GSM GPS Based School Bus Tracking and Accident Detection

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Abstract-This paper presents the design and implementation of a real-time school bus tracking and accident detection system utilizing GPS and GSM modules. The system integrates an Arduino Nano, a NEO-6M GPS module, an ADXL345 accelerometer, and a SIMA7670C GSM module to ensure continuous monitoring of vehicle movement and automatic emergency notifications. When an accident or abnormal shock is detected, the system fetches the precise GPS coordinates and immediately sends an SMS alert and a voice call to pre-configured emergency contacts. Designed with affordability, power efficiency, and modularity in mind, this solution addresses critical issues of student safety, particularly in scenarios where monitoring is otherwise limited or delayed. Its future scope includes cloud integration, AI-driven analytics, and expansion into broader intelligent transportation networks.

Keywords: Arduino Nano, GSM SIMA7670C, NEO-6M GPS, ADXL345, Accident Detection, Fleet Safety, Real-Time Monitoring.

I. INTRODUCTION

The increase in road accidents and the associated risks faced by students during school transportation have prompted the need for advanced vehicle monitoring systems. Traditional systems often rely on manual reporting and lack the capability to provide real-time alerts in emergency situations. This project seeks to fill that gap by developing a GPS-GSM- based solution that not only tracks the location of the school bus in real-time but also identifies accidents and initiates instant communication with emergency contacts. Utilizing components like the Arduino Nano, GPS and GSM modules, and an accelerometer, the system ensures that critical incidents do not go unnoticed.

The architecture of the proposed system is centered around continuous monitoring and event-driven responses. At its core, the Arduino Nano microcontroller serves as the processing unit, managing input from the ADXL345 accelerometer and the NEO-6M GPS module. The GSM SIMA7670C module enables wireless communication, ensuring that once an impact is detected and validated, alerts are delivered to the concerned parties through SMS and voice calls. A piezoelectric buzzer is used for on-site audible alerts, while a push button allows users to cancel false detections within a defined window. Together, these components form a reliable and cost-effective embedded solution that enhances both student safety and fleet management efficiency School transportation safety is a critical concern globally, with increasing demands for real-time monitoring and rapid emergency response.

Traditional tracking systems, such as wired or manual methods, are labor-intensive and lack real-time capabilities, while satellite-based systems are costly and less precise for localized applications. The advent of Internet of Things (IoT) technologies, combined with Global Positioning System (GPS) and Global System for Mobile Communications (GSM), offers a robust solution for tracking school buses and detecting accidents in real time.

This project develops a GPS/GSM-based system that leverages the NEO-6M GPS module for accurate location tracking, the ADXL-345 accelerometer for accident detection, and the SIM A7670C GSM module for reliable data transmission. The system is controlled by an Arduino Nano microcontroller, ensuring cost-effectiveness and scalability. Additional components, such as a piezoelectric buzzer for audible alerts and a push button for false alarm prevention, enhance safety and usability.

The thesis on the GPS GSM based school bus tracking and accident detection is organized into several chapters to comprehensively address the project. It begins with an Introduction, outlining the

background, objectives, and scope of the system. The Literature Review follows, providing an analysis of existing environment monitoring systems and identifying gaps that this project aims to fill. The System Design and Methodology chapter details the architecture, hardware components, software development, and data transmission for real-time monitoring. In the Implementation chapter, the development process, including the integration of hardware, software, and user interfaces, is described.

The Results and Analysis chapter evaluates the system's performance, comparing it to traditional meters in terms of accuracy and efficiency. The Discussion interprets the findings, highlighting advantages, limitations, and potential for future enhancements. Finally, the Conclusion and Future Work chapter summarizes the contributions and offers recommendations for further improvements, including advanced analytics and machine learning. The thesis is supported by Appendices with technical details and References listing all sources and resources used.

II. DESIGN PROCEDURE/ METHODOLOGY

The development of the system began with the integration of selected hardware components on a compact platform to facilitate reliable data acquisition and communication. The Arduino Nano was chosen due to its affordability, low power consumption, and sufficient processing capacity for sensor data handling. The GPS NEO-6M module continuously retrieves real-time coordinates, which are updated and stored for later use. The ADXL345 accelerometer monitors changes in acceleration along three axes, identifying sudden shifts indicative of impacts or potential accidents.

Traditional Tracking Systems: Early school bus tracking systems relied on wired connections and manual monitoring, where location data was recorded and retrieved periodically. This method is time- consuming and lacks real-time updates.

A central theme in GPS/GSM-based school bus tracking and accident detection research is the use of data analytics. Studies by Mabrouk et al. (2022) and Bashir et al. (2020) explore how the data collected from these systems can be analyzed to identify driving patterns, detect anomalies, and predict potential risks using machine learning algorithms. Real-time monitoring and data processing (via cloud- based systems or edge computing) help identify irregularities such as route deviations, sudden stops, or accident triggers. GPS/GSM-based tracking systems provide the opportunity to optimize fleet management, enhance safety protocols, and improve decision-making in applications like school transportation and emergency response, contributing to operational efficiency and student safety.

