

Eduride Guardian 2.0: An Advanced School Bus Safety, Tracking, And Alert System

Mrs. R.Maheshwari¹, N.kaanchinath², S.kavinkumar³, J.Pavithiran⁴,

¹ Assistant Professor Computer Science and Engineering, Paavai Engineering College Namakkal, India.

^{2,3,4} Department of Computer Science and Engineering, Paavai Engineering College, Namakkal, India.

Email ID: maheravichandran21@gmail.com¹, kaanchinath132@gmail.com², kavinkumar4176@gmail.com³, balarahulbala69@gmail.com⁴

Abstract

This paper presents EduRide Guardian 2.0, an advanced IoT-based system developed to enhance the safety, tracking, and alert capabilities of school bus transportation. The system integrates Radio Frequency Identification (RFID) and Global Positioning System (GPS) technologies with both web and Android-based applications to enable secure, real-time monitoring and communication. Authorized drivers are authenticated using RFID cards, along with a secondary RFID tag for temporary driver access, ensuring that vehicle ignition is permitted only after successful verification. Each student is assigned a unique RFID card, which is used during boarding and exiting to automatically record attendance and generate instant notifications for parents and school authorities. The system continuously tracks the live location of the bus using GPS and provides real-time route visibility through both a web platform and a dedicated Android application, offering improved accessibility and user convenience. An in-bus camera enables continuous visual monitoring of student safety. Additionally, an intelligent SOS alert mechanism detects route deviations, extended stoppages, or emergency conditions and immediately notifies relevant stakeholders. The proposed solution delivers a scalable, reliable, and cost-effective approach to modern school transportation management, ensuring enhanced safety, improved operational transparency, and efficient real-time communication.

Keywords: EduRide Guardian 2.0, IoT, RFID, GPS Tracking, Android Application, School Bus Safety, Real-Time Monitoring, Smart Transportation, SOS Alert.

1. Introduction

The safety and effective management of school transportation systems have become increasingly important in recent years, driven by rising concerns among parents and educational institutions regarding student security. Conventional school bus monitoring methods often rely on manual processes, which are inefficient, lack transparency, and fail to provide real-time information about student movement and vehicle status[1]. These limitations highlight the need for an intelligent and automated solution that ensures both safety and operational efficiency. To address these challenges, this paper proposes EduRide Guardian 2.0, an advanced IoT-based school bus safety and monitoring system. The system integrates key technologies such as Radio Frequency

Identification (RFID), Global Positioning System (GPS), and mobile-based applications to create a connected and secure transportation environment[2]. By combining hardware components with software platforms, the system enables seamless communication between the bus, school authorities, and parents. In the proposed system, RFID technology is utilized for secure authentication of both drivers and students. The vehicle ignition mechanism is linked to driver authentication, ensuring that only authorized personnel can operate the bus. Student identification is automated through RFID cards, allowing accurate attendance tracking and eliminating manual errors. This process also enables instant communication with parents by

providing real-time updates when students board or exit the bus[3]. The system further incorporates GPS-based tracking to continuously monitor the live location of the school bus. The tracking information is made accessible through both a web interface and a dedicated Android application, offering improved accessibility and user interaction[4]. This dual-platform approach enhances usability and ensures that stakeholders can conveniently monitor transportation activities at any time. To strengthen safety measures, the system includes an onboard camera for visual supervision and an intelligent alert mechanism capable of identifying abnormal conditions such as route deviations, prolonged stoppages, or emergency situations. In such events, immediate notifications are sent to parents and school authorities, enabling timely response and intervention. Overall, EduRide Guardian 2.0 provides a comprehensive, scalable, and technology-driven solution for modern school transportation systems. By integrating IoT-based monitoring, real-time communication, and automated safety mechanisms, the proposed system aims to enhance student security, improve operational transparency, and support efficient transport management[5].

