

# Connected Vehicles: A Prototype of V2V and V2I Communication System

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**Abstract**—Connected Vehicles represent a transformative approach in intelligent transportation systems by enabling real-time communication between vehicles (V2V) and infrastructure (V2I). This paper presents a prototype system demonstrating critical safety features such as automatic halting at red traffic signals, safe overtaking of breakdown vehicles, and collision prevention using microcontroller-based dummy vehicles with wireless radio communication. The implementation simulates real-world scenarios and emphasizes driver assistance and traffic regulation through embedded systems. Future extensions include GPS integration for real-time positioning and Wi-Fi connectivity for cloud-based monitoring.

**Index Terms**—Connected Vehicles, V2V, V2I, ESP32, IoT, Arduino Cloud, Smart Transport

## I. INTRODUCTION

The development of Intelligent Transportation Systems (ITS) is gaining momentum as cities and industries strive for safer, smarter, and more efficient mobility solutions. ITS encompasses technologies that enable dynamic communication between vehicles and traffic infrastructure to improve road safety, traffic flow, and decision-making. A crucial element of ITS is the concept of Connected Vehicles, which leverage real-time communication to enhance situational awareness and support intelligent driver assistance.

Connected Vehicles operate through two primary communication paradigms: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). These vehicles share critical information such as speed, direction, braking, and breakdown status with other vehicles and road infrastructure to coordinate safe movement. Major automobile manufacturers have already begun integrating hardware components like Wi-Fi and GPS to support such connectivity in modern vehicles.

This project focuses on implementing and demonstrating key V2V and V2I functionalities using microcontroller-based dummy vehicles equipped with nRF24L01 radio modules and ESP32 boards. Initially, the system showcased three core safety features: safe overtaking of breakdown vehicles, prevention of overtaking when the path is obstructed, and automatic stopping at red traffic signals. In the latest enhancement, Wi-Fi-based connectivity using ESP32 has been integrated to transmit real-time vehicle status to the Arduino IoT Cloud. This enables remote monitoring via a dashboard and offers better scalability and adaptability for future real-world deployments.

The resulting prototype provides a cost-effective yet powerful platform for testing connected vehicle algorithms and lays the foundation for expanding into cloud-based control, GPS integration, and intelligent traffic management in smart cities.

## II. LITERATURE REVIEW

Connected vehicles are rapidly transforming the future of intelligent transportation by enhancing road safety, reducing traffic congestion, and minimizing environmental impact. Extensive research has been conducted to improve V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication, focusing on reliability, speed, and adaptability in dynamic traffic conditions.

Uhlemann's foundational work introduces the architecture of connected vehicles, emphasizing their role in exchanging safety and operational data via intelligent onboard systems. Vehicles equipped with ADAS (Advanced Driver Assistance Systems) and C-ITS (Cooperative Intelligent Transport Systems) can communicate across V2V, V2I, V2S (Vehicle-to-Sensor), and V2Internet interfaces, significantly improving situational awareness and driving decisions. A key takeaway is the importance of interactive systems that support safety applications and enable real-time warnings to prevent collisions.

Lu et al. elaborate on technical challenges in vehicular communication, particularly within urban environments. Their work identifies issues such as signal attenuation, Doppler effects, and multipath fading as primary hurdles in establishing robust V2V networks. The paper also highlights structural and environmental constraints—like high-rise buildings and heavy vehicles—that contribute to packet loss and network partitioning. Additional barriers include lack of standardization, limited infrastructure, and high implementation costs.

To overcome these, Abdelkader et al. review enabling technologies such as DSRC (Dedicated Short-Range Communication), Wi-Fi 6, and 5G cellular communication. DSRC offers low-latency communication but suffers from scalability limitations. Wi-Fi 6 presents broader coverage and high data rates, while 5G emerges as a promising candidate with ultra-low latency and wide-area support, albeit at a higher cost. The comparison of these technologies highlights trade-offs in terms of latency, range, cost, and standardization.

With the growth of cloud computing and IoT platforms, cloud-based V2V and V2I communication is gaining traction.

This approach allows for real-time vehicle monitoring, diagnostics, and remote control through platforms like Arduino IoT Cloud. Cloud solutions reduce infrastructure requirements and offer better scalability, but introduce challenges related to latency, cybersecurity, and internet dependency.

This project builds on the literature by implementing a low-cost connected vehicle prototype using ESP32 modules for Wi-Fi-based V2V and V2I communication. Instead of relying on full protocol stacks like DSRC or 5G, a lightweight messaging protocol is used for transmitting vehicle status and position. The integration of cloud services enables live dashboard visualization and remote monitoring, making the system suitable for smart transport applications.

### III. SYSTEM OVERVIEW

#### A. Problem Statement

Despite advancements in transportation, issues like red light violations, poor overtaking decisions, and blind spot collisions remain. These contribute to road accidents, congestion, and fuel wastage. This project addresses these challenges through a connected vehicle system.

