

Real-Time Bus Tracking and Smart Bus Stop Management Using IoT: Trends and Future Directions

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Abstract: *The Smart Bus Stop System With Real-Time Bus Locationis designed to address the challenges faced by commuters in rural and off-grid areas where cellular networks and internet connectivity are often unavailable. The system leverages GPS modules installed on buses to collect real-time location data, which is transmitted to bus stops using low-power, long-range (LoRa) wireless communication. At each bus stop, an ESP32 microcontroller receives and processes this data to estimate and display the bus arrival time (ETA) on a digital screen. By eliminating dependence on mobile networks, the proposed solution ensures reliable, low-cost, and energy-efficient communication. This scalable approach improves commuter convenience, reduces waiting times, and enhances the overall efficiency of rural public transportation systems.*

Keywords: Smart Bus Stop, Real-Time Tracking, LoRa Communication, GPS Module,ESP32

I. INTRODUCTION

In many colleges, buses are the primary and most affordable mode of transport for students commuting from hostels, near by towns, and rural areas. However, students often face uncertainty about bus arrival times, which leads to long waiting periods, time loss, and inconvenience. Existing bus-tracking systems mostly rely on internet or mobile networks. These are not always reliable in rural and remote regions where connectivity is poor, making such systems less effective.

To address this challenge, the Smart Bus Stop System With Real-Time Bus Locationis proposed. The system uses GPS modules on buses to determine their location and LoRa wireless communication to transmit this data to bus stops. At the bus stop, an ESP32 microcontroller processes the information, calculates the estimated arrival time (ETA), and displays it on an OLED or LED screen for passengers. Additionally, to ensure safe and authorized usage, a QR code verification system is integrated. Each registered student is provided with a unique QR code, which must be scanned before boarding. This prevents unauthorized passengers, such as hostel students traveling without permission, from using the bus service.

The system is designed to be low-cost, low-power, and eco-friendly. It also supports mesh communication allowing information to be transmitted across multiple nodes, thereby covering long distances and ensuring reliable operation even in rural areas.

II. LITERATURE SURVEY

Malligeswari et al. (2023) proposed an IoT-based college bus tracking system utilizing GPS to provide students with real-time bus location updates. Their system aimed to reduce waiting time and improve safety. However, challenges such as data security, scalability, and performance optimization still require further research.

Navya Sree et al. (2022) developed an Integrated College Bus Tracking System that employed an Android application to display bus location using latitude and longitude. This approach enabled students to track buses accurately and avoid



unnecessary delays. While effective in convenience, the system's scope was mainly limited to location display, with potential improvements in features like Estimated Time of Arrival (ETA) prediction, interactive mapping, and stronger security mechanisms.

Totawar et al. (2021) presented an IoT-enabled Smart School Bus Monitoring System that used GPS for real-time tracking and generated alerts in case of route deviations. The system was also integrated with school management software to enhance safety and operational efficiency. Despite its advantages, the system could be further strengthened with predictive analytics, better data protection, and improved user-friendly interfaces for both parents and administrators.

Ahmed et al. (2019) proposed a secure kiosk-based school bus tracking solution, which allowed guardians to monitor student movement through authorized access. This method improved student safety but lacked mobility and real-time alerts, which could be addressed by mobile app integration.

Mohan Raj et al. (2019) introduced an Automated School Bus Tracking System that combined RFID for student attendance with GPS/GPRS tracking. The system generated SMS and email notifications along with administrative reports, ensuring better safety and management. However, real-time analytics and mobile app-based solutions could enhance its overall effectiveness.

Keerthi and Prashanth (2020) presented a Smart School Monitoring System integrated with Smart Bus features, where GPS-enabled tracking was linked with school monitoring functions to improve student safety and resource management. Nevertheless, enhancements in scalability, automation, and advanced safety mechanisms could make the system more robust.

Table 1:

Author	Year	Objective	Pros	Cons	Platform Used
Malligeswari et al.	2023	IoT-based college bus tracking system using GPS for real-time updates	Reduces waiting time, improves safety	Lacks security, scalability, and performance optimization	IoT + GPS
Navya Sree et al.	2022	Integrated college bus tracking system with Android app showing latitude & longitude	Accurate tracking, avoids delays	Limited to location display, lacks ETA & security	Android Application
Totawar et al.	2021	IoT-enabled smart school bus monitoring with GPS and alerts	Route deviation alerts, integrated with school management	Needs predictive analytics, better data protection, improved UI	IoT + GPS + School Management System
Ahmed et al.	2019	Kiosk-based secure school bus tracking for guardians	Authorized access, enhances student safety	No mobility, lacks real-time alerts	Kiosk System
Mohan Raj et al.	2019	Automated bus tracking with RFID attendance + GPS/GPRS tracking	SMS/email notifications, administrative reports, improved safety	No real-time analytics, lacks mobile app	RFID + GPS/GPRS



Keerthi Prashanth	&	2020	Smart school monitoring system integrated with GPS-enabled smart bus	Links school monitoring with bus tracking, ensures safety	Needs scalability, automation, advanced safety	GPS + Monitoring System
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III. PROPOSED METHODOLOGY