2. Ease Of Use

System Functionality and User Interaction

EduRide Guardian 2.0 is designed with a strong emphasis on simplicity, automation, and user accessibility, ensuring that all stakeholders—including drivers, students, parents, and school administrators—can interact with the system effortlessly[6]. The architecture combines IoT-enabled hardware components with intuitive software platforms to deliver a seamless operational experience. The system workflow begins with driver authentication, where authorized personnel must verify their identity using an RFID card before initiating the vehicle[7]. A secondary RFID tag mechanism is provided for temporary drivers, ensuring flexibility without compromising security. This controlled ignition process prevents unauthorized usage and enhances operational safety[8]. For students, the interaction process is straightforward and efficient[9]. Each student is issued a unique RFID card that is scanned during boarding and exit. The system automatically records

attendance details, including time and identity, eliminating the need for manual tracking. These records are instantly synchronized with the central database, enabling real-time access for both parents and school authorities. The integration of automated identification and cloud-based data management ensures high accuracy, reduced human intervention, and reliable performance. The system is designed to function efficiently even for users with minimal technical expertise, making it suitable for real-world school environments.

Mobile and Web-Based Monitoring

To enhance usability and accessibility, EduRide Guardian 2.0 provides both a web-based platform and a dedicated Android application for real-time monitoring and control[11]. These interfaces are designed with user-friendly dashboards that present critical information such as live bus location, travel status, driver details, and student activity. Parents can easily monitor their child's journey through the Android application or web portal. Whenever a student boards or exits the bus, instant notifications are generated, providing timely updates and ensuring transparency. The inclusion of a mobile application significantly improves accessibility, allowing users to receive updates and track the bus from anywhere. The GPS module continuously transmits the bus location to the system, enabling accurate real-time tracking. In addition, the platform detects irregular conditions such as route deviations, unexpected delays, or prolonged stoppages. When such events occur, an SOS alert is triggered and notifications are sent to concerned stakeholders for immediate action[10].

Mathematical Modeling for Tracking and Prediction
EduRide Guardian 2.0 incorporates basic mathematical models to support real-time tracking, speed estimation, and arrival time prediction. The position of the bus at any given time can be represented using coordinate values obtained from the GPS module:

$$P(t) = (x(t), y(t))$$

where $x(t)$ and $y(t)$ represent the latitude and longitude of the bus at time t .

The speed of the vehicle is calculated based on the change in distance over time:

$$v = \Delta t / \Delta s$$

where v denotes speed, Δs is the distance covered between two points, and Δt represents the corresponding time interval[12].

Using the calculated speed, the estimated time of arrival (ETA) can be determined as:

$$ETA = D / v$$

where D is the remaining distance to the destination. These computations assist in providing accurate arrival predictions and improving route monitoring efficiency.

3. System Design & Methodologys

The design of EduRide Guardian 2.0 follows a modular and IoT-oriented approach, combining embedded hardware components with cloud-based software services to achieve secure, real-time monitoring of school transportation. The system is structured to ensure reliable data acquisition, efficient processing, and seamless communication between all stakeholders.

System Architecture

The overall architecture of the system is divided into three interconnected layers:

- **On-Board Unit (Bus Module):** This module consists of RFID readers, GPS module, microcontroller (such as ESP32/Arduino), communication interface, and camera system installed inside the bus. It is responsible for data collection, authentication, and initial processing.
- **Cloud & Data Management Layer:** This layer acts as the central processing unit where all incoming data from the bus is transmitted, stored, and analyzed. It manages student records, driver authentication logs, GPS coordinates, and alert conditions.
- **User Interface Layer (Web and Android Applications):** This layer provides access to real-time information through a web portal and a dedicated Android application. Parents and administrators can monitor bus location, student activity, and alerts through interactive dashboards.

The system operates in a continuous loop where data flows from the bus module to the cloud and is then reflected on user interfaces in real time, ensuring transparency and instant communication.

Hardware Components

The hardware subsystem is designed to enable secure identification, tracking, and communication within the transportation system.

