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A Hybrid Approach for Enhanced V2V Wireless Communication

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Abstract - This project proposes a hybrid V2V communication system using both Wi-Fi and LoRa technologies to enhance the reliability, range, and security of ITS. Traditional V2V systems have to face high mobility, dynamic topology, interference, and limited range. Wi-Fi offers high-speed data transfer but has short coverage, while LoRa is a long-range technology with lower data rates. The hybrid system applies Wi-Fi for short-range and high-speed communication and LoRa for longer-range and more stable links. To further ensure reliability in data transmission, adaptive modulation and coding schemes are adopted to dynamically adjust transmission parameters according to channel conditions.

***Key Words*:** V2V, Wi-Fi, LoRa, Communication, topology, mobility, reliability

1.INTRODUCTION

[1] With the rapid growth of smart transportation systems, Vehicle-to-Vehicle (V2V) communication has become a critical technology to improve road safety, traffic management, and environmental monitoring. [2] V2V systems allow vehicles to share essential information such as speed, location, environmental conditions, and hazard alerts, helping prevent accidents and ensuring smoother traffic flow. This project focuses on developing a hybrid V2V communication system that combines LoRa (Long Range) and Wi-Fi technologies to enable reliable and efficient data exchange between two robotic vehicles. [3] LoRa offers long-range, low-power communication ideal for rural or low-connectivity

environments, while communication suitable for urban settings. [4] Wi-Fi provides high-speed, short-range Each robotic vehicle in the system is equipped with an ESP32 microcontroller and a suite of sensors, including an ADXL345 accelerometer for motion detection, ultrasonic sensors for obstacle detection, BMP180 for temperature and pressure measurement, NEO-6M GPS for location tracking, and a flame sensor for fire hazard detection.[5] Additional safety mechanisms include a panic button to trigger emergency alerts and a DF Player audio module for real- time voice warnings. [6] The system integrates with Google Firebase for cloud-based data storage and connects to a mobile application developed using MIT App Inventor for real-time vehicle monitoring, alert notifications, and data visualization. [7] Vehicle movement is controlled using L293D motor drivers and DC motors, while an I2C LCD display provides on-board status updates. [8] This project demonstrates the feasibility and effectiveness of combining multiple communication technologies and IoT components to create a smart, responsive, and scalable V2V system capable of enhancing both driver and passenger safety.

2. BODY OF THE PAPER

Sec 2.1 OBJECTIVES

1. Develop a hybrid V2V communication system: To design and implement a system that uses both LoRa (for long-range, low-power communication) and Wi-Fi (for short-range, high-speed data transfer) between two robotic vehicles.

2. Integrate multi-sensor data acquisition: To collect and process real-time data from sensors such as the ADXL345 accelerometer, ultrasonic sensors, BMP180 environmental sensor, NEO-6M GPS, and flame sensor for enhanced situational awareness

. 3. Enable real-time alerts and safety mechanisms: To implement emergency features such as a panic button for manual alerts and a DF Player audio module for sound notifications when critical events or hazards are detected.

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4. Provide cloud-based data storage and monitoring: To connect the system to Google Firebase for storing sensor data, event logs, and system status in real time.

5. Develop a mobile application interface: To create a user-friendly app using MIT App Inventor for remote monitoring, receiving notifications, and visualizing vehicle data on a smartphone.

SEC 2.2 METHODOLOGY

The development of the hybrid vehicle-to-vehicle (V2V) communication system follows a structured, stepwise approach as outlined below: The system design and architecture of this project integrate both hardware and software components to enable smart communication between two robotic vehicles. At the core of each vehicle is an ESP32 microcontroller, which serves as the main processor responsible for collecting data from sensors, making decisions, and managing communication. To enable long-distance and low-power data exchange between the vehicles, LoRa modules are used , while the built-in Wi-Fi capability of ESP32 ensures high-speed local communication and connectivity with the cloud database, Google Firebase. Each vehicle is equipped with multiple sensors: the ADXL345 accelerometer for motion and vibration detection, an ultrasonic sensor for obstacle avoidance, a BMP180 sensor for temperature and pressure monitoring, a NEO-6M GPS module for real-time location tracking, and a flame sensor for fire detection. Additional components include the DF Player module for sound alerts, an I2C LCD for displaying system status, and L293D motor drivers for controlling DC motors. In terms of communication flow, sensor data is collected by each vehicle's ESP32, processed, and then exchanged between the vehicles using LoRa. Simultaneously, this data is uploaded to Firebase via Wi-Fi, allowing real-time visualization and monitoring through a mobile application developed using MIT App Inventor. The software development involves writing embedded C/C++ code for the ESP32 to handle sensor readings, data processing, decision-making (such as detecting obstacles or hazards), and managing communication channels. Logic is implemented to trigger panic alerts, play audio warnings through DF Player, and push real-time updates to Firebase. The system is tested in different scenarios, including urban and rural environments, to evaluate the performance of LoRa and Wi-Fi communication. Sensor accuracy, communication reliability, mobile app functionality, and system responsiveness are all validated. Finally, the project is demonstrated by showing the robotic vehicles actively communicating, updating each other about obstacles, environmental conditions, and emergency situations in real time. System performance is analyzed, improvements are identified, and the results are documented for future enhancements.