Figure: Wired Tracking

These sensor readings are continuously evaluated, and if a threshold is surpassed, the system identifies it as an impact event. Upon impact detection, the system activates the buzzer and initiates a countdown timer, during which the push button can be pressed to cancel a false alert. If no manual cancellation occurs, the system proceeds to collect the latest GPS data and composes an SMS containing the incident's location coordinates. This message is sent to emergency contacts via the GSM module, followed by an automated call to further ensure that the alert is acknowledged.

Several studies have highlighted the critical role of IoT in transforming traditional vehicle tracking and safety systems into advanced, smart solutions. GPS/GSM-based school bus tracking and accident detection systems leverage GPS and GSM technologies to enable real-time location tracking and reliable data transmission between vehicles and central systems. These systems collect real-time location and accident data, transmit it to cloud platforms, and facilitate continuous monitoring, real- time analytics, and optimized fleet

management. Research by authors such as Al-Mashaqbeh et al. (2020) and Al-Rodhan et al. (2021) emphasizes the importance of GPS/GSM-based systems in enhancing applications like school transportation, emergency response, and fleet management, enabling timely decision-making, improved safety, and operational efficiency.

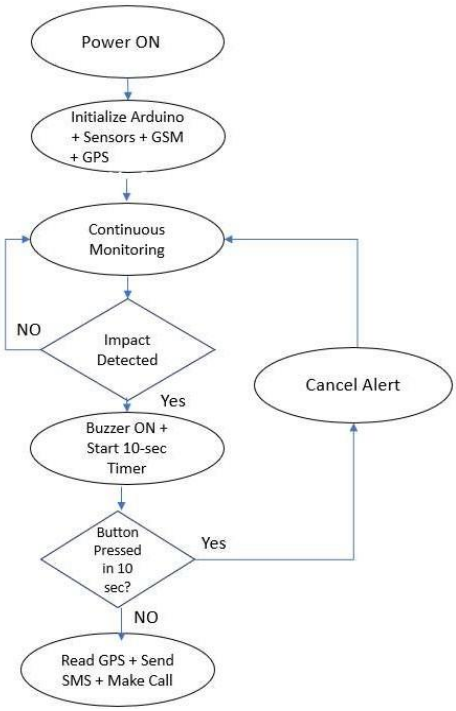

Figure: WORK FLOW

The firmware, written in Arduino IDE, includes logic to manage event thresholds, debounce sensor noise, control serial communication, and interface with the GSM module through AT commands. Once alerts have been dispatched, the system either resumes monitoring or enters a safe state, depending on the configuration. All events are logged internally, and the system can be extended to interface with external dashboards or IoT platforms. During deployment, the hardware was enclosed within a protective casing and mounted securely inside a school bus to withstand vibrations and environmental conditions. Field testing demonstrated the system's resilience and accuracy in varied scenarios, including controlled impact tests and real-time location tracking during travel

Traditional tracking systems, such as wired monitoring, rely on periodic data collection and lack real-time updates, making them unsuitable for dynamic applications like school bus tracking. Satellite-based systems offer wide coverage but are expensive and lack granularity for localized tracking. Cellular-based IoT systems, using GSM or LTE, provide reliable connectivity but face challenges in remote areas and high power consumption. Wi-Fi and Bluetooth-based systems are limited by short-range connectivity, rendering them impractical for large- scale deployments.

Existing systems often face issues such as high costs, limited scalability, and false positives in accident detection. The proposed system mitigates these by using affordable hardware, a false alarm cancellation mechanism, and optimized power management, making it suitable for widespread adoption in school transportation.

III. IMPLEMENTED DESIGN

Use an Arduino Nano as the main microcontroller to manage all sensors and modules. Interface an ADXL345 accelerometer with Arduino via I2C communication for accident/shock detection. Connect the NEO-6M GPS module to Arduino to fetch real- time latitude and longitude .Interface the A7670C SIM module (GSM) for sending SMS and making calls. Power the GSM module separately using a Li- ion battery to ensure stable operation and avoid voltage drops. Connect a Piezoelectric buzzer to Arduino for accident alert indication .Add a push button that acts as a "false detection cancellation" switch within a 10-second window.
Use necessary resistors, capacitors, and voltage level converters if needed (since GSM and GPS might work at different voltages).

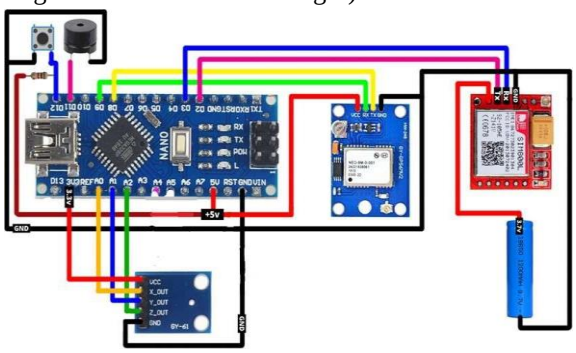

Figure: Schematic diagram

During testing, the system exhibited consistent performance in both normal driving conditions and simulated accident scenarios. In regular operation, the sensors maintained accurate real-time tracking, and the system remained in standby mode, efficiently monitoring accelerometer data. When a simulated accident was triggered, the accelerometer detected the event within milliseconds, activated

the buzzer, and began the countdown window for manual cancellation.

