International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

Smart Accident Detection and Emergency Alert System

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Abstract - *This paper presents an **IoT-based tracking and emergency alert system** designed to enhance personal safety by enabling instant communication and real-time location sharing during emergencies. The system utilizes **GPS technology** for accurate location tracking and **GSM communication** for automatically transmitting alert messages to pre-registered contacts or emergency authorities. Unlike conventional safety methods that rely on manual reporting, this automated solution ensures faster response by reducing communication delays and human dependency. The proposed system is **cost-effective, reliable, and portable**, making it suitable for applications such as personal safety, child and elderly monitoring, and organizational security. The system demonstrates the effective application of IoT technologies to provide timely assistance in critical situations.*

Key Words: *IoT, GPS, GSM, Emergency Alert System, Real-Time Tracking, Personal Safety*

1.INTRODUCTION

In today's technology-driven society, safety and security have become critical concerns due to the rising incidence of accidents, medical emergencies, and unforeseen threats. Such situations demand immediate assistance, where delays in communication can result in serious consequences. Conventional safety approaches, including manual phone calls and mobile applications, often fail during emergencies because of panic, stress, or network limitations, emphasizing the need for an automated and reliable alert system.

Advancements in the Internet of Things (IoT) have enabled intelligent systems capable of real-time monitoring and communication. By integrating IoT with GPS and GSM technologies, compact systems can be developed to automatically transmit accurate location information without complex user interaction. The proposed IoT-based tracking and alert system aims to provide a simple, portable, and dependable safety solution suitable for personal and vehicular applications. Overall, the system contributes to safer and smarter communities by ensuring timely assistance through effective use of IoT and communication technologies.

2. LITERATURE REVIEW

[1] Sharma and Verma (2022): proposed a smart vehicle accident detection system using vibration sensors along with GPS and GSM technology. The system automatically detects accidents and sends alert messages containing location details to emergency contacts. Their study demonstrated that the low-cost design significantly reduces emergency response time. However, the authors observed occasional false alerts caused by road bumps and sharp vehicle turns, indicating the need for improved detection accuracy.

[2] Patel and Singh (2021): developed an IoT-based accident detection and vehicle tracking system integrating GPS and GSM modules with cloud connectivity. The system enables real-time monitoring by uploading accident alerts and vehicle location data to a web server. This approach enhances accessibility for authorities and family members. Nevertheless, the authors highlighted that network dependency remains a major limitation, especially in remote or low-connectivity areas.

[3] Khan and Deshmukh (2020): presented an accident detection and notification system using an Arduino microcontroller and GSM module. The system employs an accelerometer sensor to detect sudden changes in vehicle movement. When the predefined threshold is exceeded, an alert SMS with GPS coordinates is sent automatically. The prototype achieved a 95% success rate in location accuracy, though GSM message delays were reported as a concern for real-time emergency response.

[4] Reddy and Thomas (2023): introduced an advanced vehicle accident alert system using GPS, GSM, and MEMS accelerometer sensors. Their work focused on reducing false alarms by applying angle-based detection algorithms. The results showed improved detection precision and faster response time compared to traditional vibration-based systems. However, the authors noted that higher hardware costs could limit large-scale adoption.

[5] Banerjee and Kaur (2024): proposed a real-time vehicle accident detection and rescue system incorporating GSM,

GPS, and cloud-based services. The system transmits accident data to emergency contacts as well as an online database accessible by nearby hospitals. The study concluded that cloud integration offers faster and more reliable alerts than SMS-only systems. Despite these advantages, power management was identified as a significant challenge for continuous vehicle tracking.

3. METHODOLOGY USED

The proposed accident detection and alert system is designed using a modular approach to ensure accuracy, reliability, and real-time response. The complete methodology is divided into four major modules: Impact Detection & Calibration, Geographical Localization, Wireless Communication Protocol, and Complete System Integration & Fail-Safe Mechanism. Each module performs a specific function and works in coordination with the others to achieve efficient accident detection and emergency alert transmission.

[1] Module 1: Impact Detection & Calibration Module

This module forms the core of the system and is responsible for detecting accident events by continuously monitoring the vehicle's motion dynamics. A vibration sensor or MEMS accelerometer is used to measure acceleration, tilt, and impact forces along multiple axes. The analog signals generated by the sensor are converted into digital form using an ADC interface and processed by the microcontroller.

