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An IoT Enabled Intelligent School Bus Safety and Emergency Response System

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Abstract: ***Ensuring schoolchildren's safety during transportation has become a major concern for both parents and schools. This project introduces an Internet of Things-based Smart School Bus Monitoring and Student Safety System that provides student attendance real-time monitoring, tracking, and immediate alerts. RFID cards are given to students in order to track boarding and disembarking, and parents receive SMS notifications about their child's whereabouts. Students or drivers can quickly generate alerts using live GPS location by pressing an emergency button located inside the bus. Accidents are avoided and a safe environment is created by safety systems like speed control, gas and fire sensors, and alcohol detection. In general, this is an affordable and efficient system that enhances student security and offers peace of mind to parents and school authorities***

.Keywords: IoT, RFID, GPS, GSM, school bus safety, real-time monitoring, emergency response, student tracking.

I. INTRODUCTION

Due to increasing traffic congestion, traffic accidents, and the lack of real-time monitoring systems, ensuring schoolchildren's safety and security during transportation has become a significant challenge. Conventional school bus systems pose safety risks and have inadequate emergency response because they rely on manual procedures and slow communication between parents and school administrators. Intelligent transport systems with computer-assisted decision-making and real-time monitoring are now possible thanks to recent advancements in the Internet of Things (IoT). IoT combines sensors, devices, and embedded wireless communication modules to continuously collect, process, and transmit data. For school transportation safety, RFID, GPS, and GSM have demonstrated efficacy in real-time monitoring, identification, and instant notification. In order to improve student safety and operational transparency, this paper presents an Internet of Things based Smart School Bus Monitoring and Student Security System. The system makes use of GPS for real-time location and speed , GSM for immediate alert notifications, and RFID for automatic boarding/deboarding records. Alcohol sensors, gas and fire sensors, and an emergency alarm system all contribute to increased safety. The system offers an affordable, scalable solution, decreases human intervention, and speeds up emergency response times.

II. LITERATURE SURVEY

Parents and school administrators can use mobile and web apps to track the location of the bus thanks to an IoT-based school bus tracking system that uses a QR code for authentication and real-time GPS monitoring. Although there are no emergency handling or child safety sensors, parents are automatically notified of schedule changes and student boarding [1].

An advanced IoT system that ensures improved authentication reliability to identify students on the bus and notify parents in real time has been developed using RFID, GPS, ESP32-CAM, and GSM modules. A panic switch emphasises the significance of multi-layer safety integration by instantly alerting authorities and guardians to emergencies [2].

Parental tracking via mobile app is made possible by a system on the Blynk IoT platform that combines GPS and RFID attendance. Another system tracks location and attendance in real time using RFID, IR sensors, GPS, and a Raspberry Pi, but it is more complex and expensive in terms of hardware [3].

When alcohol is detected, a system that uses RFID, GPS, GSM, speed control, and alcohol detection turns off the ignition and sends SMS alerts for boarding, arrival, and emergencies. Although it lacks cloud and mobile app features,it provides strong safety coverage [4].

III. COMPONENT DESCRIPTION

The suggested system is made up of several hardware parts that cooperate to provide effective safety and monitoring. With built-in WiFi support, the ESP32 microcontroller serves as the central unit, processing data and managing all operations. When students get on or off the bus, the RFID system—which consists of RFID cards and a reader—is used for automatic student identification and attendance tracking.

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The bus's location and speed are provided in real time by a GPS module (Neo-6M), and it is possible to send SMS alerts and make calls to parents and authorities using a GSM module (SIM900A). Sensors like the MQ sensor, which detects alcohol and dangerous gases, and the fire sensor, which detects fire hazards within the bus, are used to ensure safety.

