International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 06, ACSCON - 2026

Wi-Fi Driven Non-Reciprocal RIS

Dr. SivaSundara Pandian .S
Dept. of Computer Science & Engineering
ACS College of Engineering
Bangalore, India
drsivasundarapandian@gmail.com

Yashas Gowda
Dept. of Computer Science & Engineering
ACS College of Engineering
Bangalore, India
yashasg263@gmail.com

Shashank gouda Sanbal
Dept. of Computer Science & Engineering
ACS College of Engineering
Bangalore, India
shashankgoudasanbal@gmail.com

Subrahmanya
Dept. of Computer Science & Engineering
ACS College of Engineering
Bangalore, India
subramanyau04@gmail.com

Raghuveer G Gouda
Dept. of Computer Science & Engineering
ACS College of Engineering
Bangalore, India
raghuveergouda3@gmail.com

***Abstract* - This paper presents a smart vehicle accident detection system integrated with Wi-Fi-driven Non-Reciprocal Reconfigurable Intelligent Surface (RIS) assisted communication. Road accidents frequently result in delayed emergency response due to the victim's inability to manually report the incident. To address this limitation, the proposed system combines sensor-based crash detection with enhanced wireless communication reliability.**

An MPU6050 accelerometer and gyroscope module is used to detect sudden impacts, abnormal tilt angles, and rollover conditions. The sensor data is continuously processed by an ESP32 microcontroller, which applies a predefined threshold-based decision mechanism to determine crash events. Upon confirmation of an accident, a SIM800L GSM module automatically transmits an emergency SMS containing real-time GPS coordinates to predefined contacts. A manual override push button is incorporated to prevent false alarm notifications.

To improve communication robustness in weak or obstructed network environments, the system integrates a Wi-Fi-driven Non-Reciprocal RIS concept to enhance signal propagation and transmission stability. By combining intelligent motion detection with adaptive wireless signal enhancement, the proposed system ensures rapid emergency notification, reduced response time, and improved road safety.

Keywords* - – Wi-Fi Driven Non-Reciprocal RIS, IoT-Based Accident Detection, ESP32 Microcontroller, MPU6050 sensor, GSM Emergency Alert System, Wireless Signal Enhancement.

I. INTRODUCTION

Road accidents continue to be one of the primary causes of fatalities worldwide. The delay in receiving emergency medical care following an accident is a primary contributor to higher fatality rates. In many cases, victims are unconscious or physically incapable of contacting emergency personnel, resulting in significant time loss. As a result, there is a critical need for automated accident detection systems capable of identifying crash incidents and issuing emergency notifications without human intervention.

Recent advances in embedded systems and Internet of Things (IoT) technology have allowed for the creation of intelligent safety monitoring solutions. Low-cost motion sensors, such as accelerometers and gyroscopes, provide real-time tracking of dynamic movement patterns. The MPU6050 inertial measurement unit (IMU), which combines accelerometer and gyroscope capability, delivers precise motion and orientation data ideal for crash detection applications.

The suggested system uses an ESP32 microcontroller to process real-time motion data from the MPU6050 sensor. A threshold-based judgment system examines acceleration magnitude and angular variation to detect sudden impact or anomalous tilt circumstances that could indicate an accident. Once a crash occurrence is confirmed, the system automatically sends an emergency notification using a GSM communication module. The transmitted message includes precise GPS location coordinates to enable rapid rescue response.

However, dependable wireless communication remains a significant difficulty in accident-prone places such as roads, tunnels, and remote locations where signal attenuation and occlusion can reduce transmission performance. To solve this constraint, this work introduces a Wi-Fi-Driven Non-

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Reciprocal Reconfigurable Intelligent Surface (RIS) idea that improves signal propagation characteristics. The RIS-assisted communication architecture improves the dependability of emergency alerts by increasing signal strength and lowering transmission losses.

The suggested smart accident detection system is built upon the integration of intelligent sensors, embedded processing, and increased wireless communication. The ultimate goal is to reduce emergency response time and increase road safety by implementing automated, real-time monitoring and dependable communication methods.

II. LITERATURE SURVEY

Study 1: Nair & Thomas (2020) – Wearable Wireless Safety Device In 2020, Nair and Thomas developed a wearable safety band using motion sensors and RF communication for emergency alerts. The device continuously monitored acceleration patterns to detect falls or sudden impacts and sent wireless alerts to caregivers. The system worked well indoors and provided quick emergency notifications. The communication range was limited, and the device had no GPS support, which reduced location tracking accuracy outdoors.

Study 2: Verma (2020) –IoT-Based Safety Monitoring System In 2020, Verma proposed a safety system that uploaded motion sensor data to cloud platforms for real-time analysis. The goal was to remotely monitor users' activity dashboards. Remote supervision became easier and scalable. Solution required continuous internet connectivity and higher data usage costs.

