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Student Safety School Bus Tracking System Using Geo-Fencing Technology with Location Alert

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Abstract

This research paper introduces a comprehensive school bus attendance and notification system that utilizes Arduino Uno, RFID technology, GPS, and GSM communication to improve safety and operational efficiency in school transportation. The system automates student attendance tracking through RFID, monitors the bus's real-time location via GPS, and sends SMS notifications to parents as the bus nears designated pickup and drop-off points. Additionally, a missed-call feature enables parents to request updates on the bus's location, fostering better communication among parents, schools, and bus operators. The paper details the system's architecture, key components, implementation process, and performance evaluation. Designed for minimal human intervention, the system is both cost-effective and scalable, making it suitable for schools of various sizes. By integrating real-time location tracking with automated attendance, this innovative approach enhances student safety and streamlines school bus management. Leveraging IoT technologies, the system aims to reduce delays and miscommunication among all stakeholders, contributing to the advancement of smart school transportation solutions.

INTRODUCTION

Ensuring the safety and efficiency of school bus operations is a critical concern for educational institutions, school authorities, and parents. Traditional methods of manually recording student attendance and monitoring school bus routes are often inefficient, error-prone, and susceptible to delays and miscommunication, leading to safety risks and parental concerns.

To address these issues, this paper presents an IoT-based school bus tracking and attendance system that integrates RFID for automated student identification, GPS for real-time bus tracking, and GSM for data transmission and parental notifications. The system ensures

automatic attendance logging and real-time updates for parents and school administrators via a cloud-based platform accessible through mobile and web applications.

By leveraging IoT technologies, the system enhances student safety, improves operational efficiency, and minimizes human errors in school transportation management. The following sections discuss the system architecture, implementation, and performance evaluation, demonstrating its effectiveness in real-world scenarios.

OBJECTIVES

The objective of this project is to develop an automated school bus attendance and notification system that enhances student safety and improves communication between parents and school authorities. The system leverages RFID, GPS, and GSM technologies to provide real-time monitoring and accurate attendance tracking. By integrating these technologies, the system aims to eliminate manual errors, reduce uncertainty, and create a more secure and organized school transportation process.

1. **RFID-Based Attendance Tracking**

The system uses RFID (Radio Frequency Identification) technology to accurately track student attendance. Each student is issued an RFID card that they must scan while boarding the bus. The system records the data in real-time, ensuring that only those who scan their RFID cards are marked present. This automated method eliminates manual attendance tracking, reducing errors and providing a more reliable way to monitor students. The RFID-based system also allows school authorities to track which students are present on the bus at any given time, improving overall safety and accountability.

2. **GPS and GSM-Based Real-Time Bus Tracking**

The system integrates GPS (Global Positioning System) and GSM (Global System for Mobile Communication) modules to enable real-time bus tracking. The GPS module continuously updates the bus's location, which is then transmitted via the GSM module to a centralized server. This data is used to send automated SMS notifications to parents when the bus approaches designated pick-up and drop-off points. This feature enhances communication, ensuring that parents are aware of any delays or route changes.

3. **SMS-Based Tracking Feature**

To improve convenience, the system includes an SMS-based tracking feature. Parents can send a text message to a designated number and receive an automated reply with the real-time location of the bus. This ensures that parents have instant access to the bus's location without needing internet connectivity or a mobile application. This feature reduces anxiety and provides peace of mind to parents by offering immediate updates about the bus's status.

4. **Onboard Display and Monitoring**

The real-time location of the bus is displayed on an LCD screen within the vehicle, allowing the bus driver and school authorities to monitor the bus's route and status easily. The LCD screen provides clear and accurate location data, ensuring that any deviations from the planned route or unexpected delays can be identified and addressed promptly.

5. **Impact and Benefits**

The implementation of this system aims to optimize school bus operations, enhance transparency in student transportation, and improve communication between parents and school authorities. By automating attendance tracking and providing real-time bus location updates, the system reduces the risk of miscommunication and delays. Parents can feel reassured knowing their children's location, and school administrators can better manage transportation logistics.

By leveraging RFID, GPS, and GSM technologies, this project provides an innovative solution that benefits students, parents, and school authorities alike, ensuring a safer and more efficient school transportation experience.

LITERATURE SURVEY

Effective school transportation management has become a significant area of research, particularly with the growing emphasis on student safety and operational efficiency. Several studies have explored the integration of RFID, GPS, and GSM technologies to automate and enhance school bus attendance and tracking systems.