Component	Image	Description
ESP-32		Wi-Fi enabled microcontroller. Processes sensor data, communicates with cloud wirelessly. Main control unit of the system.
SIM900A		GSM module for sending/receiving SMS. Enables real-time parent/authority alerts using standard SIM card.
RFID Reader		Reads RFID card data and sends to controller. Ensures accurate student attendance monitoring.
RFID Card		Issued to each student. Scanned at boarding/deboarding to log attendance and trigger parent notifications.
NEO-6M GPS		Provides real-time latitude/longitude of the vehicle for live school bus tracking.
MQ Sensor		Detects harmful gases and alcohol. Sends alerts when levels exceed safe limits.
Fire Sensor		Detects smoke and fire inside the bus. Triggers immediate alerts to prevent emergencies.
LCD Display		Shows system status, student attendance, and alerts for easy driver monitoring.
Relay Module		Electrically operated switch controlling high-power devices using low-power signals.
Push Button		Emergency input device. Instantly triggers alert with live GPS location to authorities.
Wiring		Links all hardware components for stable data and power transmission.
Adapter		Converts AC to DC power. Provides stable supply for smooth system operation.

IV. METHODOLOGY

As soon as the system is switched on, all devices, i.e., RFID, GPS, GSM module, sensors, WiFi module, and display, are activated simultaneously. The ESP32 controller initializes all devices and establishes communication between them. The system runs in a loop. It keeps working all the time and responds to any situation that may arise.

Each student is provided with a unique RFID card. When a student boards or deboards the school bus, the RFID device scans the RFID card and keeps the student's status as IN BUS or OUT OF BUS. The system recognizes the student and records the action along with the current time. Meanwhile, the GPS module keeps track of the exact location of the school bus. The GSM module sends a message along with a Google map link to parents and school authorities.

The GPS module keeps track of the location and speed of the school bus. The location and speed of the school bus are available online through a web-based system via WiFi. In case the speed of the school bus exceeds a predetermined speed, the system generates a warning alert.

For the safety aspect, fire sensors and MQ sensors are installed in the bus to sense the fire hazards, gas leakage, or alcohol consumption by the student. If there are any abnormalities detected, the system immediately alerts the authorities through the buzzer, display of messages on the LCD, and sending notifications along with the live student location.

The emergency button is also installed in the bus to handle critical situations. If the button is pressed, the system immediately alerts the authorities with the live student location, sends SMS notifications, and makes calls to the emergency contacts and school authorities.

The LCD display is used to display the live student status, alerts, and system notifications, which are easily visible to the driver.

Additionally, the system data, student activities, and alerts are displayed through the web server developed using the ESP32.

The entire system is automated with minimal involvement of the human factor, which increases the accuracy and reliability of the system and ensures the safety of the students.

A. Block Diagram

The block diagram of the proposed system shows the complete system with all components connected. ESP32 is used as a microcontroller that acts as the central unit that integrates all other components. The input components include an RFID reader, GPS module, fire sensor, MQ sensor, and an emergency push button. The RFID reader is used for identifying students, whereas the GPS module is used for identifying the location of the bus. Sensors detect fire, gas leakage, alcohol, etc. The system also includes an LCD display for displaying messages. The microcontroller is connected with all other components.

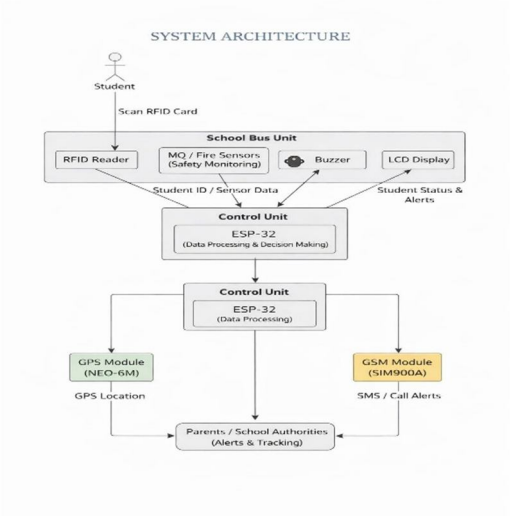


Fig1. Block Diagram of the Proposed System

B. System Flowchart

The flowchart of the proposed system represents the step-by-step working process of the smart school bus monitoring system. The working process starts with system initialization, in which all components of the system, such as an RFID reader, GPS module, GSM module, sensor, LCD display, and buzzer, are activated. Next, it continuously checks for input conditions such as RFID card scan, sensor input, and emergency button status.