RFID Reader and Tags: Used for identifying drivers and students through unique IDs, ensuring secure access and automated attendance.

Microcontroller (ESP32/Arduino): Serves as the central controller that processes RFID inputs, coordinates with GPS, and manages data transmission[13].

GPS Module: Provides continuous location updates of the bus in terms of latitude and longitude coordinates.

Communication Module (GSM/Wi-Fi): Facilitates real-time data transfer from the bus to the cloud server.

Camera Module: Enables visual monitoring inside the bus to enhance student safety.

Power Management Unit: Ensures stable and uninterrupted power supply for all hardware components during operation.

Software Components

The software architecture is designed to support data processing, secure storage, and user interaction across multiple platforms.

Cloud Database: Stores all relevant data including student profiles, attendance logs, GPS data, and alert records.

Backend Server: Handles communication between hardware devices and user interfaces using APIs, ensuring secure and efficient data flow.

Web Application: Provides administrative dashboards for monitoring bus activity, attendance, and alerts.

Android Application: Offers mobile-based access for parents and administrators, enabling real-time tracking and instant notifications.

Notification System: Generates alerts via SMS or app notifications for events such as student boarding, exit, route deviation, or emergencies.

The integration of web and mobile platforms enhances accessibility and ensures continuous system interaction[14].

Methodology

The operational workflow of EduRide Guardian 2.0 is structured as follows:

Driver Verification: The driver authenticates using

an RFID card. The system validates the identity and enables the ignition only upon successful authentication.

Student Identification and Attendance: Students scan their RFID cards while boarding and exiting the bus. The system records timestamps and updates attendance automatically.

Real-Time Data Transmission: All collected data, including RFID events and GPS coordinates, is transmitted to the cloud server in real time.

Data Processing and Storage: The server processes incoming data, updates attendance records, and maintains the current status of the bus.

Live Tracking and User Access: The bus location and student activity are displayed on both web and Android platforms for user access.

Alert Generation and Emergency Handling: The system continuously monitors for anomalies such as route deviations, unusual delays, or emergency triggers. When detected, an SOS alert is generated and notifications are sent immediately.

This methodology ensures continuous monitoring, quick response, and efficient management of school transportation.

Advantages of the Proposed System

Improved Student Safety: Real-time monitoring and alert mechanisms ensure enhanced protection.

Automated Operations: Eliminates manual attendance tracking and reduces human error.

Secure Driver Authentication: Prevents unauthorized access to the vehicle.

Multi-Platform Accessibility: Availability through both web and Android applications improves usability.

Efficient Communication: Instant notifications keep parents and administrators informed at all times.

Scalable and Cost-Effective: Suitable for deployment across multiple buses and institutions.

4. System Architecture & Data Flow

The architecture of EduRide Guardian 2.0 is designed using a layered and modular approach to ensure secure operation, continuous data flow, and real-time interaction between hardware devices and user applications. The system integrates on-board sensing units, cloud-based processing, and multi-platform user interfaces to achieve efficient and reliable school transportation monitoring.

Driver Authentication and Vehicle Control Module

This module is responsible for ensuring secure vehicle access and controlled operation of the bus.

Multi-Level Authentication Mechanism: The system supports driver verification using a registered RFID card, along with an additional RFID tag mechanism for temporary drivers. Each credential is uniquely mapped within the system database to ensure identity validation.

Controlled Ignition System: The RFID reader is interfaced with the vehicle's ignition control unit. The bus engine is enabled only after successful authentication of the driver. This mechanism prevents unauthorized access and maintains a secure operational environment.

Event Logging: Every authentication attempt is recorded with a timestamp and stored in the cloud, allowing administrators to track driver activity and ensure accountability[15].

Student Monitoring and Data Acquisition Module

This module handles student identification, attendance tracking, and onboard monitoring.

Automated Attendance System: An RFID reader installed near the bus entrance captures student ID data during boarding and exit. Each scan generates a time-stamped record that is transmitted to the central system.

