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Vehicle-to-Vehicle Communication System for Accident Detection

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Abstract: ***This paper presents the design and implementation of a Vehicle-to-Vehicle (V2V) communication system for real-time accident detection and alert generation using embedded technology. The proposed system integrates an Arduino Nano microcontroller with sensors and communication modules such as MPU6050, GPS, GSM, and NRF24L01 to monitor vehicle motion, detect accidents, and transmit critical information. The MPU6050 sensor detects sudden changes in acceleration to identify accident conditions, while the GPS module provides precise location and speed data. Upon detection of an accident, the system automatically sends an emergency alert message via GSM to predefined contacts and simultaneously transmits warning data to nearby vehicles using NRF communication. The receiver unit processes the incoming data, displays it on an LCD, and activates a buzzer for immediate alert. The system is designed to operate in real time with minimal human intervention, ensuring faster emergency response and improved road safety. Experimental results demonstrate the reliability and effectiveness of the proposed system in detecting accidents and providing timely alerts, making it a cost-effective solution for intelligent transportation systems.***

Keywords: Vehicle-to-Vehicle (V2V) Communication, Accident Detection, Arduino Nano, MPU6050 Sensor, GPS Module, GSM Module, NRF24L01, Wireless Communication, Real-Time Monitoring, Intelligent Transportation System.

I. INTRODUCTION

The rapid increase in the number of vehicles on roads has led to a significant rise in traffic congestion and road accidents, resulting in serious injuries, loss of life, and economic damage. One of the major challenges in accident management is the delay in detecting accidents and providing timely medical assistance. In many cases, victims are unable to communicate their situation, which further increases the risk of fatalities. Therefore, there is a strong need for an automated system that can detect accidents in real time and instantly notify emergency services and nearby vehicles. With the advancement of embedded systems and wireless communication technologies, intelligent transportation systems (ITS) have emerged as an effective approach to enhance road safety and reduce accident-related risks. This paper proposes a Vehicle-to-Vehicle (V2V) communication-based accident detection and alert system using Arduino Nano, MPU6050 sensor, GPS module, GSM module, and NRF24L01 transceiver. The system continuously monitors vehicle motion and detects sudden changes in acceleration to identify accident conditions. Upon detection, it automatically sends an alert message containing location and speed information via GSM, while simultaneously transmitting warning signals to nearby vehicles using NRF communication. The receiver unit processes the received data, displays it on an LCD, and activates a buzzer to alert drivers. The proposed system aims to reduce emergency response time, improve communication between vehicles, and provide a cost-effective solution for enhancing road safety.

II. LITERATURE REVIEW

Several research works have been carried out in the field of accident detection and vehicle safety systems using embedded and communication technologies. Early systems focused on basic accident detection using sensors and manual alert mechanisms. With the advancement of microcontrollers, researchers developed automated systems using platforms such as Arduino to detect accidents based on vibration or impact and send alerts through GSM modules. These systems significantly reduced human intervention and improved response time, but were limited to single-vehicle monitoring without communication with nearby vehicles. Recent studies have explored the integration of GPS and GSM technologies to provide real-time location tracking along with accident alerts. Such systems are capable of sending SMS notifications containing coordinates of the accident site, enabling faster emergency response. Furthermore, sensor-based approaches using accelerometers and MEMS devices, such as MPU6050, have been widely used for detecting sudden changes in motion and improving accuracy in accident identification. However, these systems often face challenges such as false triggering due to road conditions and dependency on network availability.

With the emergence of intelligent transportation systems (ITS), more advanced solutions have been proposed using Internet of Things (IoT) and wireless communication technologies. IoT-based accident detection systems allow real-time data transmission to cloud platforms for monitoring and analysis. Additionally, Vehicle-to-Vehicle (V2V) communication using wireless modules like NRF24L01 has been introduced to enable direct communication between vehicles, helping to prevent secondary accidents. Despite these advancements, there is still a need for a cost-effective, real-time, and reliable system that combines accident detection with immediate alert generation and inter-vehicle communication, which is addressed in this proposed work.