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When a student scans an RFID card, it checks the student status and updates it to IN BUS or OUT BUS. In addition, it checks the current location of the student using GPS. Next, it sends an SMS with location details to parents and school authorities. At the same time, it checks the location of the bus using GPS and its speed. If it exceeds the maximum speed limit, it sends warning messages.

The system also checks for safety sensor conditions such as fire, smoke, and alcohol. If it detects any abnormal conditions, it activates the buzzer and sends an alert message with live location. In addition, it checks for an emergency button status. If it is pressed, it sends an emergency alert and makes a call to authorities.

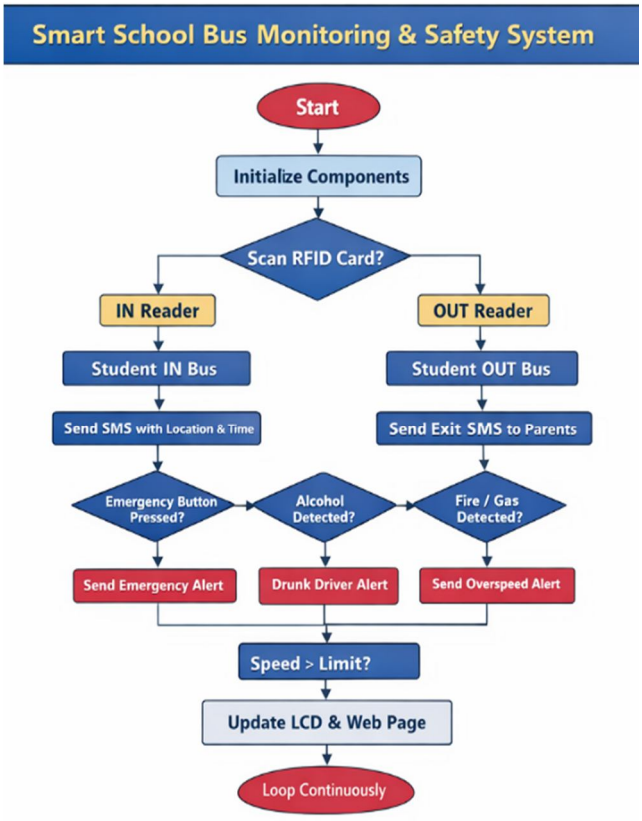


Fig. 2. System Operation Flowchart

V. RESULTS

The Smart School Bus Monitoring and Student Safety System was created and modeled based on concepts and ideas obtained from various studies and literature.

The system was able to incorporate and utilize RFID, GPS, GSM, and IoT technologies to effectively monitor and track school buses.

The utilization of RFID technology was able to accurately identify and track students entering and exiting the bus, thus improving attendance monitoring.

The utilization of GPS technology was able to provide accurate information on the real-time location of the bus, thus allowing real-time tracking.

The utilization of GSM technology was able to provide real-time notifications to parents on the entry, exit, and arrival of their children at their destination.

The emergency speed check, alcohol detection, and sensor-based alerting system were able to improve safety.

The system was able to demonstrate accuracy, communication efficiency, reduced time, and increased safety.

The utilization of IoT technology in school bus monitoring was able to improve student safety, efficiency, and parental trust.

The system was also able to demonstrate cost efficiency, scalability, and real-time intelligent transportation system utilization.