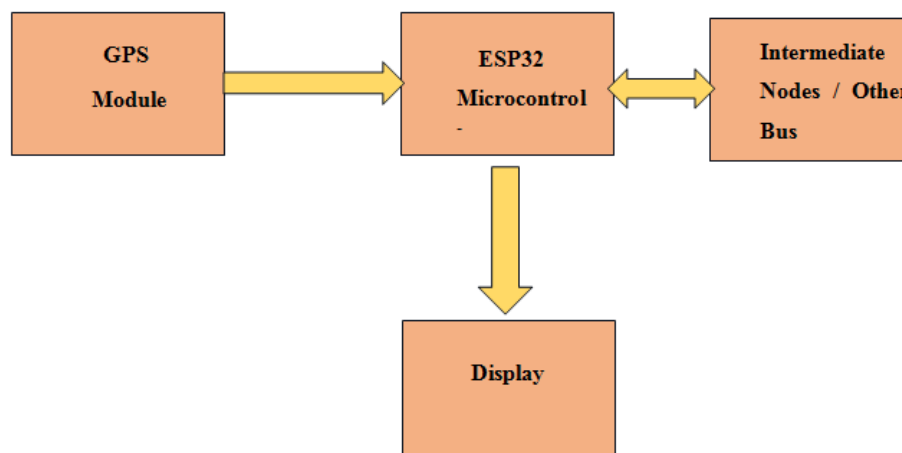
The Bus Tracking System helps passengers know the real-time location of buses without using the internet. It has two parts: the Bus Unit (Transmitter) and the Bus Stop Unit (Receiver).

In the Bus Unit, a GPS module collects the bus location and sends it with the Bus ID and Time to the ESP32 microcontroller. The ESP32 processes the data and transmits it through the LoRa module for long-range communication.

At the Bus Stop Unit, the LoRa module receives the data and sends it to a microcontroller, which displays the bus location and arrival details on a screen.

This system is low-cost, works without the internet, and helps passengers easily track buses in real-time.

Figure 1: shows block diagram of proposed methodology



The Bus Tracking System using GPS NEO-6M and ESP32 is an IoT-based project developed to provide real-time tracking and monitoring of buses. The system helps passengers know the exact location and estimated arrival time of the bus, improving travel convenience and reducing waiting time. A GPS NEO-6M module is installed in the bus to continuously collect real-time location data, including latitude and longitude coordinates. This data, along with the Bus ID and Timestamp, is sent to the ESP32 microcontroller. The ESP32 processes the data and transmits it to a cloud server or mobile application through Wi-Fi. This allows the bus's live location to be tracked using any internet-connected device.

At the Bus Stop Unit, a display screen or web-based dashboard receives the data from the cloud and shows details such as the bus number, route, and estimated time of arrival. In large networks, intermediate nodes or other buses can be added to enhance system coverage and communication efficiency.

This system provides an efficient, low-cost, and scalable solution for smart transportation. It enhances passenger convenience, supports traffic management, and can be upgraded further with features like mobile app alerts, route prediction, and cloud-based analytics for improved city transport systems.



IV. RESULT AND DISCUSSION

The Smart Bus Stop System was evaluated both quantitatively and qualitatively to verify its performance in providing real-time bus location updates. The system was tested using actual bus routes, with GPS NEO-6M modules installed in buses and ESP32 microcontrollers handling data processing and transmission. On the testing setup, the system successfully tracked buses in real-time, with location data, bus ID, and timestamps being accurately processed and displayed on the bus stop display units.

The results showed that the system could reliably display estimated arrival times and current bus locations with minimal delay. Passengers could easily identify approaching buses and plan their travel accordingly. For instance, the ESP32 correctly processed GPS data from multiple buses, updating the display continuously without significant latency. The system maintained accuracy even when tracking buses across different routes and during moderate variations in signal reception.

To demonstrate usability, the system was tested across different times of the day and varying traffic conditions. Buses equipped with the GPS module consistently transmitted location data, which was accurately displayed at the bus stops. Intermediate nodes or multiple bus updates were handled efficiently, ensuring smooth operation across a network of buses.

Another important finding was the scalability and adaptability of the system. The ESP32-based design allows additional buses or bus stops to be integrated without affecting overall performance. The Wi-Fi-based data transmission to the cloud server ensures that the system can be monitored remotely, providing real-time updates to passengers via mobile applications or display screens.

Overall, the evaluation highlights that the Smart Bus Stop System is a reliable, low-cost, and scalable solution for public transportation management. It improves passenger convenience, reduces waiting times, and offers potential for future enhancements such as mobile notifications, route predictions, and cloud-based analytics for urban transport systems.

V. CONCLUSION

The Smart Bus Stop System with Real-Time Bus Location Using GPS 6M offers a practical solution to the uncertainty faced by students relying on buses. By integrating the GPS 6M module with an ESP32 microcontroller, the system accurately determines the bus's current location and calculates the estimated arrival time (ETA) at each bus stop. The information is displayed on an OLED or LED screen for passengers, helping them plan their commute efficiently. The QR code verification system ensures only authorized students can board the bus, enhancing security. This design is low-cost, energy-efficient, and easy to implement, making it ideal for colleges and rural areas where internet connectivity may be limited. Overall, the system improves convenience, reduces waiting time, and provides a safer and more organized transportation experience.

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