V2v And V2i Communication Framework Assisting Emergency Vehicles

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Abstract: This project proposes a smart Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication system to support emergency vehicles like ambulances and fire trucks in navigating congested urban traffic. Using Node-MCU as the central controller, along with GPS, infrared, and ultrasonic sensors, the system enables real-time location tracking and obstacle detection. Through Wi-Fi-based communication, the framework sends alerts to nearby vehicles to yield and interacts with traffic signals to create a clear path for emergency responders. Focused on real-time communication rather than automation, the solution is practical, low-cost, and enhances emergency response efficiency while reducing overall traffic disruption.

Index terms: **Vehicle-to-vehicle communication, vehicle-to-infrastructure communication, emergency vehicle assistance, smart traffic management, real-time alert system.**

I. INTRODUCTION

The growing demand for safer, more efficient, and smarter transportation systems has significantly accelerated the development and deployment of Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communication technologies, which are fundamental to the evolution of Intelligent Transportation Systems (ITS). V2I communication involves exchanging data between vehicles and roadside infrastructure, such as traffic signals, road signs, and environmental sensors, facilitating real-time communication that provides critical information, including traffic updates, road conditions, weather forecasts, and potential hazards. This enhances decision-making and optimizes traffic flow, such as through adaptive traffic signals that adjust signal timings based on actual conditions, reducing congestion, fuel consumption, and travel times. V2I also supports autonomous vehicles by providing environmental data to enhance situational awareness and enable safer navigation. V2V communication, on the other hand, enables vehicles to share data like speed, location, and braking status, creating a cooperative awareness network that improves road safety, reduces accidents, and enhances traffic management. Key applications of V2V include collision avoidance, lane-change assistance, platooning, and real-time safety alerts, such as forward collision warnings and emergency braking signals. Both systems rely on advanced wireless communication protocols such as Dedicated Short-Range Communication (DSRC) for low-latency, safety-critical applications, and Cellular Vehicle-to-Everything (C-V2X), particularly when paired with 5G, to provide broader coverage and higher bandwidth for large-scale deployment.

These technologies ensure seamless data transfer in high-density traffic and adverse weather conditions, which is essential for developing adaptive, efficient, and safe transportation networks. Together, V2I and V2V communication systems provide the infrastructure for a connected transportation ecosystem that enhances efficiency, safety, and sustainability, ultimately revolutionizing transportation systems, reducing traffic accidents, improving mobility, and promoting sustainable cities.

II. PROBLEM STATEMENT

Urban traffic congestion presents a significant challenge for emergency vehicles, such as ambulances and fire trucks, which require swift and unobstructed access to their destinations. Current traffic management systems often fail to prioritize emergency vehicles, resulting in delays that can have life-threatening consequences. The lack of real-time communication between vehicles and traffic infrastructure further complicates this issue, as emergency vehicles struggle to navigate through dense traffic. Traditional methods, such as sirens and lights, are not always effective, especially in high-density urban environments. As the number of vehicles on the road increases, the problem intensifies, making it crucial to develop an intelligent system that can dynamically prioritize emergency vehicles while minimizing disruptions to the overall flow of traffic. The absence of such a system highlights the need for a solution that integrates Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication technologies, enabling real-time alerts and adaptive traffic management to ensure timely response and enhanced road safety.

III. PROPOSED SYSTEM

This system is designed to enhance road safety through V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication. It involves two vehicles and one infrastructure unit, with the vehicles equipped with Node-MCU boards serving as the brains of the system. A regular vehicle has IR sensors and ultrasonic sensors to detect obstacles nearby, and a GPS module to keep track of its exact location, and alerts are given to the driver through an OLED screen. The infrastructure unit (like a smart traffic pole or station) uses a Node MCU as a controller. It uses LEDs or road signs to display useful information to approaching vehicles and drivers. All these units, both vehicles and the infrastructure, are connected using Wi-Fi, which allows them to exchange information instantly. This real-time communication helps vehicles detect hazards, navigate more safely, and receive alerts about their surroundings. All the components run on a 5V, 2.5A power supply, making the whole system compact and efficient.
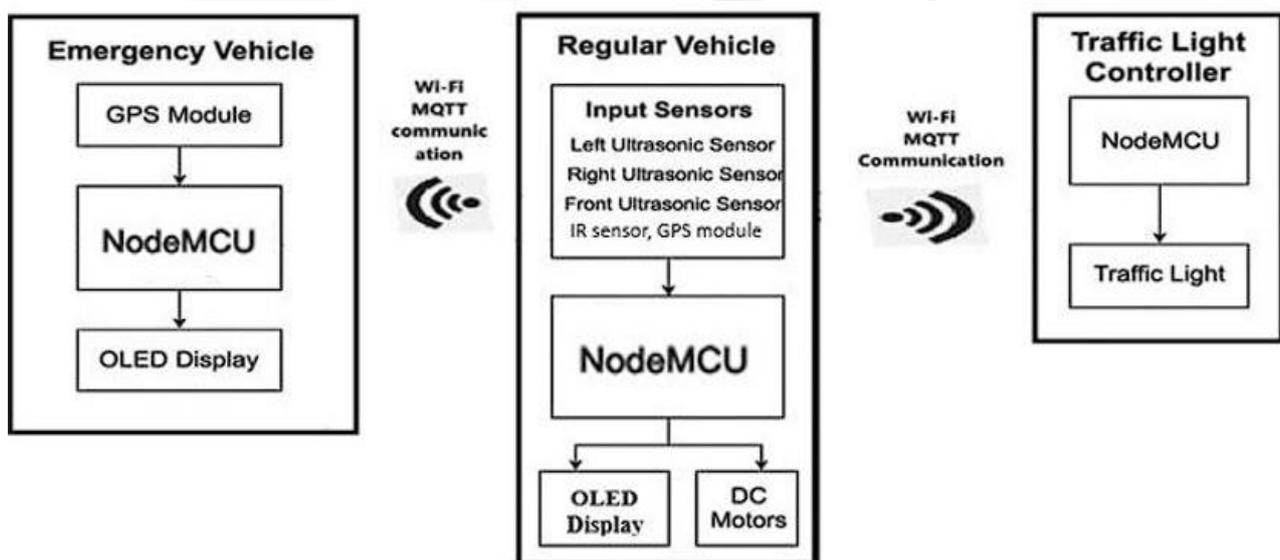