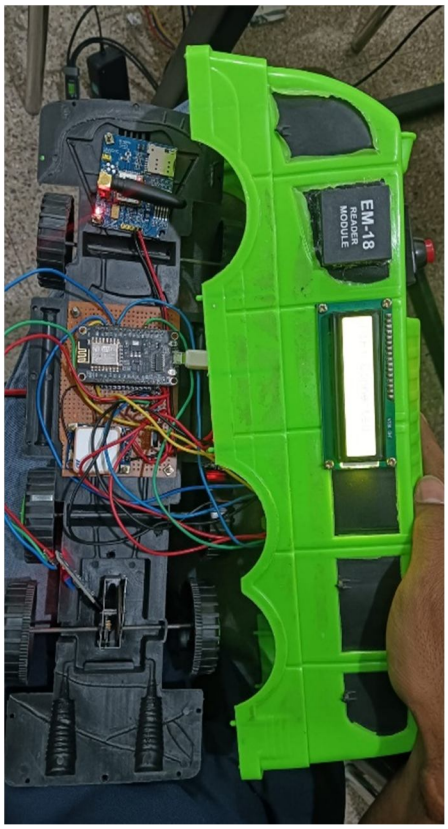


Fig. 3. System Prototype Result

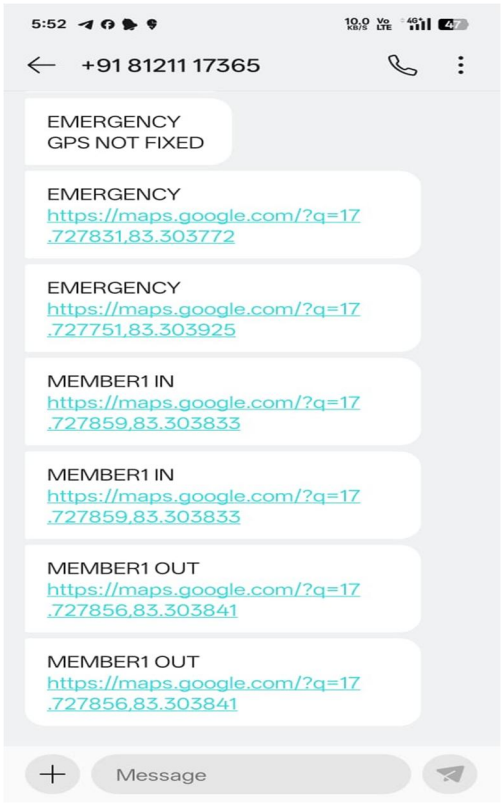


Fig. 4. Sms alert

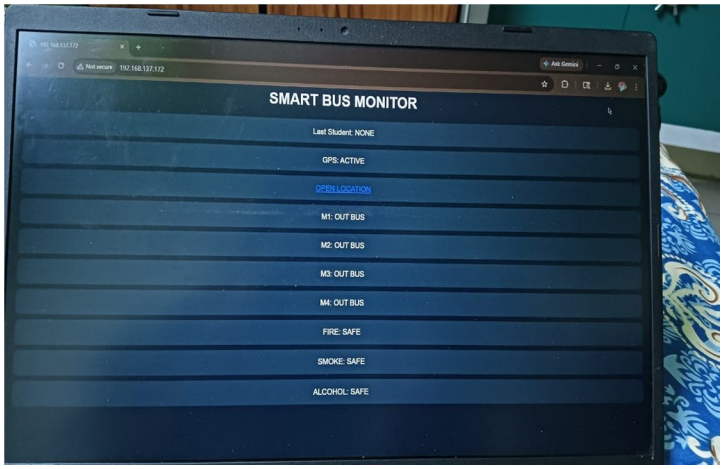


Fig. 5. Web page

VI. CONCLUSION

The proposed system, "IoT-based Smart School Bus Monitoring and Student Safety System," will provide an efficient and reliable solution to ensure the safety of school children during transportation. This system will utilize various technologies such as RFID, GPS, GSM, and sensors to track the bus in real time, monitor attendance, and send notifications to parents and school authorities.

The system will reduce manual intervention and errors to a great extent because it will be able to perform various operations such as student identification, attendance, and status updates. It will also enhance safety because it will be able to monitor the conditions inside the bus using sensors such as fire, smoke, and alcohol sensors. The system will also include an emergency alert system. inclusion of a web-based monitoring system will also enhance transparency because it will enable real-time monitoring of the bus and activities inside the bus. This system will also enable faster response time in emergency situations and improve communication between parents and school management.

