Implentation Of Iot-Based Communication System for Electric Vehicle Fleet

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***Abstract*—The rapid growth of electric vehicles and increasing traffic density demand intelligent communication systems to enhance road safety and operational efficiency. This research presents an IoT-based communication system for electric vehicle fleet that integrates real-time sensing, wireless communication, and cloud connectivity. The proposed system utilizes an ESP32 microcontroller, GPS module, MPU6050 sensor, and voltage monitoring to detect accidents, track vehicle location, and monitor battery health. A MobileNet SSD-based vision model is incorporated for object detection to improve situational awareness. Vehicle-to-vehicle communication is established using RF modules to provide immediate alerts to nearby vehicles, while IoT platforms enable remote monitoring and emergency notifications. The system is designed to be cost-effective, scalable, and suitable for smart transportation environments. Experimental results demonstrate improved response time, enhanced safety, and reliable communication, making the system a promising solution for next-generation intelligent transport and electric vehicle management systems.**

***Index Terms*—IoT, Electric Vehicle fleet, V2V Communication, Accident Detection, GPS Tracking, Smart Transportation.**

I. INTRODUCTION

The rapid expansion of transportation systems, coupled with the increasing adoption of electric vehicles (EVs), has significantly transformed modern mobility. However, this growth has also introduced critical challenges such as road accidents, traffic congestion, delayed emergency response, and lack of real-time coordination among vehicles. Traditional vehicle safety mechanisms, including airbags, manual hazard signals, and basic GPS tracking, operate independently and are largely reactive in nature. These systems fail to provide proactive safety measures or real-time communication between vehicles, which is essential in today's dynamic traffic environments.

Recent advancements in Internet of Things (IoT), embedded systems, and artificial intelligence (AI) have opened new possibilities for developing intelligent transportation systems. Vehicle-to-Everything (V2X) communication, which includes Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Cloud (V2C) communication, plays a vital role in enabling real-time data exchange and improving road safety. By allowing vehicles to share critical information such as speed, location, and hazard alerts, V2X systems can significantly reduce accident risks and enhance traffic management efficiency.

In this context, the proposed system focuses on the implementation of an IoT-based communication framework specifically designed for electric vehicle fleet. The system integrates multiple technologies, including ESP32 microcontrollers, GPS modules, accelerometer and gyroscope sensors (MPU6050), and voltage monitoring units, to enable comprehensive vehicle monitoring and communication. Additionally, an AI-based object detection model using MobileNet SSD is incorporated to identify vehicles and pedestrians in real time, thereby enhancing situational awareness and decision-making capabilities.

The system employs RF communication modules operating at 433 MHz to establish direct vehicle-to-vehicle communication, ensuring immediate alert transmission even in the absence of internet connectivity. Furthermore, IoT platforms are utilized to send emergency notifications, track vehicle parameters remotely, and provide real-time updates to users and authorities. This integration of hardware and software components ensures a seamless and efficient communication system.

The primary objective of this research is to develop a cost-effective, scalable, and reliable solution that enhances safety, reduces response time during emergencies, and supports smart transportation infrastructure. By combining IoT, AI, and wireless communication technologies, the proposed system aims to bridge the gap between conventional vehicle systems and intelligent connected ecosystems, contributing to the advancement of next-generation electric mobility and smart city applications.

II. LITERATURE SURVEY

A. IoT-Based Vehicle Communication Systems

The emergence of Internet of Things (IoT) technologies has significantly influenced the development of intelligent transportation systems. Several studies have explored IoT-enabled frameworks for real-time vehicle monitoring, focusing on parameters such as speed, location, and engine status. These systems typically utilize sensors, microcontrollers, and cloud platforms to enable seamless data exchange between vehicles and centralized servers. Researchers have highlighted the effectiveness of IoT in improving fleet management, predictive maintenance, and traffic optimization. However, many existing models rely heavily on continuous internet connectivity, which may limit performance in remote or low-network areas. Additionally, most IoT-based systems focus on data collection rather than real-time inter-vehicle communication. This creates a gap in immediate hazard alerting and accident prevention. The current research addresses these limitations by combining IoT capabilities with direct communication technologies to ensure faster and more reliable information sharing.

B. Vehicle-to-Vehicle (V2V) Communication Technologies

Vehicle-to-Vehicle (V2V) communication has been widely studied as a solution for enhancing road safety and reducing accident rates. Existing research primarily focuses on communication protocols such as Dedicated Short-Range Communication (DSRC) and cellular-based V2X (C-V2X) systems. These technologies enable vehicles to exchange information like speed, direction, and braking status in real time. Studies have demonstrated that V2V communication can significantly reduce collision risks and improve traffic flow. However, high implementation costs, infrastructure dependency, and complexity often limit large-scale adoption, especially in developing regions. Some research has explored the use of low-cost RF communication modules as an alternative, offering simple and effective short-range communication. Despite this, challenges remain in achieving reliability and scalability. The proposed system builds upon these studies by integrating cost-effective RF-based V2V communication with IoT and AI, providing a practical and scalable solution for real-world deployment.