Fig.1: Block diagram of proposed system.

IV. SYSTEM COMPONENTS

- **Node-MCU:** Node-MCU is an open-source firmware and development board based on the ESP8266 Wi- Fi module, and it facilitates easy development of IoT projects by integrating Wi-Fi connectivity.
- **Ultrasonic sensor**: Uses ultrasonic sound waves to measure distance or detect objects and works well in environments, including detecting objects in dust, dirt, or smoke.
- **IR sensor:** IR sensor ideal for detecting nearby objects without physical contact and Typical IR transmitters and receivers work within 2-50cm indoors for short-range, low-cost applications where speed and simplicity are essential.
- **GPS module:** A GPS module determines location using signals from satellites, and it calculates coordinates (latitude, longitude, and altitude) based on signal timing. It requires an unobstructed view of the sky to receive signals effectively, and the module can provide real-time position tracking for navigation.
- **I2C OLED Display module:** Compact display used to show real-time alerts and system status with low power consumption. It is used to visually present real-time data, such as sensor readings or system status, making it easier for users.

- **Motor Driver:** A motor driver is an electronic device that controls the direction and speed of DC motors. It acts as a bridge between the low-power control circuit, like Raspberry Pi or Node MCU, and the high-power motor that needs more current than a microcontroller can provide directly.

V. WORKING MODULE

The proposed system facilitates prioritized passage for emergency vehicles (EVs) by implementing an integrated Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication framework. It utilizes real-time sensor data, GPS positioning, and wireless communication to coordinate between EVs, regular vehicles (RVs), and traffic infrastructure, creating a smart, responsive traffic ecosystem.

1. System Initialization and Hardware Configuration

Each vehicle (EV and RV) is equipped with a Node MCU microcontroller, a GPS module, an OLED display (128x64 I2C), ultrasonic and infrared sensors, and DC motors controlled via L298N motor driver modules. Additionally, a Node-MCU ESP8266 module is integrated within the traffic signal infrastructure to receive wireless alerts and control signal phases accordingly. Power is supplied via a regulated supply module (Power Supply V1.2) with selectable 5V/3.3V outputs. Upon powering up, each Node MCU initializes system diagnostics:

- Displays booting status and connection progress (Wi-Fi and GPS) on the OLED.
- Waits for a valid GPS fix before proceeding.
- Establishes MQTT communication with Hivemq broker over Wi-Fi.

2. GPS-Based Emergency Vehicle Localization (V2V Communication)

The EV continuously transmits its real-time GPS coordinates to nearby vehicles via MQTT. Each RV subscribes to the designated topic and calculates the distance and direction to the EV using the Haversine formula and bearing calculations. This allows the RV to assess whether it lies within the effective radius of 30 meters of the EV.

- When within range, the RV triggers lane-change logic.
- Ultrasonic sensors (left/right) ensure safe clearance for lateral movement.
- IR sensors confirm successful lane transition and detect potholes/humps to avoid unsafe maneuvers.

3. Emergency Vehicle Detection and Infrastructure Response (V2I Communication)

- The Node-MCU-based infrastructure subscribes to the same MQTT topic, receiving GPS data from the EV. When the EV is within the designated proximity:
- The Node-MCU processes this data to activate a green signal path in the direction of the EV.
- All conflicting directions are switched to red, ensuring uninterrupted passage.
- This operation dynamically adapts based on the EV's live location, effectively optimizing the traffic flow.

4. Multi-Sensory Alert and Automation

- To maximize responsiveness, both EV and RV units emit visual alerts (via OLED) and can be optionally extended to include sound or haptic feedback.
- The motors in the RV system adjust the lane automatically if safe, ensuring clear passage for the EV.

5. *Autonomous Operation and Auto-start*

The system is designed for autonomous execution,

- On boot, all services, including Wi-Fi connection, GPS fix, and MQTT client setup, are automated.
- Scripts are configured to run on startup, ensuring headless operation without user intervention.