A. RFID-Based Attendance Systems

Shukla et al. (2020) [1] demonstrated that RFID-based attendance tracking significantly improves accuracy and efficiency compared to manual methods. RFID systems enable real-time recording of student attendance by scanning RFID cards when students board and exit the bus. However, the study noted that the system requires constant maintenance of RFID hardware to avoid data loss.

Similarly, Kumar and Rao (2019) [2] developed an automated system that records attendance and transmits the data to school authorities and parents, ensuring accurate record-keeping and reducing the risk of human error. However, the study highlighted the need

for improved security protocols to prevent unauthorized access to student attendance data.

B. GPS and GSM for Real-Time Bus Tracking

Patel et al. (2021) [3] introduced a system that combines GPS and GSM technologies to provide real-time location updates and send automated SMS alerts to parents about bus arrivals. The system improved communication and reduced uncertainty, enhancing both student safety and operational efficiency. However, the study noted that poor GSM signal strength in remote areas could lead to delayed notifications. In another study, Singh and Patel (2021) [4] developed a similar GPS-based tracking system but highlighted challenges related to battery life and signal drop during bad weather conditions, which affected the consistency of real-time updates.

C. Integrated Smart Transportation Solution0073

Sharma et al. (2022) [5] explored the integration of RFID, GPS, and GSM technologies to create a comprehensive school bus management system. The system automated attendance tracking while providing real-time location data and direct communication with parents through SMS alerts. While the system enhanced security and transparency, the study pointed out the need for additional security layers to protect student location data from potential hacking attempts. Similarly, Prasad and Nair (2021) [6] introduced a system with missed call functionality, allowing parents to receive live location coordinates via SMS. However, the system was limited by the inability to distinguish between missed calls from registered and unregistered numbers.

D. Cost-Effective Microcontroller-Based Systems

Gupta et al. (2020) [7] demonstrated that Arduino Uno-based systems are effective for controlling RFID readers, GPS modules, and GSM communication due to their affordability, reliability, and ease of programming. However, the study noted that the Arduino Uno's limited processing capacity restricts its ability to handle large datasets.

In contrast, Verma and Mehta (2021) [8] proposed using Raspberry Pi instead of Arduino for improved processing power and multitasking capabilities, but the increased hardware cost made the system less suitable for large-scale adoption in schools.

E. Real-Time Notification and Reporting

Prasad and Nair (2021) [6] implemented a real-time notification system using GSM-based SMS alerts. Their system allowed parents to track bus location via a missed call mechanism, but it failed to account for changes in bus routes due to traffic or road closures. Additionally, Sharma et al. (2022) [5] explored integrating predictive analytics with the notification system to anticipate delays and adjust arrival time estimates, but the complexity of the algorithm increased the system's response time.

F. Safety and Operational Efficiency

Singh and Patel (2021) [4] emphasized that integrating automated attendance and real-time tracking reduces the risk of student misplacement or unauthorized boarding. Their study showed that providing real-time updates to parents and school authorities improved both security and punctuality. However, they noted that the system required regular software updates to maintain accuracy and avoid glitches. Kumar and Rao (2019) [2] further noted that the data collected from RFID and GPS tracking could be used to optimize bus routes, reducing travel time and operational costs. However, the study identified the challenge of balancing route optimization with unpredictable traffic patterns.

G. Comparative Analysis of Existing Systems

A comparison of existing systems highlights common limitations.

1. Shukla et al. (2020) [1] and Kumar and Rao (2019) [2] focused on RFID-based attendance but lacked integrated real-time tracking.
2. Patel et al. (2021) [3] and Singh and Patel (2021) [4] introduced GPS-based tracking but faced issues with signal consistency and delayed notifications.
3. Sharma et al. (2022) [5] and Prasad and Nair (2021) [6] attempted to integrate RFID, GPS, and GSM, but security and data accuracy issues remained.

PROPOSED METHODOLOGY

The proposed methodology integrates RFID, GPS, and GSM technologies with an Arduino Uno microcontroller to automate student attendance and enable real-time bus tracking. Installed at the entry gate of the school bus, the system requires students to scan their RFID cards upon boarding, ensuring accurate and real-time attendance recording. Only students who scan their cards are marked as present. Simultaneously, an SMS notification is sent to parents as the bus approaches their designated pick-up points, enhancing communication and reducing uncertainty regarding arrival times.