C. AI-Based Accident Detection and Smart Monitoring

Artificial Intelligence (AI) has become a key component in modern vehicle safety systems, particularly in areas such as object detection, driver behavior analysis, and accident prediction. Deep learning models like MobileNet SSD and YOLO have been widely used for real-time object detection due to their efficiency and accuracy. Research indicates that integrating AI with sensor data can enhance situational awareness and enable proactive safety measures. Additionally, sensors such as accelerometers and gyroscopes have been used to detect sudden impacts and abnormal motion patterns, indicating potential accidents. While these systems improve detection accuracy, many existing solutions operate independently without integrating communication mechanisms for immediate alerts. Furthermore, some models require high computational resources, limiting their use in embedded systems. The proposed approach addresses these gaps by combining lightweight AI models with sensor-based detection and real-time communication, ensuring both accuracy and rapid response in emergency situations.

III. PROPOSED SYSTEM

The proposed system presents an integrated IoT-based communication framework designed to enhance safety, monitoring, and real-time coordination among electric vehicle (EV) fleet. It combines embedded hardware, wireless communication, and intelligent processing to enable proactive accident detection, vehicle tracking, and inter-vehicle alerting. The system is structured into two primary units: the Sender Vehicle Unit and the Receiver Vehicle Unit, supported by cloud-based IoT services.

The Sender Vehicle Unit is installed in the transmitting vehicle and serves as the core data acquisition and processing module. It is built around the ESP32 microcontroller, which manages multiple sensors and communication modules. A GPS module continuously tracks the vehicle's real-time location, while the MPU6050 sensor (accelerometer and gyroscope) detects sudden changes in motion, enabling accurate accident identification. A voltage sensor monitors the battery condition of the electric vehicle, ensuring operational safety. Additionally, a camera integrated with a lightweight AI model (MobileNet SSD) performs real-time object detection to identify nearby vehicles and pedestrians, enhancing situational awareness.

For communication, the system employs a 433 MHz RF transmitter to send critical alerts directly to nearby vehicles without relying on internet connectivity. This ensures minimal latency and reliable communication even in remote areas. An emergency push button is also included to allow manual alert triggering in critical situations. Simultaneously, the ESP32 connects to an IoT platform, enabling cloud-based data transmission, remote monitoring, and emergency notifications.

The Receiver Vehicle Unit is responsible for receiving and displaying alerts from nearby vehicles. It consists of an Arduino Nano connected to a 433 MHz RF receiver module. When an alert is received, the system activates a buzzer to provide an audible warning and displays relevant information on an LCD screen. This ensures that drivers are immediately informed about potential hazards, allowing them to take preventive actions.

The integration of IoT with RF-based Vehicle-to-Vehicle (V2V) communication provides a hybrid approach that balances real-time responsiveness and remote accessibility. Unlike traditional systems that operate in isolation, this proposed model enables continuous interaction between vehicles and cloud services. The design is cost-effective, modular, and scalable, making it suitable for deployment in smart transportation systems, especially in developing regions where infrastructure limitations exist.

Overall, the proposed system aims to bridge the gap between conventional vehicle safety mechanisms and intelligent connected systems by delivering a reliable, efficient, and real-time communication solution for electric vehicle fleet.

IV. METHODOLOGY

A.System Architecture and Design

The proposed system follows a modular and distributed architecture designed to ensure efficient data collection, processing, and communication between vehicles and cloud platforms. The overall framework is divided into two main units: the sender vehicle unit and the receiver vehicle unit. The sender unit is responsible for sensing, processing, and transmitting data, while the receiver unit focuses on alert reception and driver notification. An ESP32 microcontroller is used as the central processing unit due to its integrated Wi-Fi capabilities, low power consumption, and suitability for IoT applications. Multiple sensors, including GPS, MPU6050, and voltage sensors, are interfaced with the ESP32 to collect real-time data related to vehicle location, motion, and battery health.

The system is designed to operate in both online and offline modes to ensure reliability under different network conditions. For local communication, a 433 MHz RF module is used to establish direct vehicle-to-vehicle (V2V) communication. This enables the transmission of emergency alerts without relying on internet connectivity, reducing latency and improving response time. For remote monitoring and data logging, the ESP32 connects to a cloud-based IoT platform, which stores and visualizes real-time data. This dual-mode communication strategy ensures that the system remains functional even in areas with poor network coverage.