III. METHODOLOGY

The proposed Vehicle-to-Vehicle (V2V) communication system is designed to detect accidents in real time and generate immediate alerts using embedded hardware and wireless communication technologies. The system is divided into two main units: the transmitter unit installed in the vehicle and the receiver unit placed in a nearby vehicle or monitoring system. The transmitter unit is responsible for sensing, processing, and transmitting data, while the receiver unit handles data reception, display, and alert generation.

In the transmitter unit, an Arduino Nano is used as the central controller to interface with all components. The MPU6050 sensor continuously monitors acceleration and motion of the vehicle. The GPS module provides real-time location and speed data. These inputs are processed by the microcontroller to detect abnormal conditions. If the acceleration exceeds a predefined threshold, the system identifies it as an accident. Upon detection, the GSM module sends an SMS alert containing location and speed details to a predefined mobile number. Simultaneously, the NRF24L01 module transmits accident data wirelessly to nearby vehicles.

The receiver unit consists of an Arduino Nano, NRF24L01 module, LCD display, and buzzer. The NRF module continuously listens for incoming data from the transmitter. Once data is received, the microcontroller processes it and displays relevant information such as accident status and location on the LCD. If an accident signal is detected, the buzzer is activated to provide an immediate audio alert. The system operates in real time, ensuring quick communication and response. This methodology ensures efficient accident detection, fast alert generation, and improved road safety through inter-vehicle communication.

IV. IMPLEMENTATION

The proposed Vehicle-to-Vehicle (V2V) communication system was implemented using Arduino Nano and various hardware modules including MPU6050 sensor, GPS module, GSM module, NRF24L01 transceiver, LCD display, buzzer, and a buck converter. The system was developed in two separate units: the transmitter unit and the receiver unit. All components were assembled on a breadboard and powered using a regulated 5V supply to ensure stable operation.

In the transmitter unit, the Arduino Nano was interfaced with the MPU6050 sensor using the I2C protocol to continuously monitor acceleration values. The GPS module was connected using SoftwareSerial communication to obtain real-time location and speed data. The GSM module was also connected via SoftwareSerial to send SMS alerts during accident conditions. The NRF24L01 module was interfaced using SPI communication for wireless data transmission. The Arduino program was developed using Arduino IDE, where all sensors and modules were initialized, and accident detection logic was implemented using predefined threshold values.

The receiver unit was implemented using another Arduino Nano connected with the NRF24L01 module to receive transmitted data. A 16×2 LCD display with I2C interface was used to show the received information, such as accident status and location. A buzzer was connected to a digital pin to provide an audible alert when an accident signal was detected. The receiver continuously listened for incoming data, and upon receiving accident information, it activated the buzzer and displayed warning messages.

The system was tested under different scenarios including normal driving and simulated accident conditions. Proper calibration of sensor thresholds was performed to reduce false detection. The implementation successfully demonstrated real-time accident detection, wireless communication between vehicles, and immediate alert generation, confirming the effectiveness of the proposed system.

V. RESULTS AND DISCUSSION

The proposed Vehicle-to-Vehicle (V2V) communication system for accident detection and alert was successfully implemented and tested using Arduino Nano and integrated modules such as MPU6050, GPS, GSM, NRF24L01, LCD, and buzzer. During normal driving conditions, the system continuously monitored vehicle parameters like acceleration, speed, and location without triggering any false alerts. The MPU6050 sensor recorded stable values within the defined threshold, and the LCD displayed real-time data indicating a safe driving condition. The GPS module provided accurate location details under open sky conditions, and the system maintained smooth communication between transmitter and receiver units.

When an accident was simulated by introducing sudden impact or abnormal acceleration, the system successfully detected the condition based on predefined threshold values. Immediately, the GSM module sent an SMS alert containing location and speed details to the predefined mobile number. At the same time, the NRF24L01 module transmitted accident data to the receiver unit, where the LCD displayed the warning message and the buzzer was activated to provide an audible alert. The system responded quickly with minimal delay, demonstrating effective real-time operation. Although minor limitations such as GSM network dependency and GPS signal delay were observed, the overall performance was reliable. The results confirm that the system is capable of detecting accidents accurately and providing timely alerts, making it suitable for enhancing road safety.