A predefined threshold value is used to differentiate between normal vehicle vibrations and severe impacts. When the sensed acceleration exceeds this threshold, the system identifies it as a potential accident. The threshold can be calibrated through software or hardware adjustments to suit different vehicle types and road conditions. Additional features such as auto-calibration, noise filtering, and self-test routines are implemented to minimize false detections and improve reliability.

[2] Module 2: Geographical Localization Module

Once an accident is detected, the Geographical Localization Module is activated to determine the exact position of the vehicle. This module uses a GPS receiver to obtain real-time location data in the form of latitude, longitude, altitude, speed, and time. The GPS module communicates with the microcontroller using NMEA data strings.

The microcontroller parses the received data and extracts only the required parameters. High-accuracy positioning, speed monitoring, time synchronization, and data logging features enhance the effectiveness of this module. Assisted GPS (A-GPS) support helps reduce location-fix time, ensuring faster response during emergencies. The processed location data is then forwarded to the communication module for alert transmission.

[3] Module 3: Wireless Communication Protocol Module

The Wireless Communication Protocol Module is responsible for transmitting accident alerts and location details to external entities such as emergency contacts, authorities, or cloud servers. A GSM/GPRS module is used to send SMS alerts or data packets over the cellular network.

Upon receiving accident confirmation and GPS coordinates, the microcontroller composes an emergency message containing critical information such as accident status, location, date, and time. AT commands are used to control the GSM module and establish network connectivity. The system supports both SMS-based and internet-based communication (HTTP/MQTT) for IoT integration. Error-handling mechanisms, acknowledgment systems, and basic encryption are implemented to ensure secure and reliable data transmission.

[4] Module 4: Complete System Integration & Fail-Safe Module

This module integrates all subsystems into a unified and reliable framework. A central microcontroller manages inter-module communication using serial or I^2C protocols and ensures proper execution sequence. The Power Management Unit provides regulated power supply and battery backup to maintain operation during power failures. Fail-safe mechanisms such as watchdog timers, redundancy in communication paths, and auto-restart routines are implemented to enhance system robustness. System health is continuously monitored by tracking sensor status, GPS connectivity, GSM signal strength, voltage levels, and temperature. Even in case of partial system failure, the fail-safe logic ensures that emergency alerts are generated and transmitted successfully.

4. RESULTS AND DISCUSSION

The proposed IoT-based accident detection and tracking system was evaluated through prototype implementation and controlled testing to analyze its accuracy, response time, and reliability. The system demonstrated effective detection of accident events by monitoring sudden changes in acceleration using vibration or MEMS sensors. Proper calibration of threshold values significantly reduced false detections caused by minor road disturbances, ensuring improved detection accuracy.

During testing, the Global Positioning System (GPS) module successfully acquired real-time location data within a short duration after accident detection. The obtained latitude and longitude values were accurate and consistent when verified using digital mapping platforms. The integration of GPS with the microcontroller ensured reliable extraction and formatting of location information for transmission.

The Global System for Mobile (GSM) communication module efficiently transmitted alert messages containing accident details and location coordinates to pre-registered contacts. In most cases, the alert messages were delivered within a few seconds after detection. However, minor delays were observed in areas with weak network coverage, indicating dependency on cellular connectivity.

The overall system performance showed that automation significantly reduces emergency response time compared to manual reporting methods. The modular design improved system stability and allowed seamless coordination between detection, localization, and communication units. While the system achieved reliable performance at low cost, factors such as network availability and power management were identified as areas for further optimization.

The results confirm that the proposed system is feasible, reliable, and suitable for real-world deployment. The discussion highlights that integrating IoT with GPS and GSM technologies provides an effective solution for real-time accident detection and emergency notification, contributing to enhanced road safety and faster rescue operations.