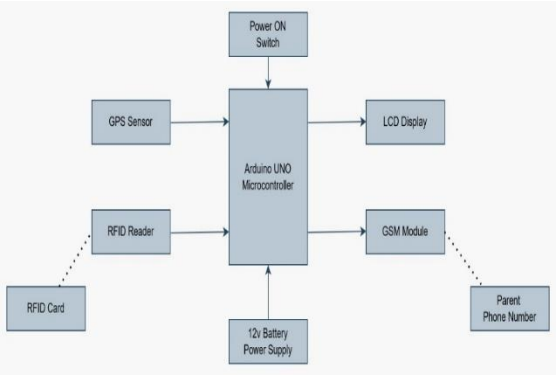

Fig 1: Research Idea

The bus's location is continuously monitored using a GPS module, with live coordinates displayed on a 16x4 LCD screen inside the vehicle for better tracking. Additionally, parents can track the bus location via a missed call-based system, where calling a pre-set number triggers an automatic SMS response containing the bus's real-time GPS coordinates. This feature adds convenience, particularly for parents who may not have access to internet-based tracking applications.

The system is designed to function autonomously with minimal human intervention, ensuring a reliable and efficient approach to school bus management.

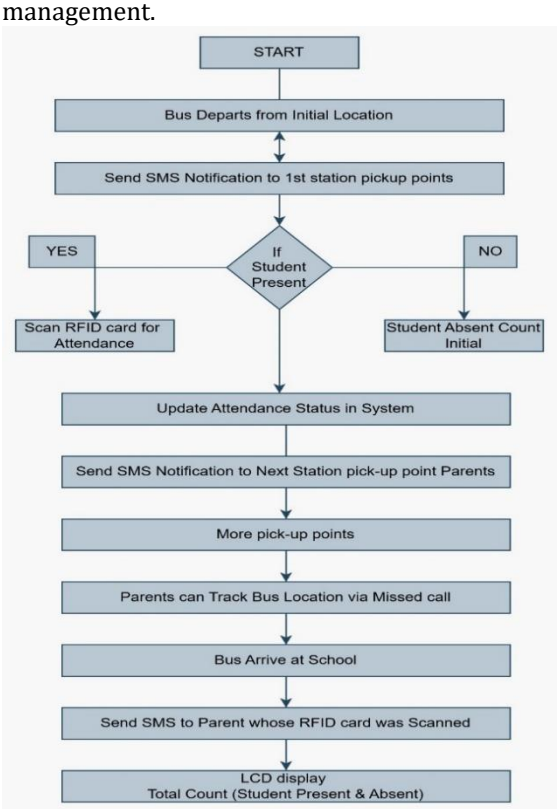

Fig. 2- Flowchart

To enhance system reliability, a 12V battery serves as the primary power source, housed in a protective enclosure to ensure safety and durability. The Arduino Uno acts as the central processing unit, handling attendance data from the RFID reader, retrieving location data from the GPS module, and managing SMS alerts via the GSM module. The entire system is developed to be cost-effective, scalable, and user-friendly, making it a practical solution for improving school transportation safety, efficiency, and communication.

PROJECT REQUIREMENTS

Hardware Requirements

1. **Arduino Uno:** The Arduino Uno microcontroller is the central processing unit of the geo-fencing school bus tracking system, based on the ATmega328P chip. It has 14 digital I/O pins, 6 analog inputs, and a USB interface for programming. The Arduino Uno processes data from the RFID, GPS, and GSM modules. It logs student attendance through RFID, tracks bus location via GPS, and sends SMS alerts through the GSM module when the bus crosses a geo-fence. Its low power consumption, ease of programming with the Arduino IDE, and real-time data handling make it ideal for managing system operations efficiently.

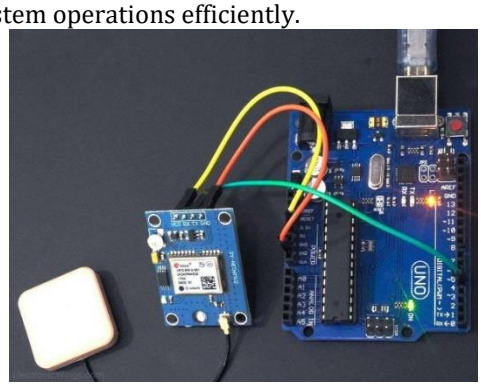

Fig. 3- Arduino UNO with GSM & GPS Module

2. **RFID Module:** The RFID module is responsible for recording student attendance. Each student is provided with an RFID card, which is scanned when they enter or exit the bus. The RFID reader captures the card information and transmits it to the Arduino Uno for attendance logging. This system minimizes errors and eliminates the need for manual attendance tracking.

