DAYANANDA SAGAR COLLEGE OF ENGINEERING

Shavigemalleshwara Hills, Kumaraswamy Layout, Bengaluru-560111, Karnataka
(An Autonomous College affiliated to VTU Belgaum, accredited by NBA & NAAC)

Department of Electronics & Communication Engineering

VI SEM BE MINI-PROJECT (22EC66) REPORT
on

Real time Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communication System

Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Engineering
in
Electronics & Communications Engineering - ECE
by

USN : 1DS22EC044	**B S Dheeraj**
USN : 1DS22EC055	**Chandan D**
USN : 1DS22EC107	**Krushik J P**
USN : 1DS23EC405	**Darshan D L**

Under the guidance
of
Dr. Trupti S Tagare
Assistant Professor
ECE Dept., DSCE, Bengaluru

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnanasangama, Macche, Santibastwada Road
Belagavi-590018, Karnataka
2024-25

Certificate

Certified that the mini-project work **(Course Code : 22EC66)** entitled "**Real time Vehicle- to-Vehicle and Vehicle-to-Infrastructure Communication System**" carried out by **B S Dheeraj** (1DS22EC044), **Chandan D** (1DS22EC055), **Krushik J P** (1DS22EC107), **Darshan D L** (1DS23EC405) are bonafide students of the Department of ECE of Dayananda Sagar College of Engineering, Bangalore, Karnataka, India in partial fulfillment for the award of Bachelor of Engineering in Electronics & Communication Engineering of the Visvesvaraya Technological University, Belagavi, Karnataka for the **VI Semester course** during the academic year 2024-25. It is certified that all corrections / suggestions indicated for the mini-project work have been incorporated in the mini-report. This **VI semester mini- project report** has been approved as it satisfies the academic requirement in respect of mini-project work prescribed for the said degree.

Mini-Project Guide Sign : Tagare

Name : **Dr. Trupti S Tagare**

Mini-Project Domain Coordinator Sign :

Name : **Dr. Shashi Raj K**

Mini-Project Convener & Chief Coordinator Sign : Tagare

Name : **Dr. Trupti S Tagare, Asst. Prof., ECE, DSCE**

Dr. Shobha K R : Shobha K R

Prof. & HOD, ECE, DSCE

Dr. SHOBHA K.R.
Prof. & HOD, Dept. of ECE

Dr. B.G. Prasad :

Principal, DSCE

Mini-Project Viva-Voce (CIE)

Name of the mini-project examiners (with date):

1: Dr. Trupti Tagare — Signature : Tagare 6/5/25

2: Dr Roopa M — Signature : 6/5/25

Declaration

Certified that the mini-project work entitled, "**Real time Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communication System**"with the course code **22EC66** (2 Credits, CIE 100 Marks) is a bonafide work that was carried out by ourselves in partial fulfillment for the award of degree of Bachelor of Engineering in Electronics & Communication Engg. of the Visvesvaraya Technological University, Belagavi, Karnataka during the academic year 2024-25 for the VI Semester Autonomous Course. We, the students of the VI sem mini-project group/batch no. do hereby declare that the entire mini-project has been done on our own. The results embedded in this mini-project report has not been submitted elsewhere for the award of any type of degree.

Student Name-1 : B S Dheeraj
USN : 1DS22EC044
Sign : B.S. Dheeraj

Student Name-2 : Chandan D
USN : 1DS22EC055
Sign : Chandan D

Student Name-3 : Krushik J P
USN : 1DS22EC107
Sign : Krushik J P

Student Name-4 : Darshan D L
USN : 1DS23EC405
Sign :

Date : 06 / 05 /2025

Place : Bengaluru

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B S Dheeraj

Chandan D

Krushik J P

Darshan D L

Abstract

This mini-project is aimed at the deployment of a real-time vehicle-to-vehicle communication system based on Wi-Fi-enabled ESP32 microcontrollers with the goal of developing intelligent transportation systems. The main aim is to emulate Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication to improve road safety and traffic control. Two ESP32 modules are used in the project—one as the transmitter and the other as the receiver.

The transmitter vehicle has an ultrasonic sensor and an MPU6050 motion sensor to sense surrounding obstacles and track real-time movement parameters. When there is a possible collision, this data is wirelessly transmitted to the receiver ESP32 via HTTP-based communication through Wi-Fi. The receiver end shows the data coming in on a 16x2 I2C LCD and acts by regulating the vehicle movement through an L298N motor driver, hence reducing its speed or bringing it to halt as required.

Aside from the self-driving response system, a web server is also included to provide manual control of the vehicles, facilitating users in reversing direction and adjusting speed remotely. This introduces flexibility for simulation and testing in real-life scenarios. The mini-project also investigates how MPU6050 data (such as acceleration and angular velocity) can be streamed and displayed to enhance navigation precision and response speed.