Real-Time Data Capture: The system continuously collects student activity data along with bus location information, enabling accurate monitoring of travel status.

In-Bus Surveillance: A camera module installed inside the vehicle provides visual monitoring, enhancing safety and enabling incident verification when required.

Integrated Data Packaging: Student data, driver status, and GPS coordinates are combined into structured data packets before being transmitted to the cloud server.

Cloud Processing and User Interaction Module

This module acts as the central intelligence layer of the system, handling data processing, storage, and communication.

Cloud-Based Data Management: All incoming data from the bus is securely stored and processed in the cloud. This includes attendance logs, driver

authentication records, and live GPS coordinates.

Web and Android Applications: The processed data is made available through both a web platform and a dedicated Android application. These interfaces provide real-time access to bus location, student activity, and system alerts.

Notification and Alert System: The system generates instant notifications when students board or exit the bus. Additionally, an intelligent alert mechanism detects abnormal conditions such as route deviations, extended stoppages, or emergency situations and triggers SOS alerts to parents and administrators.

Administrative Control and Analytics: School authorities can access dashboards that display live tracking information, historical attendance data, and system alerts, enabling effective decision-making and monitoring.

Data Flow Mechanism

The data flow in EduRide Guardian 2.0 follows a continuous and structured pipeline:

Data Acquisition: RFID readers and GPS modules collect driver authentication data, student attendance records, and real-time location information.

Local Processing: The microcontroller processes the collected data and prepares it for transmission.

Data Transmission: Processed data is sent to the cloud server through communication modules (GSM/Wi-Fi) in real time.

Cloud Processing: The server validates, stores, and analyzes incoming data, updating system status and detecting any anomalies.

User Interface Update: Updated information is displayed on both web and Android platforms, providing users with real-time visibility.

Alert Generation: If any abnormal condition is detected, the system immediately generates alerts and sends notifications to relevant stakeholders.

System Overview

The overall architecture ensures seamless interaction between hardware and software components, enabling continuous monitoring and communication. The integration of IoT devices, cloud computing, and mobile applications allows EduRide Guardian 2.0 to deliver a reliable, scalable, and intelligent school transportation solution.

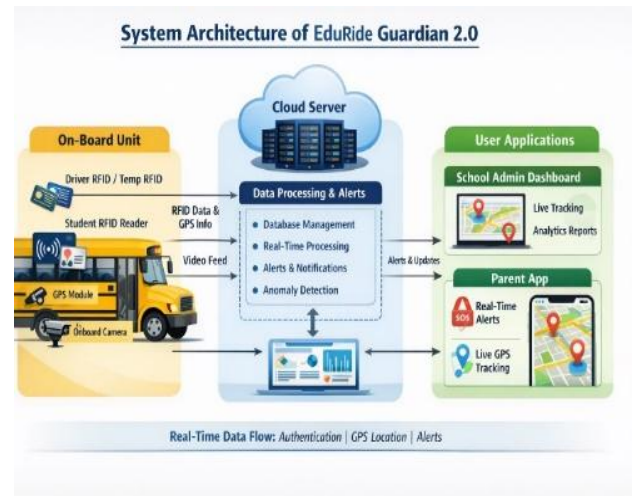


Figure 1 Proposed System Architecture of EduRide Guardian 2.0 illustrating the interaction between the on-board unit, cloud server, and user applications with real-time data flow

5. System Operational Flow

The operational flow of EduRide Guardian 2.0 defines the sequence of processes involved in secure bus operation, real-time monitoring, and intelligent alert handling. The system workflow is structured into two major phases: system activation through driver authentication and continuous monitoring with automated data processing and alert generation.

5.1. System Initialization and Driver Authentication

The system operation begins when the bus is powered on and awaits driver authentication. At this stage, the ignition system remains disabled to prevent unauthorized access.