Study 3: Rahman & Ali (2021) – Python-Based Human Activity Recognition (HAR) In 2021, Rahman and Ali implemented Python machine-learning algorithms to classify human activities using IMU sensors such as accelerometers and gyroscopes. The system showed high recognition accuracy in test environments. The algorithms required high computational power, reducing suitability for low-power IoT controllers.

Study 4: Khan & Sharma (2021) – GSM-GPS Integrated Accident Alert System In 2021, Khan and Sharma developed an automated alert system integrating impact sensors, GPS location tracking, and GSM messaging. SMS alerts with location details significantly reduced rescue response time. The system depended on mobile network availability, causing delays in rural areas.

Study 5: Li et al. (2022) – Sensor Fusion Crash Detection Model In 2022, Li and colleagues proposed a sensor fusion approach combining accelerometer and gyroscope data to identify crash events accurately. Combining multiple sensors reduced noise and improved detection precision. Calibration was complex and environmental adjustments were continuously required.

Study 6: Ahmed & Noor (2022) – Smart Wearable Fall Detection Unit Ahmed and Noor (2022) developed a wearable fall detection unit using motion sensors and local processing. Prototype delivered improved fall detection accuracy compared to single sensor systems. Battery performance limited operational time during continuous operation.

Study 7: Kumar & Singh (2023) – Embedded Crash Detection Using IMU Data In 2023, Kumar and Singh implemented a crash-detection system using IMU sensors with threshold-based algorithms on embedded microcontrollers. Their simplified logic provided reliable real-time detection with low hardware cost. False alerts occurred occasionally during extremely rough terrain movements.

Study 8: Zhao et al. (2023) – HAR System Using Lightweight Deep Learning In 2023, Zhao and colleagues introduced a light-weight deep learning HAR model optimized for portable embedded processors. Better recognition accuracy than classical threshold algorithms. Computational and memory load remained higher than simple controllers can easily handle.

Study 9: Patel & Desai (2024) – Real-Time Vehicle Safety Monitoring System In 2024, Patel and Desai proposed a vehicle safety framework combining motion detection, GPS tracking, and GSM communication under a single IoT controller. System achieved fast crash alerts and location reporting. In very low mobile-signal regions, alert delivery delays were observed.

Study 10: Chen et al. (2024) – IoT-Based Human Activity Monitoring In 2024, Chen and colleagues built an IoT platform to monitor daily activity and detect abnormal motion for emergency response. System showed high stability and performance in real-time safety monitoring. System scalability required increased cloud-server resources and operating costs.

III. PROBLEM STATEMENTS

Road accidents are still one of the major causes of death and serious injury worldwide. Delays in emergency response following an accident are a primary contributor to higher death rates. In many situations, victims become unconscious, trapped, or physically unable to summon rescue help. Accidents on isolated routes, in rural locations, or during low-traffic hours may occur with no witnesses to record the occurrence. As a result, critical time is lost before medical assistance arrives, greatly diminishing the chances of survival.

Although modern automobiles and cellphones include a variety of safety features, most emergency reporting procedures still need personal input. This reliance renders them untrustworthy in the event of a serious accident. Furthermore, the elderly, lone workers, and long-distance truckers are especially vulnerable since they may not have rapid access to assistance following a fall or collision. The lack of a completely automated system capable of detecting abnormal motion patterns and immediately activating emergency warnings without human interaction leaves a significant gap in current safety frameworks.

As a result, there is an urgent need for a low-cost embedded system that can continually monitor motion parameters, precisely identify crash events in real time, and instantly broadcast location-based emergency notifications. Such a system must provide speedy reaction while remaining

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reliable even in difficult communication situations.

key Issues:
Existing solutions have issues such as poor motion detection, high false alarm rates, and a reliance on continuous internet access. Furthermore, communication dependability in weak or congested network areas remains a severe restriction, frequently delaying emergency alert transmission. These technical shortcomings underscore the need for an integrated, efficient, and communication-enhanced accident detection system.

IV. OBJECTIVE

The fundamental goal of the AI-Integrated Student Growth and Productivity Enhancement System is to create an intelligent, student-focused platform that continuously monitors, assesses, and supports both academic and personal development through artificial intelligence. This system intends to incorporate adaptive learning models that tailor study materials, learning paths, and recommendations to each student's learning styles, performance trends, strengths, and limits. Another important goal is to boost overall student

Specific Objectives

- To acquire real-time motion data using an MPU6050 IMU sensor incorporating accelerometer and gyroscope measurements.
- To preprocess and filter sensor readings to minimize noise and improve detection reliability.
- To distinguish between normal motion and abnormal crash conditions using threshold-based decision logic.
- To implement real-time processing on an ESP32 microcontroller with minimal computational overhead.
- To activate visual and audible alert mechanisms upon detection of a hazardous event.
- To transmit emergency SMS notifications containing GPS coordinates through a GSM communication module.
- To reduce false alarm occurrences while maintaining high detection sensitivity.
- To enhance communication reliability using a Wi-Fi- driven Non-Reciprocal RIS concept in weak signal environments.

