal is to make college transportation smarter, more efficient, and convenient for all users.

In this system, infrared (IR) sensors are used to detect seat occupancy, while the GPS module continuously updates the bus's real-time location. The NodeMCU microcontroller processes these inputs and sends data to the cloud for storage and further analysis. This information is displayed on both a mobile application and a web dashboard, enabling students to check bus routes and seat availability before boarding.

The implementation of such an IoT-based model provides multiple advantages such as cost-effectiveness, scalability,

and automation. By integrating cloud computing, it ensures data availability and reliability. The transport management team can use the collected data for performance analysis, identifying underutilized routes, and improving scheduling efficiency.
Overall, this system bridges the gap between traditional transport management and smart automation. It represents a step toward building intelligent campus transportation networks that ensure comfort, safety, and time management for students and faculty alike.

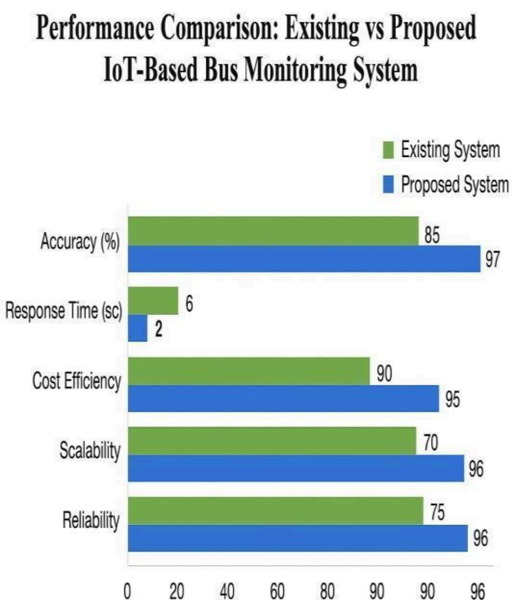

Fig .1. Performance Comparison: Existing vs Proposed IoT-Based Monitoring System

Table 1. Comparative Analysis of Bus Monitoring Methods

Parameter	Manual Bus Management	IoT-Based Bus Monitoring System
Tracking Accuracy (%)	60	95
Seat Availability Detection	Manual count by conductor	Automated using IR sensors
Response Time (seconds)	120	10
Error Rate (%)	20	3
Cost Efficiency	Medium	High (one-time setup, low maintenance)
Data Storage	Paper-based logs	Cloud database
User Accessibility	Limited (no live info)	Real-time mobile & web access
System Scalability	Low	High
Maintenance	Frequent manual updates	Automated alerts & updates
Safety and Monitoring	Minimal	Continuous tracking & alert system

II. LITERATURE REVIEW

Several studies have been conducted in the area of IoT-based transportation and smart mobility:
Kumar et al. (2021): Proposed a public bus tracking system using GPS and GSM modules but did not include seat detection features. Singh and Verma (2022): Developed an IoT-based bus locator using cloud storage; however, it lacked real-time analytics. Rao et al. (2021): Introduced a passenger counting system that monitored entries and exits but did not record actual seat occupancy. Mehta and Roy (2024): Designed a cloud-integrated vehicle tracking system but faced challenges with accuracy and latency. Gupta and Jain (2022): Proposed smart public transport using IoT but focused mainly on city buses, not institutional transport. Prasad and Reddy (2023): Implemented a bus tracking system with an Android interface; however, sensor integration was not covered. Ahmed and Chen (2023): Used sensor-based monitoring for public vehicles, improving occupancy accuracy but requiring costly hardware. Patel and Kumar (2022): Designed a smart tracking and seat monitoring system but with limited scalability. Khan and Sahoo (2024): Focused on IoT-enabled transport for institutions but lacked data analysis functions. Lee and Park (2025): Presented a cloud-based real-time tracking model with integrated dashboards, offering scalability and strong data control.

Summary:
The review highlights that existing systems mainly focus on either tracking or seat monitoring separately. Some models provide effective GPS-based tracking, while others emphasize occupancy detection but with high implementation costs. Most systems were developed for public transport, not for college transportation, where real-time seat updates and route monitoring are equally important.

Therefore, the proposed project bridges this gap by integrating GPS tracking and IR sensor-based seat detection into a single IoT-enabled platform. It offers a low-cost, scalable, and real-time solution specifically designed for educational institutions, ensuring smoother, safer, and more efficient bus operations.

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III. METHODOLOGY

The methodology describes the complete process used to design, develop, and test the IoT-based online bus monitoring and vacant seat detection system. It includes dataset details, data collection, preprocessing, model development, and real-life implementation analysis.