#### B. System Design

The system consists of three dummy vehicles and a traffic signal prototype equipped with ESP32 microcontrollers and nRF24L01 radio modules. The Arduino IDE is used for control logic implementation. Vehicles share data wirelessly and respond to traffic events like signal changes and obstacles.

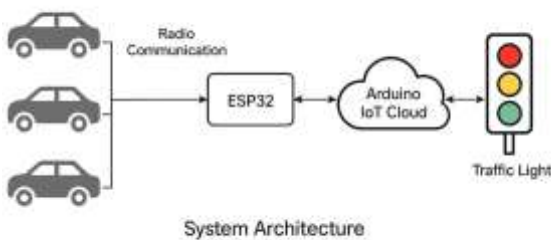


Fig. 1: System Architecture

#### C. Functional Scenarios

- **Bypass a Breakdown Vehicle:** Following vehicle safely overtakes using V2V communication.
- **Conditional Overtaking:** Overtaking occurs only if adjacent lane is free.
- **Traffic Signal Awareness:** Vehicles stop at red signals based on received status.

#### D. Cloud Synchronization

Wi-Fi allows ESP32 boards to communicate with Arduino IoT Cloud every 100ms. This enables real-time monitoring, vehicle synchronization, and cloud-based visualization of movements.

### IV. IMPLEMENTATION

The implementation used ESP32 microcontrollers with DRV8833 motor drivers and nRF24L01 modules. Vehicles are battery powered and support button-triggered scenario switching. Traffic signals are built using LEDs and BC547 transistors.

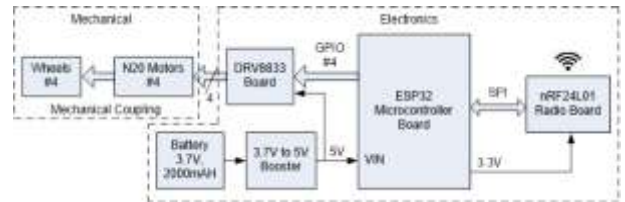


Fig. 2: Vehicle Hardware Prototype

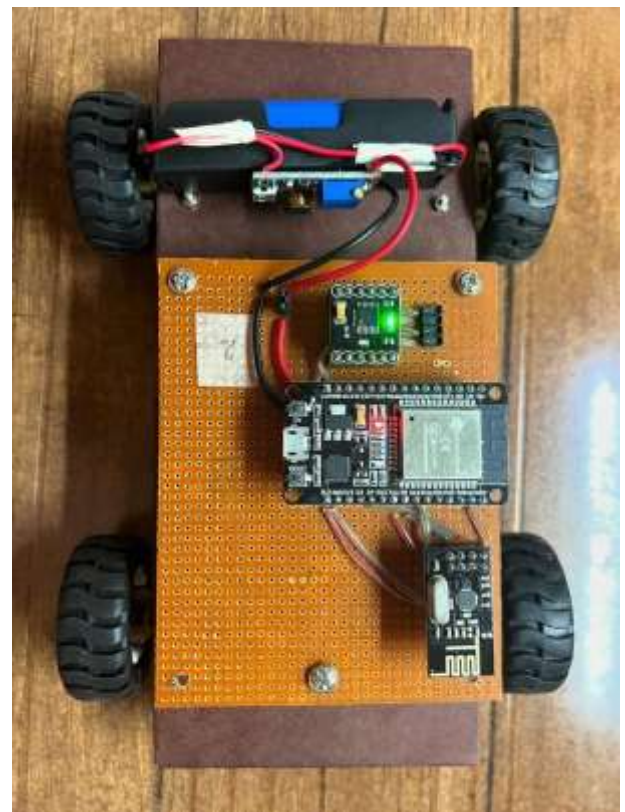


Fig. 3: Vehicle (Car)

#### A. Cloud Integration

- Real-time vehicle position/status upload to Arduino IoT Cloud.
- Cloud dashboard shows vehicle status and motion.
- Vehicles begin operation only after successful cloud sync.



Fig. 4: Cloud Dashboard Sample

#### V. RESULTS

- Vehicles stopped at red light automatically.
- Breakdowns were overtaken safely.
- Vehicles waited for side-lane traffic before overtaking. The prototype validated accurate signal-based behavior, real-time status updates every 100ms, and effective wireless communication with cloud support.

#### VI. CONCLUSION

The prototype system demonstrates key features of connected vehicle technology such as V2V safety coordination and V2I traffic compliance. Real-time cloud monitoring via Arduino IoT Cloud improves observability. The solution is scalable and cost-effective.

#### VII. FUTURE WORK

- **Web dashboard** with multi-vehicle monitoring.
- **Optimised route efficiency** for precise routing.
- **Automatic parking** according to surrounding.
- **Accident alert system** for emergencies and safety.

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