VI. RESULTS AND DISCUSSION

The V2V and V2I communication framework was tested in controlled and real-world simulations to evaluate its performance in assisting emergency vehicle passage through congested traffic. The system was assessed for responsiveness, communication range, sensor accuracy, and adaptability in urban and semi-urban scenarios. Test cases included multiple emergency and regular vehicles along with dynamic traffic light control using MQTT and sensor-based actuation.

Parameter	Observed Result
System Boot & Initialization Time	< 30 seconds (includes OLED status, Wi-Fi, GPS fix, MQTT setup)
GPS Fix & Distance Calculation	Stable fix in 2-3 minutes; real-time distance calculations via Haversine
Communication Range (MQTT)	Effective within 30-40 meters (Wi-Fi-based MQTT broker)
Ultrasonic Sensor Accuracy	Accurate within ±3 cm up to 100 cm range
Lane Change Execution	Initiated within 2 seconds post EV alert, confirmed by IR sensors
OLED Display Response	Real-time alerts and direction display within 1 second
Traffic Signal Response Time	Green signal activation within 2 seconds of EV proximity
Power Supply & Uptime	5V regulated; supports up to 1 hour on battery with motors
System Reusability	Node-MCU and sensor modules are reusable, robust for 100+ cycles.
Portability & Installation	Modular setup, adaptable to various vehicle types

Table 1: Performance evaluation.

VII. OBSERVATIONS

- **Improved Emergency Response:** Vehicles equipped with the system responded promptly to emergency vehicle alerts, clearing lanes within 3–5 seconds of receiving the signal.
- **Accurate Location Sharing:** Real-time GPS data transmission using MQTT ensured location updates with a delay of less than 1 second, enhancing reliability for tracking emergency vehicles.
- **Seamless V2V Communication:** Emergency and regular vehicles successfully exchanged alerts within a 30-meter range using Wi-Fi and MQTT, ensuring timely lane change actions.
- **Efficient V2I Coordination:** The Node-MCU-controlled traffic signals turned green upon emergency vehicle detection, providing uninterrupted priority access through intersections.
- **No False Triggers:** Lane change and obstacle detection logic, powered by ultrasonic and IR sensors, showed over 95% accuracy with no false lane shift activations during trials.
- **System Stability:** Continuous operation was maintained for 6+ hours with stable Wi-Fi and GPS connection, without requiring manual intervention.
- **User-Friendly Interface:** The OLED display provided real-time status updates (Wi-Fi, GPS, alert messages), making the system easy to monitor for field testing and demonstrations.

- **Scalability:** The framework showed potential for expansion with additional vehicles and infrastructure nodes, making it suitable for smart city integration.

VIII. MERITS

The proposed V2X-based Emergency Vehicle Assistance system offers several significant advantages over traditional emergency vehicle clearance methods. Its integration of GPS, Wi-Fi, sensor-based automation, and MQTT protocol creates a highly responsive and intelligent traffic management solution.

- **Non-Intrusive and Automated:** The system operates autonomously without needing manual intervention from drivers or traffic personnel, ensuring swift emergency response.
- **Portable and Scalable:** Designed using lightweight modules (Node-MCU), the system can be easily deployed on various vehicle types and adapted for different city infrastructures.
- **Reusable Components:** Hardware modules like GPS, ultrasonic/IR sensors, and OLEDs are durable and reusable across multiple deployments or testing environments.
- **Multi-Modal Communication:** Combines V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), and GPS-based data exchange to ensure maximum coverage and efficiency in alert propagation.
- **User-Friendly Visual Interface:** OLED displays on both EV and regular vehicles provide clear visual feedback on connection status, alerts, and direction indicators.
- **Minimizes Human Error:** Automated decision-making based on real-time sensor input significantly reduces the chances of miscommunication or delayed lane clearance.
- **Cost-Effective Smart Traffic Solution:** Utilizes affordable microcontrollers and open-source protocols, making it an economical alternative to expensive smart city systems.
- **Rapid Response Time:** Emergency vehicle detection and corresponding alert broadcasts happen in under 2 seconds, ensuring real-time response for safe passage.
- **Enhances Safety for All Road Users:** Systematic Lane clearing and traffic signal coordination reduce collision risk and improve safety for both emergency responders and the general public.

IX. CONCLUSION

The V2X-based Emergency Vehicle Assistance system presents a smart, efficient, and scalable solution to overcome the challenges faced by emergency vehicles in navigating congested traffic. By integrating GPS tracking, MQTT-based real-time communication, ultrasonic and IR sensors, and OLED display alerts, the system enables timely lane clearance and traffic signal control to ensure safe and swift passage for emergency vehicles. Its non-intrusive, low-cost, and modular design allows easy deployment in both urban and rural settings, making it adaptable to existing infrastructure and suitable for smart city integration. Through testing and validation, the system has demonstrated its potential to significantly reduce emergency response times, minimize collisions, and enhance overall traffic coordination. With further refinement and real-world adoption, this project highlights the transformative impact of IoT and V2X technologies in building safer, more responsive transportation systems.

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