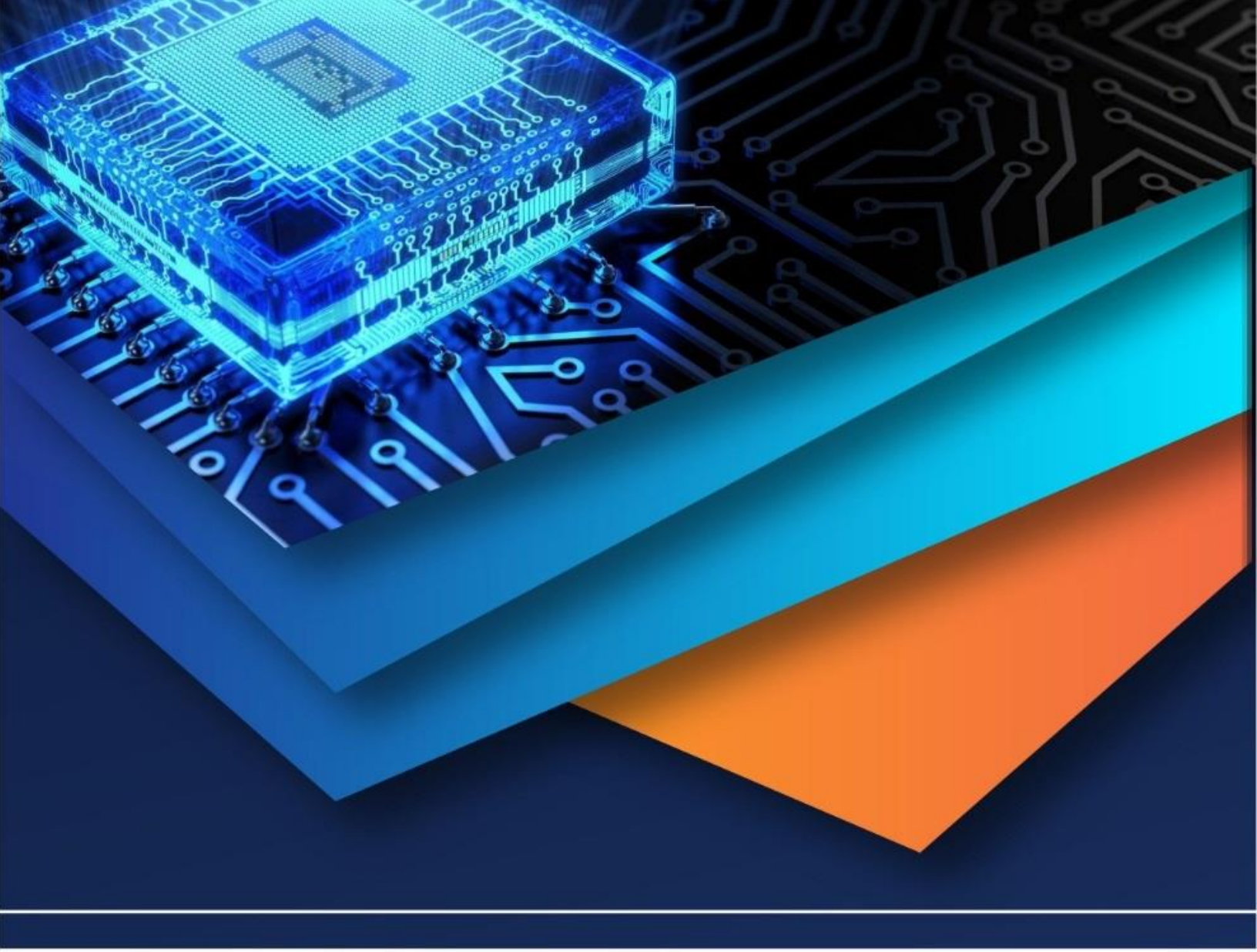
The proposed system is cost-effective, efficient, and simple to implement, making it suitable for a smart transportation system. This system will enhance safety, efficiency, and trust among parents.

VII. FUTURE ENHANCEMENTS

The system can be further enhanced by developing a mobile application and incorporating a cloud storage system for real-time monitoring. The system can include advanced features such as face recognition, camera modules, and artificial intelligence analysis. The system can be further enhanced in the future by incorporating 5G technology and other sensors.

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