The receiver unit is developed using an Arduino Nano, which processes incoming RF signals and activates output components such as a buzzer and LCD display. The buzzer provides an immediate audible warning, while the LCD displays relevant alert information, ensuring that the driver can quickly understand the situation. The architecture is designed to be scalable, allowing multiple vehicles to be integrated into the network. The modular design also enables easy upgrades and customization, making the system adaptable for various transportation scenarios and future technological advancements.

B.Data Acquisition and Processing

Data acquisition is a critical component of the proposed system, as it directly influences the accuracy and effectiveness of safety mechanisms. The system utilizes multiple sensors to capture real-time information from the vehicle environment. The GPS module continuously retrieves location coordinates, enabling vehicle tracking and route monitoring. The MPU6050 sensor, which combines a three-axis accelerometer and gyroscope, measures motion parameters such as acceleration, orientation, and angular velocity. This data is essential for detecting abnormal conditions, such as sudden impacts or rollovers, which may indicate an accident. Additionally, a voltage sensor is used to monitor the battery status of the electric vehicle, helping to prevent failures caused by voltage fluctuations.

The collected sensor data is processed by the ESP32 microcontroller using predefined algorithms and threshold values. For instance, sudden spikes in acceleration or abrupt changes in orientation are analyzed to determine the likelihood of an accident. The system filters noise and irrelevant variations to improve detection accuracy. In parallel, a camera module integrated with a lightweight deep learning model, MobileNet SSD, performs object detection to identify nearby vehicles and pedestrians. This enhances situational awareness and supports proactive decision-making by providing real-time environmental insights.

Once processed, the data is categorized based on its significance and urgency. Critical events, such as accident detection or emergency button activation, trigger immediate alerts that are transmitted via RF communication and IoT platforms. Non-critical data, such as routine location updates and battery status, is periodically sent to the cloud for monitoring and analysis. This prioritization ensures efficient use of system resources and minimizes unnecessary communication overhead. Overall, the data acquisition and processing methodology ensures high reliability, accuracy, and responsiveness in real-time vehicle monitoring.

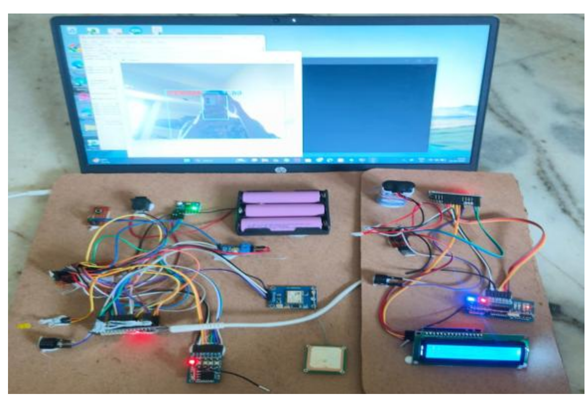
C. Communication and Alert Mechanism

The communication framework of the proposed system is designed to ensure fast, reliable, and multi-channel information exchange. It integrates both short-range wireless communication and cloud-based IoT connectivity to achieve comprehensive coverage. For immediate and localized communication, a 433 MHz RF module is used to establish direct links between vehicles. When an emergency event is detected, the sender unit transmits an alert signal containing essential information such as event type and vehicle status. This signal is received by nearby vehicles equipped with the receiver unit, enabling instant awareness without dependence on internet connectivity.

Upon receiving the RF signal, the Arduino Nano processes the data and activates the alert mechanisms. A buzzer generates an audible warning to capture the driver's attention, while an LCD display provides visual information about the alert. This dual-alert system ensures that the driver can respond promptly to potential hazards. The simplicity of RF communication makes it cost-effective and suitable for real-time applications, although it is primarily limited to short-range communication. To overcome this limitation, the system also incorporates IoT-based communication for long-range data transmission.

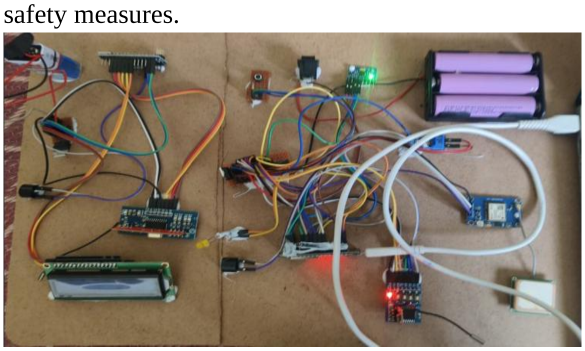
The ESP32 connects to a cloud platform, enabling remote monitoring, data storage, and notification services. In the event of an accident, the system sends alerts to predefined users or emergency contacts through the IoT platform, along with real-time location data. This facilitates quicker emergency response and improved coordination. The integration of RF and IoT communication creates a hybrid model that combines low-latency local alerts with wide-area connectivity. This approach enhances system reliability, ensures redundancy, and provides a comprehensive communication solution for intelligent transportation systems.