If the event remained uncanceled, the GPS module successfully retrieved coordinates within a five-second interval, and the GSM module transmitted an alert via SMS and followed it with a voice call to the designated emergency contact. The system's robustness was validated under various GSM network strengths, and the GPS module consistently achieved an accuracy of approximately 2.5 meters in open-sky conditions. Reliability was also ensured by fine-tuning the sensitivity of the accelerometer to minimize false positives caused by speed bumps or sudden braking. The modular nature of the system, combined with the use of low-power components, supported efficient energy use and potential for solar- powered implementation. In terms of cost, the project proved to be highly affordable compared to commercially available fleet tracking and emergency response systems, making it accessible for school administrations with limited budgets.

While the system delivered reliable results in most conditions, limitations were observed in densely populated urban environments where GPS signals were less stable, and in remote areas with weak GSM coverage. However, these drawbacks could be mitigated in future versions through the use of higher-precision GPS modules, enhanced network modules (such as LTE or NB-IoT), and fallback protocols

IV. RESULT & DISCUSSION

The implementation of a GPS-GSM-based school bus tracking and accident detection system marks a significant step toward safer and smarter student transportation. The system demonstrated its ability to effectively track vehicle location, detect abnormal events like collisions, and immediately notify relevant stakeholders through automated SMS and calls.

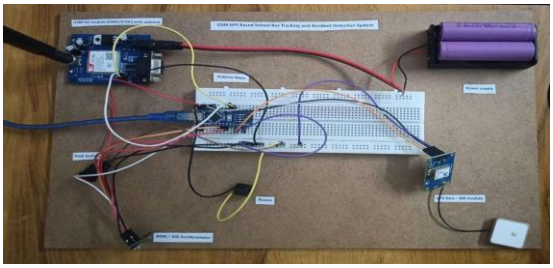

Figure: Under normal condition

With its compact design, low power consumption, and cost-effective hardware, the solution proves to be viable for large-scale deployment across school fleets. Looking ahead, the system offers ample opportunities for enhancement. Integration with cloud platforms would allow historical data storage and visualization, supporting route analysis and driver behavior monitoring. A dedicated mobile application could provide real-time tracking for parents and administrators, ensuring transparency and peace of mind.

Additionally, AI-based predictive models could be introduced to analyze driving patterns and preemptively identify risky behaviors. Energy efficiency could be improved through the use of solar panels, enabling autonomous operation in remote areas without access to power infrastructure. The addition of security layers like encryption and blockchain could safeguard data and ensure secure communication. With these enhancements, the GPS- GSM-based system has the potential to evolve into a comprehensive platform for smart transportation and emergency management, reinforcing its importance in the future of public and educational mobility

Figure: Cellular based IoT system

V. CONCLUSION

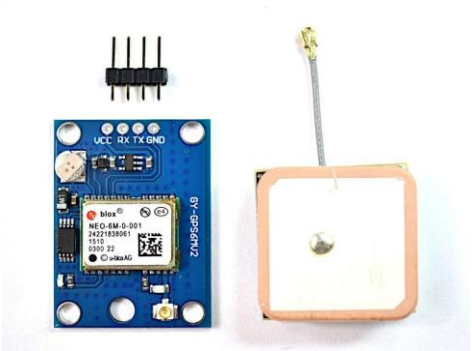

Figure: GPS NEO - 6M

In conclusion, GPS/GSM-based school bus tracking and accident detection systems represent a

significant advancement in transportation safety and fleet management, offering enhanced efficiency, accuracy, and real-time monitoring capabilities compared to traditional methods. By integrating GPS and GSM technologies, these systems enable reliable, wide-area communication, continuous location tracking, and improved insights for applications like school transportation, emergency response, and route optimization. Their ability to provide real-time analytics and predictive modeling allows for better safety protocols, proactive decision-making, and a more secure and efficient approach to managing school transportation systems.

GPS/GSM-based school bus tracking and accident detection systems play a vital role in smart transportation by providing real-time, accurate location and safety data essential for optimizing fleet management and ensuring student safety. Leveraging GPS's precise tracking and GSM's reliable, wide-area communication capabilities, these systems monitor parameters like vehicle location, speed, and sudden impacts, enabling better route optimization, accident response, and operational efficiency. Their ability to operate in both urban and remote areas and transmit data efficiently makes them ideal for enhancing transportation safety and reliability. By integrating GPS/GSM-based tracking systems, schools and transport authorities can improve route planning, respond quickly to emergencies, and support safer transportation practices, ultimately contributing to a more secure and intelligent transportation infrastructure.

The development and implementation of a GPS-GSM-based school bus tracking and accident detection system demonstrates a significant advancement in transportation safety and monitoring technology. By leveraging GPS's precise location tracking and GSM's reliable cellular communication capabilities, the system provides an efficient and dependable solution for real-time tracking and accident detection in school transportation. The system's ability to monitor parameters such as location, speed, and sudden movements with high accuracy ensures valuable data for enhancing safety, optimizing routes, and improving emergency response.

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