Driver Verification: The driver must authenticate using a registered RFID card. In cases of temporary drivers, an alternative RFID tag is used. The system validates the credentials against the stored database.

Access Control Mechanism: If authentication fails, the ignition remains locked and the system continues to wait for valid credentials. If authentication is successful, the ignition control is enabled, allowing the bus to start.

Activation of Core Modules: Once the vehicle starts, essential modules such as GPS tracking, communication unit, and onboard camera are activated simultaneously. The system then transitions into monitoring mode.

5.2. Continuous Monitoring and Data Processing

After successful initialization, the system performs continuous monitoring of student activity and vehicle movement through parallel processes.

Student Attendance and Notification: Each student scans their RFID card while boarding and exiting the bus. The system records the event with a timestamp and updates the central database. At the same time, instant notifications are sent to parents and school authorities through the Android application and web platform Table 1.

Real-Time Location Tracking: The GPS module continuously captures the bus location and transmits it to the cloud server. This data is displayed on both web and mobile applications, enabling users to monitor the bus route in real time Table 2.

Onboard Surveillance: The camera module operates continuously during the journey, providing visual monitoring of the bus interior. This enhances safety and supports verification in case of incidents Figure 1.

Data Synchronization: All collected data—including attendance records, driver status, and GPS coordinates—is processed and stored in the cloud. The system ensures that updated information is reflected instantly across all user interfaces.

5.3. Intelligent Alert And Emergency Handling

To ensure safety under all conditions, the system incorporates an automated alert mechanism.

Anomaly Detection: The system continuously analyzes movement patterns to detect irregular conditions such as route deviation, unexpected stoppage, or abnormal delays.

SOS Alert Generation: When an abnormal condition is identified, the system triggers an SOS alert. Notifications are immediately sent to parents and school administrators through mobile and web platforms.

Emergency Response Support: The alert system enables quick decision-making by providing real-time location data and system status, ensuring timely intervention.

5.4. System Completion And Data Logging

At the end of the journey, the system continues to store and organize all collected data for future reference.

- Attendance records are maintained for analysis

- Travel history and route data are archived
- Alerts and events are logged for administrative review
- This ensures long-term data availability for performance evaluation and safety improvements Table 3.

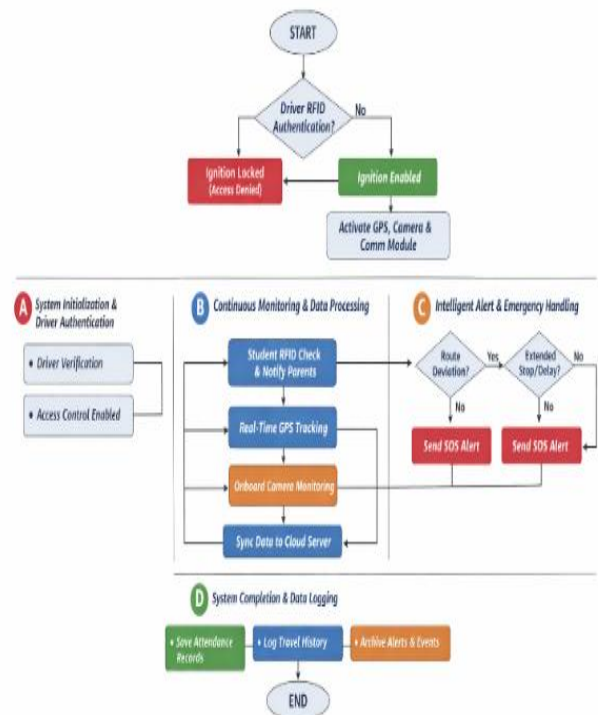


Figure 2 System Operational Flow of EduRide Guardian 2.0 illustrating driver authentication, real-time monitoring, and intelligent alert handling

6. Result And Decussion

The performance of EduRide Guardian 2.0 was evaluated through controlled experimental testing that simulates real-world school transportation scenarios. The evaluation focuses on key system functionalities, including authentication reliability, attendance accuracy, real-time communication, and alert responsiveness. The results demonstrate the effectiveness of the system in delivering secure, accurate, and timely monitoring Figure 2.