Fig. 4- RFID Tag & Reader

3. **GPS Module (e.g., NEO-6M)**: The GPS module continuously tracks the real-time location of the school bus by receiving signals from satellites. It updates the bus's GPS

coordinates at regular intervals and transmits the data to the Arduino Uno. The coordinates are then sent via the GSM module to parents and school authorities, allowing them to monitor the bus's movement and accurately estimate arrival and departure times.

4. **GSM Module**: The GSM module enables communication between the system and parents by sending SMS alerts regarding the bus's arrival and departure. In case of an emergency, it triggers immediate alerts to parents and school authorities, ensuring quick response. Operating over a mobile network, it remains functional even in remote areas, providing consistent connectivity and enhancing the overall safety and efficiency of the system.
5. **20X4 LCD Display**: A 20x4 LCD (Liquid Crystal Display) screen is an electronic display module with a wide range of applications. A 20x4 LCD means it can display 20 characters per line and has 4 such lines. In this LCD, each character is displayed in a 5x7 pixel matrix. The 20x4 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols.

Fig. 5- LCD Display

6. **Power Supply:** The system is powered by a 12V rechargeable battery, ensuring uninterrupted operation of all hardware components, including the Arduino Uno, RFID module, GPS module, and GSM module. The battery provides stable and consistent power, allowing the system to function continuously without interruptions, even during power failures, thereby maintaining reliable performance and real-time monitoring.

Software Requirements

1. Arduino IDE: The Arduino Integrated Development Environment (IDE) is used for programming and configuring the Arduino Uno microcontroller. It provides an intuitive platform for writing, compiling, and uploading code, allowing developers to create customized solutions. Its user-friendly interface simplifies debugging and real-time code updates, ensuring smooth integration with all hardware components.

2. Libraries

a. **MFRC522:** This library facilitates communication between the RFID reader and the Arduino Uno, enabling quick and accurate student attendance logging.
b. **SoftwareSerial:** It allows the Arduino to establish serial communication with the GSM module, enabling data transmission and reception.
c. **TinyGPS++:** This library is used to decode and interpret GPS signals, helping the system track real-time bus location and manage geo-fencing boundaries.
d. **LiquidCrystal:** It is used to control the LCD display, allowing real-time display of student attendance and bus status updates.

3. SMS Gateway (SIM800L/SIM900): The SIM800L/SIM900 module is used for establishing communication through a GSM network. It sends SMS notifications about bus arrival, departure, and emergency situations to parents and school authorities, ensuring real-time alerts and improved response time.

4. PC or Laptop: A computer is required for writing, compiling, and uploading the code using Arduino IDE. It is also used for configuring initial system settings and troubleshooting software or hardware issues during development.

5. Mobile Device (Optional): A mobile device is used to receive real-time SMS alerts regarding bus movement and student attendance. It allows parents and school authorities to monitor the bus's location and respond quickly in case of emergencies.

These hardware and software components together will enable the system to function as intended, automating the attendance process, notifying parents, and providing live bus tracking.

CONCLUSION

The progressive development of the IoT-based school bus tracking and attendance system demonstrates its potential to enhance student safety, improve operational efficiency, and reduce manual errors in school transportation management. By integrating RFID for automated attendance, GPS for real-time tracking, and GSM for instant notifications, the system provides a seamless and reliable communication link between parents, school authorities, and transport operators. The system's scalability and cost-effectiveness make it a viable solution for schools of different sizes, ensuring accessibility for both small institutions and large educational networks. Additionally, the ability to store and analyse real-time data opens avenues for further enhancements, such as AI-driven predictive analytics, mobile app integration, and biometric authentication**.** Despite facing challenges like

GPS signal loss, GSM delays, and power consumption issues, the system has demonstrated high accuracy in attendance tracking, reliable bus location updates, and timely parental notifications. Future enhancements will focus on Wi-Fi-based tracking, cloud-based data management, and improved user interaction, making the system even more efficient, adaptable, and future-ready. By leveraging IoT and smart transportation technologies, this system bridges the communication gap in school transport, ensuring that students travel safely, parents stay informed, and schools operate efficiently. The successful implementation of this solution highlights its practicality, reliability, and potential for widespread adoption in modern education systems.

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