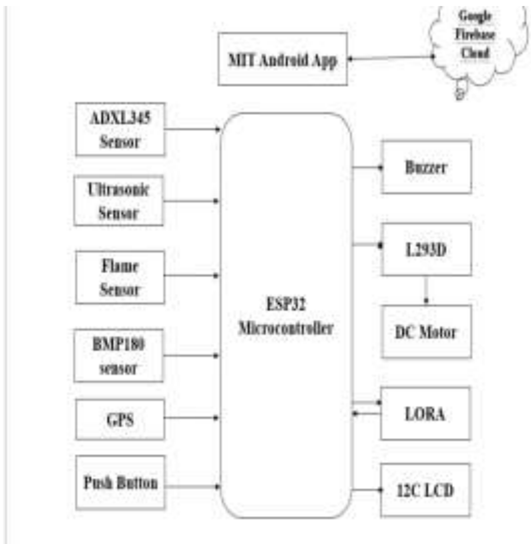

Fig1:Block Diagram of V2V Wireless communication

SEC 2.3 IMPLEMENTATION

The implementation of the hybrid V2V communication system is based on an ESP32 microcontroller, which serves as the central unit, integrating sensing, processing, and communication. Wi-Fi will provide high-speed, short-range data exchange, while LoRa provides long-range, low-power communication, maintaining connectivity continuously. Various sensors, such as ADXL345, ultrasonic, BMP180, and

GPS, are used to measure motion, distance, temperature, and location. An L293D motor driver is used for the vehicle's motion control, while a buzzer is used for safety purposes. It also consists of an LCD that will present real-time data and an MP3 module to provide audio notifications. Communication between vehicles and the monitoring system will be controlled using an Android app built using MIT App Inventor and connected over Google Firebase Cloud. The programming of the system is done in Embedded C using Arduino IDE, and encryption techniques ensure secure data exchange. Dynamic switching between Wi-Fi and LoRa promotes reliability, range, and performance to assist in intelligent transportation by enhancing vehicle coordination and road safety.

Algorithm: ESP32 Multi-Sensor Monitoring and Alert System

1. Initialization Phase

Step 1: Start the system and initialize Serial communication for debugging.

Step 2: Connect the ESP32 to Wi-Fi using the given SSID and password.

Step 3: Initialize Firebase connection using the project host and authentication key.

Step 4: Initialize the LCD display and show the startup message.

Step 5: Initialize all sensors:

- ADXL345 accelerometer
- BMP180 temperature sensor
- GPS module
- Ultrasonic sensor
- Flame sensor

Step 6: Configure motor driver pins and buzzer pin as OUTPUT.

Step 7: Set emergency button pin as INPUT and attach interrupt for emergency alert.

Step 8: Initialize the LoRa communication module for long-range alerts.

2. Main Loop Phase

Step 9: Read the control command from Firebase.

Step 10: If command is:

- 1 → Move Forward
- 2 → Move Backward
- 3 → Turn Left
- 4 → Turn Right
- 5 → Stop the Motor

Update the LCD with the movement status.

Step 11: Check if the emergency button interrupt is triggered.

If triggered:

- Send emergency alert to Firebase
- Turn ON buzzer
- Display "EMERGENCY" on LCD

Step 12: Read GPS data.

If valid → Upload latitude & longitude to Firebase.

If invalid → Upload default coordinates.

Step 13:Read accelerometer values (X, Y, Z).

Display the values on LCD and Serial.

Step 14: Read temperature from BMP180 and update LCD & Firebase.

Step 15: Read flame sensor status.

If flame detected → Set `flame = TRUE` else `FALSE`.

Step 16: Measure distance using the ultrasonic sensor.

Convert echo time to distance in cm.

3. Alert Handling Phase

Step 17: If distance < threshold OR flame detected:

- Create alert message
- Send alert via LoRa
- Update alert status in Firebase

• Activate buzzer

• Display alert message on LCD

Step 18: Check if any LoRa message is received.

If message received:

• Read the packet

• Extract values (distance, flame)

• Display them on LCD

• Turn ON buzzer shortly for notification

4. System Maintenance Phase

Step 19:Refresh Wi-Fi and Firebase connection if disconnected.