Table.1.Comparison of System Parameters Under Normal and Accident Conditions

Parameter	Normal Condition	Accident Condition
GPS Output	Active (Location Shown)	Active (Location Shown)
System Status	SAFE / Normal Drive	Accident detected
GSM Alert	Not Sent	SMS Sent to Emergency Contact
NRF Communication	Normal Data Transfer	Accident Data Transmitted
Buzzer	OFF	ON
LCD Display	Normal Drive	Accident Warning

VI. APPLICATIONS

The proposed Vehicle-to-Vehicle (V2V) accident detection and alert system can be applied in various real-world scenarios to improve road safety and emergency response. It can be integrated into private and commercial vehicles to automatically detect accidents and send immediate alerts with location details to emergency contacts. The system is useful for public transportation such as buses and taxis to enhance passenger safety. It can also be used in fleet management systems to monitor vehicles and respond quickly during emergencies. Additionally, it supports smart transportation and intelligent traffic systems by enabling communication between vehicles to prevent secondary accidents. Overall, the system provides a cost-effective solution for reducing accident impact and improving timely assistance.

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VII. LIMITATIONS AND FUTURE WORK

A. Current Limitations

The proposed Vehicle-to-Vehicle (V2V) accident detection and alert system, although effective, has certain limitations that may affect its performance under specific conditions. One of the major limitations is the dependency on GSM network availability for sending SMS alerts. In areas with poor network coverage, such as remote locations or tunnels, there may be delays or failure in message delivery. Similarly, the GPS module requires a clear view of the sky to provide accurate location data, and its performance may degrade in dense urban areas or indoor environments. Another limitation is the restricted communication range of the NRF24L01 module, which is suitable only for short-distance vehicle-to-vehicle communication. This limits the system's ability to alert vehicles beyond a certain range. Additionally, the MPU6050 sensor may sometimes generate false accident detections due to sudden braking, road bumps, or rough driving conditions if threshold values are not properly calibrated. The system also depends on a stable power supply, and fluctuations in voltage can affect the performance of sensitive modules.Furthermore, the system currently provides only basic alert functionality without advanced features such as real-time cloud monitoring, data storage, or integration with emergency services. Despite these limitations, the system serves as a cost-effective and efficient solution, and these challenges can be addressed in future enhancements.

B. Future Enhancements

The proposed Vehicle-to-Vehicle (V2V) accident detection and alert system can be further enhanced by integrating advanced technologies to improve performance and scalability. The system can be connected to Internet of Things (IoT) platforms for real-time cloud monitoring and data storage, allowing remote access and analysis. A dedicated mobile application can be developed to provide instant alerts, live tracking, and user-friendly interaction. The use of artificial intelligence and machine learning can enable predictive accident detection based on driving patterns and environmental conditions. Additionally, replacing the NRF module with advanced communication technologies such as 5G or VANET can extend communication range and reliability. Integration with emergency services for automatic calling, along with smart traffic management systems, can further reduce response time. These enhancements will make the system more efficient, intelligent, and suitable for modern smart transportation systems.

VIII. CONCLUSION

This paper presented the design and implementation of a Vehicle-to-Vehicle (V2V) communication-based accident detection and alert system using embedded technologies. The system integrates an Arduino Nano with MPU6050 sensor, GPS module, GSM module, and NRF24L01 transceiver to enable real-time monitoring, accident detection, and communication. The MPU6050 sensor effectively detects sudden changes in acceleration to identify accident conditions, while the GPS module provides accurate location and speed information. Upon detection of an accident, the system successfully sends alert messages via GSM and transmits warning signals to nearby vehicles using wireless communication.

The receiver unit processes the received data, displays it on an LCD, and activates a buzzer to alert drivers, thereby helping to prevent further collisions. The system operates with minimal human intervention and demonstrates reliable performance during testing under different conditions. Overall, the proposed solution provides a cost-effective and efficient approach to improving road safety by reducing emergency response time and enhancing communication between vehicles. The system also offers a strong foundation for future advancements in intelligent transportation systems.