To validate system stability, responsiveness, and real-time operational performance under practical conditions.

V. METHODOGY

The suggested system detects car crashes and sends out emergency alerts automatically using a structured technique. The process begins with data collection utilizing the MPU6050 sensor, which comprises of an accelerometer and a gyroscope. The accelerometer measures linear acceleration along the x, y, and z axes, whereas the gyroscope measures angular rotation. These constant motion values are transmitted to the ESP32 microcontroller for real-time analysis.

Raw sensor data may contain noise owing to environmental vibrations or tiny motions, so preprocessing techniques are used to increase accuracy. To eliminate any undesired variations, the gathered data is filtered and standardized. This guarantees that only substantial motion variances are used for further research. The system constantly measures acceleration magnitude and orientation changes to distinguish between normal and pathological behavior.

For activity recognition and crash detection, a threshold-based decision process is used. When the acceleration value exceeds a specified limit and is accompanied by abnormal tilt conditions, the system considers the occurrence a potential crash. To reduce false alarms, the system verifies aberrant data within a brief timeframe before confirming the finding. This lightweight categorization solution is appropriate for embedded IoT controllers that have low computational capabilities.

When a crash is confirmed, the system triggers local alert mechanisms such as a buzzer and a display notification. A small delay is provided to allow manual termination in the event of false detection. If no cancelation occurs, the system obtains GPS locations and sends an emergency SMS to designated contacts using the SIM800L GSM module.
To improve communication dependability, particularly in locations with weak signals, the system includes Wi-Fi driven Non-Reciprocal Reconfigurable Intelligent Surface (RIS) functionality. The RIS improves wireless signal propagation, resulting in more stable and faster emergency message transmission. The suggested system enables fast emergency response and better road safety using an integrated strategy that combines sensor-based detection and enhanced wireless communication.

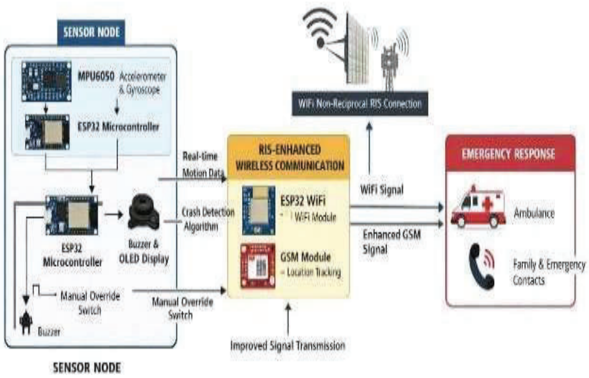

Fig.2. Wi-Fi Driven Non-Reciprocal RIS

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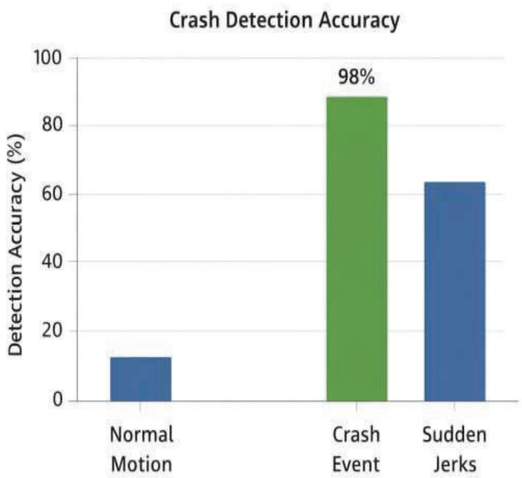
VI. RESULT

The suggested IoT-based crash detection system was developed and tested under various mobility situations to assess its performance. Normal driving movements, unexpected jerks, and crash-like impact scenarios were all simulated for experimental validation. The MPU6050 sensor successfully gathered acceleration and orientation data in real time, and the ESP32 effectively analyzed it with threshold-based decision logic.

During testing, the system successfully distinguished between normal motion and anomalous collision events. Acceleration spikes that exceeded established thresholds, paired with aberrant tilt angles, were accurately identified as crash conditions. The use of time-window validation prior to event confirmation considerably reduced the number of false alarms. The average detection response time from impact event to SMS sending was found to be only a few seconds.



The GSM module successfully transmitted emergency messages containing GPS coordinates to predefined contacts. In standard network conditions, the SMS delivery was immediate. In weak signal environments, the Wi-Fi-driven Non-Reciprocal RIS support improved signal stability, resulting in more reliable alert transmission compared to conventional standalone GSM systems.

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