Step 20: Clear LCD and update the latest sensor data.

Step 21: Repeat the entire loop continuously.

SEC 2.4 RESULT

The hybrid V2V communication model that integrates Wi-Fi and LoRa delivers a more dependable and effective system for next-generation intelligent transport. Wi-Fi provides rapid, low-delay data exchange for vehicles within close range, while LoRa contributes extended coverage and stronger performance in blocked or distant conditions. When Wi-Fi quality drops because of interference, movement, or environmental obstacles, LoRa automatically maintains the essential safety messaging channel. This dual-radio operation minimizes data loss, prevents communication interruptions, and keeps vehicles continually informed of each other's presence. Testing shows improved reliability, stronger link stability, and more consistent message delivery. Overall, the hybrid approach strengthens road safety, supports uninterrupted V2V communication, and offers a flexible, future-ready framework for connected and autonomous vehicle systems.

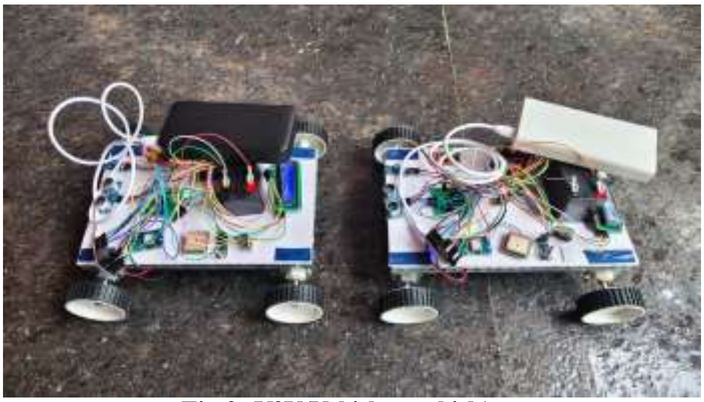

Fig 2: V2V(Vehicle to vehicle) setup

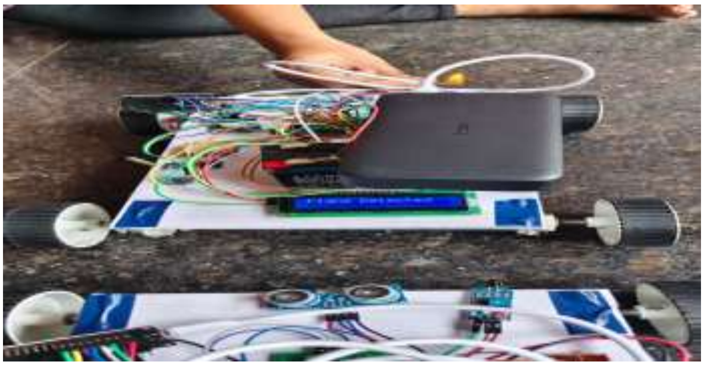

Fig 3:Flame Detected

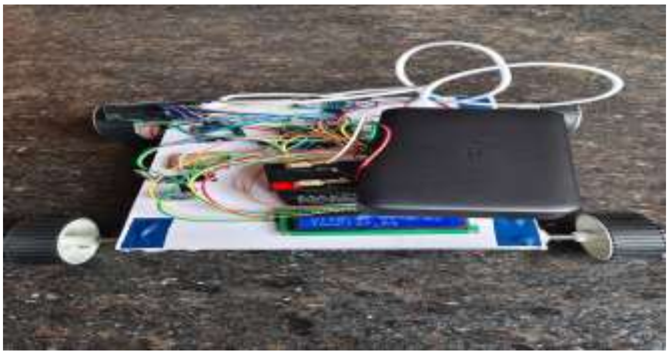

Fig: 4 XY Temp Readings

Fig 5: Alert messages for emergency Situations

3. CONCLUSION

The Vehicle-to-Vehicle (V2V) Communication System using LoRa and Wi-Fi enhances safety, efficiency, and coordination between vehicles. By leveraging advanced technologies such as ESP32, LoRa, GPS, sensors, and cloud integration via Google Firebase, the system allows for real-time data exchange, emergency alerts, and location tracking, ensuring better decision-making in critical situations. This project demonstrates the potential for using affordable and accessible hardware components to create a robust communication network between vehicles, which can be extended to various industries such as automated fleets, smart cities, emergency response, and industrial applications. With a simple, modular design, this system provides a scalable and effective solution for improving vehicular communication, enhancing road safety, and streamlining operations in multiple domains. In conclusion, this project lays the groundwork for more advanced and intelligent transportation systems that will revolutionize how vehicles interact with each other and their surroundings, leading to safer, smarter roads and operations.

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