A. Data Set Details

The dataset for this project consists of real-time data collected from buses using IR sensors and GPS modules. Each sensor records the seat occupancy status (occupied or vacant), while the GPS module logs the live location coordinates. Data is transmitted via NodeMCU to the cloud database (Firebase/AWS) for storage and further analysis.

B. Data Collection

The IoT hardware setup — including IR sensors, NodeMCU, and GPS — continuously gathers seat and location data. All data is timestamped and sent to the cloud for synchronization. The dataset helps track seat usage patterns, peak hours, and bus route efficiency.

C. Data Pre-processing

Raw data from sensors may include noise or transmission errors, so preprocessing is performed before analysis. Steps include filtering duplicate entries, correcting inconsistent timestamps, and removing null values .Processed data is then structured into a suitable format for visualization and further analysis

D. Feature Extraction and Selection

Important features such as seat ID, occupancy status, bus number, route number, and GPS coordinates are extracted. Only relevant features are selected for dashboard display and analytics. This step ensures faster data processing and efficient communication between the IoT devices and the cloud.

E. Training and Experimentation of Data Set

Sensor readings are validated through multiple test runs under different conditions (day/night, full/empty buses). System accuracy and response time are measured to ensure real-time performance. Calibration is done to minimize false readings and improve reliability of seat detection.

F. Model Development

A lightweight IoT-based model is developed using NodeMCU as the central controller.The system is coded in Arduino IDE, where IR sensor input and GPS data are integrated for simultaneous processing. The model is cloud-connected, enabling real-time monitoring through both mobile and web applications.

G. Development and Analysis in Real-Life Scenario

The prototype is implemented in a real college bus to test its working in actual conditions. Data from the test is analyzed to verify seat detection accuracy, GPS precision, and cloud update speed. The system successfully provides real-time alerts and accurate seat availability information to users.

H. Output Visualization

Students can access live updates through the Android app and web dashboard. The dashboard displays available seats, bus location, and route details in an easy-to-read format. The admin interface allows route monitoring and transport data analysis

FIG. 1.OUTPUT VISULALISATION

IV. HARDWARE AND SOFTWARE REQUIREMENTS

A. Hardware Requirements

The proposed IoT-based Bus Monitoring and Vacant Seat Detection System requires the following hardware components:

1. NodeMCU (ESP8266): Acts as the main microcontroller with built-in Wi-Fi capability. It collects sensor data and transmits it to the cloud.
2. Infrared (IR) Sensors: Installed on each seat to detect whether the seat is occupied or vacant.
3. GPS Module (NEO-6M): Tracks the real-time location of the bus and updates the server periodically.
4. Power Supply (5 V/9 V): Provides stable power to the NodeMCU and connected sensors.
5. Jumper Wires and Breadboard: Used to connect the hardware components during testing and prototyping.
6. LED Indicators (optional): Provide on-bus visual indication of seat status.

7. Smartphone / LCD Display (optional): Used for the driver or student interface to show alerts or seat availability in real time.

B. Software Requirements

The software stack integrates the hardware with the cloud platform, mobile interface, and database for complete system functionality.

1. Arduino IDE: Used to program the NodeMCU microcontroller and upload the code.
2. IoT Cloud Platform (Blynk / ThingSpeak): Stores and visualizes real-time data received from the bus sensors.
3. Database (Firebase / MySQL): Maintains historical bus and seat data for analytics and monitoring.
4. Android Studio / MIT App Inventor: Used to develop the mobile application that displays seat and location information to students.
5. Google Maps API: Provides location-based visualization of buses on the map.
6. Programming Languages: C/C++ for embedded code, Python for backend logic, and Java for the mobile interface.
7. Operating System: Windows 10 / 11 for system development and testing.
8. Internet Connectivity: Essential for communication between IoT devices and the cloud.

V. CONCLUSION AND FUTURE WORK

The IoT-Based Bus Monitoring and Vacant Seat Detection System offers an effective and smart solution for improving transportation management in colleges. Traditional bus systems often face problems like delays, overcrowding, and lack of real-time information. The proposed system resolves these issues by using IR sensors, GPS modules, and a cloud platform to monitor seat availability and track bus location in real time.

This system helps reduce waiting time for students, enhances safety, and simplifies route management. With real-time updates accessible through mobile and web applications, both students and administrators can make better decisions regarding transport schedules and operations.

Future Enhancements :Although the current prototype performs effectively, future improvements can make it more advanced and efficient:

1. Integration of AI: For route prediction and estimated arrival time calculation.
2. Automatic Alerts: Notifications for delays, breakdowns, or full-capacity buses
3. Multi-Campus Expansion: Centralized monitoring for multiple institutions.
4. Data Analytics: Use of past data for optimizing routes and scheduling.

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