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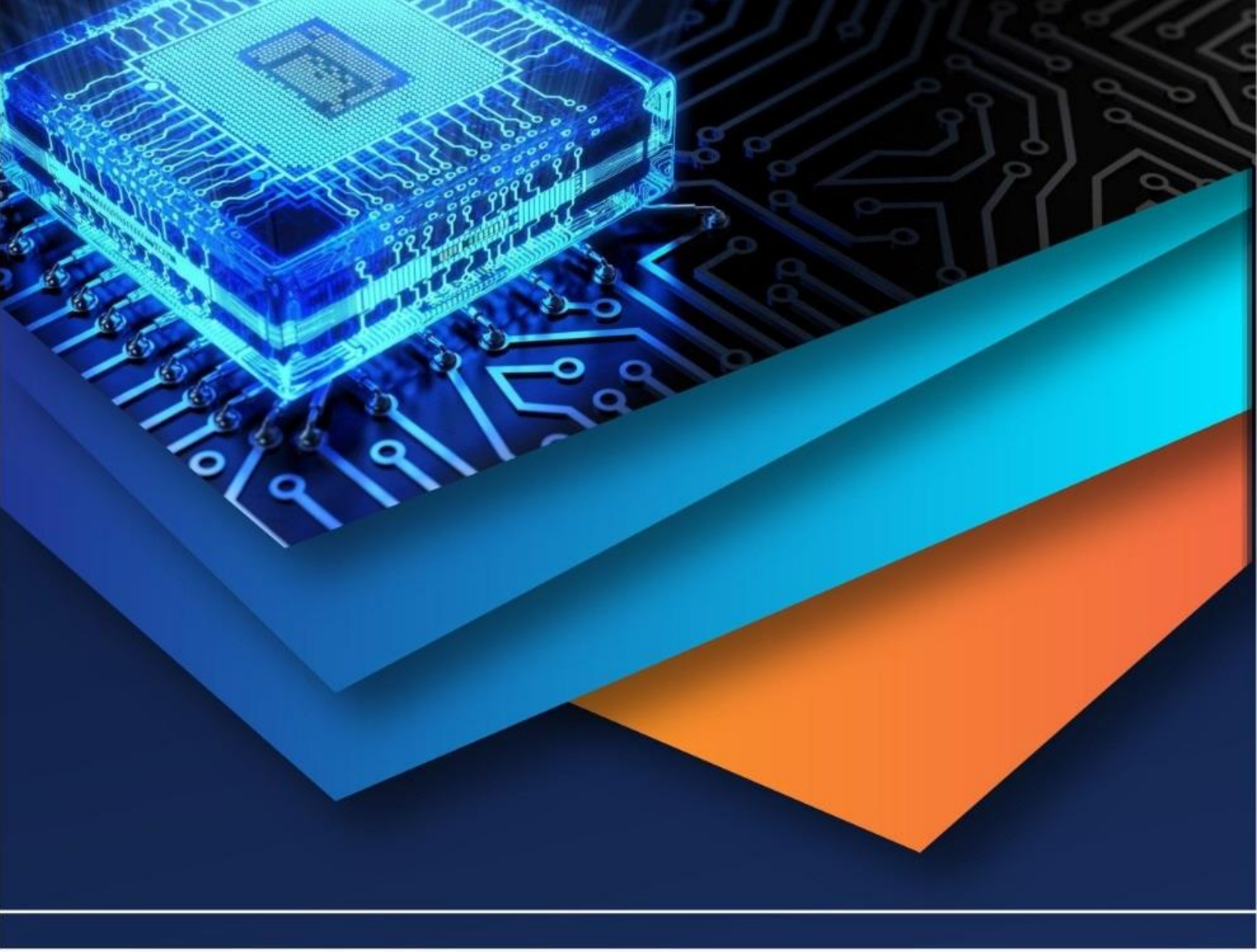

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