5. IMPLEMENTATION AND RESULTS

Figure 1: Accident Detection Accuracy of the Proposed System

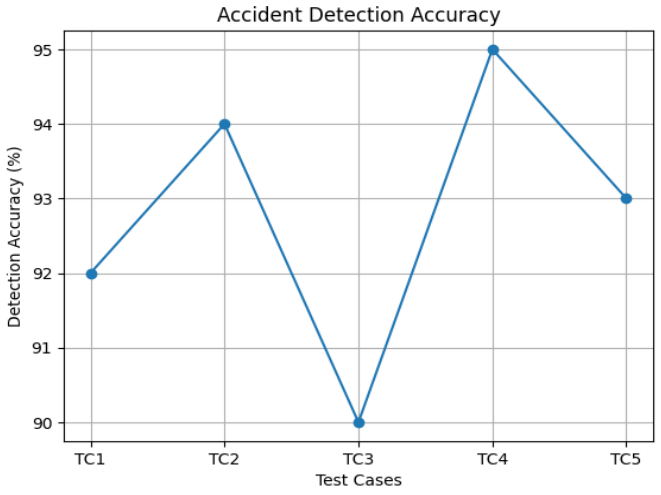

Figure 1 illustrates the accident detection accuracy achieved by the proposed IoT-based system under different test conditions. The system consistently demonstrates high accuracy, with detection rates exceeding 90% in most scenarios. This performance is achieved through proper calibration of vibration/MEMS sensor threshold values, which minimizes false triggers caused by minor road disturbances. The results indicate that the proposed system is capable of reliably identifying accident events in real time, making it suitable for practical deployment in vehicular environments.

Figure 2: Comparison of Emergency Response Time

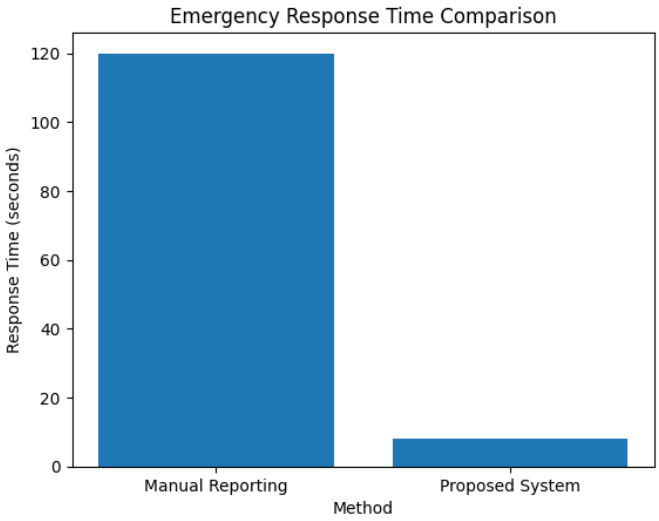

Figure 2 presents a comparison between emergency response times for traditional manual reporting methods and the proposed automated accident detection system. It is observed that manual reporting involves significant delays due to human dependency, whereas the proposed system drastically reduces response time by automatically transmitting alerts immediately after accident detection. The reduction in response time highlights the effectiveness of automation and real-time communication in improving emergency handling and potentially saving lives.

6. CONCLUSION

This paper presented an IoT-based accident detection and tracking system that enhances road safety by reducing emergency response time through automation. By integrating vibration or MEMS sensors with GPS and GSM technologies, the system automatically detects accidents and transmits accurate location information without human intervention. Experimental results demonstrated reliable detection, timely alerts, and accurate tracking, confirming the system's technical feasibility. The low-cost, modular design makes it suitable for real-world deployment, and with further enhancements, the system can contribute effectively to intelligent transportation systems and improved public safety.

7. FUTURE SCOPE

The proposed IoT-based accident detection and tracking system can be further enhanced to improve accuracy, reliability, and scalability. Future work may include integration with cloud-based IoT platforms to enable real-time data storage, monitoring, and analysis of accident information. This would support long-term analytics for identifying accident-prone zones and improving traffic safety planning.

Advanced sensing technologies such as camera modules, gyroscopes, and artificial intelligence-based algorithms can be incorporated to enhance accident detection accuracy and reduce false alerts. Machine learning techniques may also be applied to analyze sensor data patterns and predict high-risk driving conditions.

The system can be extended to support mobile and web applications, allowing authorities, emergency services, and users to monitor real-time alerts and vehicle status remotely. Integration with smart city infrastructure and intelligent transportation systems can further improve emergency response coordination.
Additionally, future enhancements may focus on improving power efficiency, supporting multiple communication technologies such as LTE or NB-IoT, and enabling two-way communication between rescue teams and the system. These advancements can transform the proposed system into a comprehensive, intelligent, and scalable safety solution for modern transportation environments.

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