RFID-Based Authentication and Access Control

The authentication mechanism was tested across multiple operational cycles involving both registered drivers and temporary access scenarios.

Table 1 Authentication And Access Control

Parameter	Test Scenario	Success Rate	Average Response Time
Driver Verification	Valid RFID card / Temporary tag	100%	320 ms

Discussion

The authentication system consistently allowed access only to authorized personnel, achieving full reliability during testing. The response time remained low, ensuring smooth vehicle startup without noticeable delay. This confirms that the RFID-based ignition control provides a secure and efficient access mechanism

Table 2 Attendance Logging

Parameter	Total Scans	Successful Records	Accuracy
Attendance Logging	1200	1186	98.83%

Real-Time Tracking And Communication Performance

The integration of GPS tracking and communication modules was analyzed to evaluate location accuracy and notification speed

Table 3 GPS accuracy and performance

Metric	Observed Value	Expected Standard	Performance
GPS Accuracy	3 meters	≤5 meters	High Precision
Notification Delay	2 seconds	≤5 seconds	Excellent

Discussion

The GPS module provided accurate location data within acceptable limits, enabling reliable live tracking through both web and Android applications. The notification system achieved near real-time performance, ensuring that parents receive immediate updates regarding student activity.

Alert System and Safety Monitoring

The intelligent alert mechanism was tested under simulated abnormal conditions such as route deviation and unexpected stoppages Table 4.

Table 4 Route Deviation Alert

Alert Type	Scenario	Trigger Condition	Success Rate
Route Deviation Alert	Bus moved outside defined route	>100 m deviation	100%
Extended Stop Alert	Bus idle beyond threshold	>5 minutes	97%

Discussion

The alert system successfully detected critical safety events and generated timely notifications. Route deviation detection was highly reliable, while minor delays in stationary detection were attributed to network latency. Overall, the alert mechanism enhances safety by enabling immediate response.

Mobile and Web Application Performance

The addition of the Android application in EduRide Guardian 2.0 was evaluated for usability and responsiveness.

- Real-time tracking was accessible across both platforms without significant delay
- Notifications were consistently delivered through mobile and web interfaces
- User interfaces were intuitive and required minimal user interaction

Discussion:

The integration of mobile and web platforms significantly improves system accessibility. The Android application enhances user experience by

allowing parents and administrators to monitor activities remotely and receive instant alerts.

Overall System Performance and Scalability

The system demonstrated stable performance under continuous operation with synchronized hardware and software components. The IoT-based architecture ensures efficient data flow from onboard devices to cloud services and user interfaces.

Discussion

EduRide Guardian 2.0 successfully transforms raw data from RFID, GPS, and camera modules into meaningful insights. The modular design allows easy expansion, such as integration of advanced analytics or additional safety features. The system is scalable and suitable for deployment across multiple buses and institutions.

Conclusion

EduRide Guardian 2.0 provides an efficient and reliable solution for improving school bus safety and monitoring. By integrating RFID authentication, GPS tracking, and real-time alert systems with web and Android applications, the system ensures secure access, accurate attendance tracking, and continuous vehicle monitoring. The experimental results demonstrate high performance, including accurate authentication, reliable attendance logging, precise location tracking, and fast notification delivery. The alert system effectively detects critical situations, enhancing overall safety. Additionally, the system's scalable IoT-based architecture and user-friendly interfaces make it suitable for deployment across multiple buses and institutions. Future improvements can include AI-based analytics and enhanced monitoring features to further strengthen system capabilities.