V. RESULTS AND DISCUSSIONS



The developed IoT-based communication system for electric vehicle fleet was successfully implemented and evaluated under different operating conditions to analyze its performance, reliability, and effectiveness. The system demonstrated accurate real-time data acquisition from multiple sensors, including GPS for location tracking, MPU6050 for motion analysis, and voltage sensors for battery monitoring. The integration of these components enabled continuous monitoring of vehicle parameters, ensuring that critical information was readily available for processing and transmission. The GPS module provided consistent and precise location data, which was effectively transmitted to the cloud platform, allowing remote tracking and visualization.

The accident detection mechanism was tested by simulating sudden impacts and abnormal motion conditions. The MPU6050 sensor accurately detected abrupt changes in acceleration and orientation, triggering emergency alerts within a minimal response time. The system successfully differentiated between normal driving conditions and critical events by applying threshold-based filtering techniques. Additionally, the emergency push button functioned reliably, allowing manual alert activation when required. The inclusion of AI-based object detection using MobileNet SSD enhanced environmental awareness by identifying nearby vehicles and pedestrians in real time, contributing to proactive safety measures.



The RF-based vehicle-to-vehicle communication system exhibited low latency and reliable performance within its operational range. Alerts transmitted from the sender unit were promptly received by the receiver unit, where the Arduino Nano processed the signal and activated both visual and audible warnings. The buzzer effectively captured driver attention, while the LCD display provided clear and concise information about the alert. This ensured that drivers could take immediate action to avoid potential hazards. The system performed consistently even in scenarios where internet connectivity was unavailable, highlighting the effectiveness of RF communication as a backup mechanism.

The IoT integration using a cloud platform enabled remote monitoring and real-time notification capabilities. Data related to vehicle location, battery status, and emergency events was successfully transmitted and visualized, demonstrating the system's ability to support fleet management and emergency response. Notifications sent through the IoT platform ensured that concerned authorities or users were informed without delay. The hybrid communication model, combining RF and IoT, proved to be robust and reliable, offering both local and global connectivity.

Overall, the results indicate that the proposed system significantly improves vehicle safety, reduces response time during emergencies, and enhances communication between vehicles. The system's cost-effectiveness, scalability, and real-time performance make it suitable for practical implementation in smart transportation systems. However, limitations such as RF range constraints and dependency on sensor calibration were observed, suggesting areas for further improvement. Despite these challenges, the system demonstrates strong potential for enhancing road safety and supporting next-generation electric vehicle ecosystems.

VI. CONCLUSION

This research presents the design and implementation of an IoT-based communication system for electric vehicle fleet to improve road safety, real-time monitoring, and emergency response. The system integrates embedded sensors, RF-based vehicle-to-vehicle communication, and cloud-based IoT platforms for intelligent transportation. Using components such as the ESP32 microcontroller, MPU6050 sensor, GPS module, and voltage sensor, it monitors vehicle conditions, detects accidents, and tracks location in real time. AI-based object detection further enhances safety by identifying road obstacles and risks.

Experimental results show that the system accurately detects abnormal events and sends alerts with low delay. The RF module enables reliable local communication without internet access, while the IoT platform supports remote monitoring and instant notifications. This hybrid approach improves reliability and coverage.

Overall, the proposed system is cost-effective, scalable, and practical for real-world use, especially in developing regions. It helps reduce accident risks, improve emergency response time, and supports the growth of smart mobility solutions.

VII. FUTURE WORK

Although the proposed system shows promising results, several improvements can enhance its performance and applicability. Future development can include advanced communication technologies such as 5G and C-V2X for higher speed, lower latency, and better scalability, enabling large-scale smart city deployment. Edge computing can also be added for faster local processing and reduced cloud dependency.

The AI capabilities can be improved using advanced deep learning models for better object detection, driver behavior analysis, and accident prediction. Additional sensors like LiDAR or ultrasonic sensors can further improve environmental awareness. Optimizing power consumption and hardware efficiency will also support long-term use in electric vehicles.

Security and privacy should be strengthened through encryption and secure communication protocols. Blockchain can be explored for tamper-proof vehicle communication. Integration with emergency services and traffic management systems can further increase real-world usefulness, creating a smarter and more reliable transportation system.

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