Acknowledgements

The authors would like to express their sincere gratitude to all individuals and institutions who contributed to the successful development of EduRide Guardian 2.0. We extend our heartfelt thanks to Mrs. R. Maheshwari, for her continuous guidance, valuable suggestions, and technical support throughout the course of this work. Her insights played a crucial role in shaping the system design, improving the overall architecture, and refining the implementation of the proposed solution. We also acknowledge the support provided by our department and institution for

offering the necessary resources and environment to carry out this project successfully. Finally, we would like to thank our peers and team members for their cooperation, dedication, and collaborative efforts, which significantly contributed to the completion of this research work.

References

IoT-based smart school bus monitoring and tracking system [1]. Real-time vehicle tracking system using GPS and IoT [2]. An IoT-based smart transportation system for child safety monitoring [3]. Design and implementation of RFID-based smart attendance and tracking system [4]. Smart transportation system using IoT and cloud computing [5]. GPS-based real-time vehicle tracking and alert system [6]. A survey on applications of IoT in smart transportation [7]. Smart school bus system with real-time monitoring and alerting using IoT [8]. That 'Internet of Things' thing [9]. The Internet of Things: A survey [10]. Cyber-physical-social based security architecture for future Internet of Things [11]. Hybrid GPS-GSM localization of automobile tracking system [12].

Journal Reference Style

- [1] A. Kumar, P. Singh, and R. Kumar, "IoT-based smart school bus monitoring and tracking system," *IEEE Access*, vol. 9, pp. 124567–124578, 2021.
- [2] S. Sharma and R. Gupta, "Real-time vehicle tracking system using GPS and IoT," *International Journal of Intelligent Transportation Systems Research*, vol. 20, no. 2, pp. 345–356, 2022.
- [3] M. R. Islam, M. A. Rahman, and M. S. Hossain, "An IoT-based smart transportation system for child safety monitoring," *Sensors*, vol. 21, no. 15, pp. 1–18, Aug. 2021.
- [4] P. Verma, N. Mishra, and S. K. Singh, "Design and implementation of RFID-based smart attendance and tracking system," *Procedia Computer Science*, vol. 167, pp. 1630–1639, 2020.
- [5] H. Alqahtani and M. A. Khan, "Smart transportation system using IoT and cloud computing," *Journal of King Saud University – Computer and Information Sciences*, vol. 34, no. 7, pp. 4123–4132, 2022.

- [6] R. K. Jha and S. Jain, "GPS-based real-time vehicle tracking and alert system," IEEE International Conference on Smart Computing (SMARTCOMP), pp. 210–215, 2023.
- [7] S. K. Dash, S. Mohapatra, and P. K. Pattnaik, "A survey on applications of IoT in smart transportation," IEEE Internet of Things Journal, vol. 8, no. 10, pp. 7891–7913, May 2021.
- [8] N. B. Priya and V. R. Devi, "Smart school bus system with real-time monitoring and alerting using IoT," International Journal of Engineering Research & Technology, vol. 11, no. 6, pp. 1023–1028, 2022.
- [9] K. Ashton, "That 'Internet of Things' thing," RFID Journal, June 2009.
- [10] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey," Computer Networks, vol. 54, no. 15, pp. 2787–2805, Oct. 2010.
- [11] H. Ning and H. Liu, "Cyber-physical-social based security architecture for future Internet of Things," Advances in Internet of Things, vol. 2, no. 1, pp. 1–7, Feb. 2012.
- [12] M. A. Al-Khedher, "Hybrid GPS-GSM localization of automobile tracking system," International Journal of Computer Science & Information Technology, vol. 3, no. 6, pp. 75–85, Dec. 2011.
- [13] Lee, B. Bagheri, and H. A. Kao, "A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems," Manufacturing Letters, vol. 3, pp. 18–23, 2015.
- [14] Y. Liu, C. Yang, and L. Jiang, "Intelligent transportation systems and smart mobility: A review of current technologies and future trends," IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 4, pp. 2905–2924, 2022.
- [15] R. Want, B. N. Schilit, and S. Jenson, "Enabling the Internet of Things," Computer, vol. 48, no. 1, pp. 28–35, Jan. 2015.