This research is applicable in the scenario of next-generation smart transport systems and self-driving solutions, providing an elementary model towards more sophisticated V2X (Vehicle-to-Everything) communications. Anticipated outcomes are accurate obstacle detection, real-time vehicle-to-vehicle data transmission, and automatic motor response—demonstrating the viability of low-cost embedded platforms for vehicular communication.

Keywords: *ESP32, Vehicle-to-Vehicle Communication, Vehicle-to-Infrastructure, Wi-Fi, Ultrasonic Sensor, MPU6050, L298N Motor Driver, Real-Time Systems, Smart Transportation, IoT.*

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Nomenclature and Acronyms

Abbreviations (Alphabetical Order) :

IEEE	Institute of Electrical & Electronics Engineers
DSCE	Dayananda Sagar College of Engineering
ECE	Electronics & Communication Engineering
:	
:	

Chapter-1

Introduction

In the present era the growth of the vehicles has been increasing day by day and led to the fast urbanization and it has become important to maintain and improve the road safety, traffic management and reducing the congestion. So our project is successfully completed by aiming the main challenges of the modern road transport.

The mini-project focusses on developing the real time communications between the two vehicles by using the microcontrollers like ESP32 with some onboard sensors. This system enables to transfer the speed data from vehicle to vehicle and when there is an obstacle detection the vehicle will stop and passes the information to all other vehicles through Wi-Fi by using UDP protocol to transfer the data and it displays on the screen of the other vehicle that there is a collision detected and the other vehicle gets stopped immediately by taking that signal has more priority or giving the high priority to that signal. This is how the vehicle-to- vehicle communication work in our project by using Wi-Fi as an access point.

And another goal the mini-project focusses is that real time communication between vehicle and the infrastructure that is traffic lights. Like whenever there is an emergency vehicle in near the traffic signal the traffic light turns into green and makes a way for the emergency vehicle when the vehicle passes the emergency signal to the traffic light that is RSU (Road side units) by using Wi-Fi technology and when the vehicle passes the traffic light signal and it sends the signal that is there is no emergency, then the traffic lights behaves normally by using VAC technology where the most of the traffic signals are using vehicle automated control technology where the timers for turning the green light is set upped depending upon the vehicle density in that particular road.[1][12]

So, this is how the real time vehicle-to-vehicle and vehicle-to-infrastructure communication works our project main agenda focusses on real time communication between vehicle to vehicle and vehicle to infrastructure with giving minimum delay and establishing the communication more faster by using the Wi-Fi technology.[3]

Chapter-2

Literature Review

Vehicular communication systems have advanced rapidly with the development of Intelligent Transportation Systems (ITS). V2I and V2V communications have been investigated by researchers and engineers on multiple fronts to support safety, traffic efficiency, and driver assistance. In this section, we survey current research activities, discussing their strengths, weaknesses, and how our contribution enhances and fills these gaps. (Table 2.1)

Sl.	Paper Title	Hardware and Software uses	Methodology Uses
1	Vehicle-to-Vehicle Communication for Collision Avoidance[2022]	8051 Microcontroller, ZigBee Module, Ultrasonic Sensors, LCD Display, Buzzer, Servo Motor. Keil Software, Arduino IDE, Embedded C, ZigBee Protocol, Proteus (Simulation).	Provides an overview of V2V technologies and their impact on reducing accident rates. Supports real-time data exchange for emergency vehicle detection.
2	Provides an overview of V2V technologies and their impact on reducing accident rates. Supports real-time data exchange for emergency vehicle detection.[2019]	ESP32 Microcontroller, Wi-Fi & Bluetooth Module, Amplifier Antenna, Battery, Solar Panel Onboard Unit (OBU), Ultrasonic Sensor. Arduino IDE, ESP32WiFi Library, C/C++ (Arduino-based).	ESP32-based Roadside Units (RSUs) for V2I communication. It highlights challenges in wireless signal propagation, network interference, and real-time decision-making.
3	Connected Vehicles: V2V and V2I Road Weather and Traffic Communication Using Cellular Technologies[2023]	CAN Bus, temperature & wind sensors, cameras, Mk5/Mk6 transceivers, RSUs, weather & visibility sensors (Vaisala PWD-22, DSC-111), traffic lights, IoT sensors. Embedded Linux, LTE, 5G, V2X communication, Python, Wireshark.	V2V and V2I enhance road safety and weather monitoring. Supports the scalability of our project to smart city applications.
4	Geo-Based Resource Allocation for Joint Clustered V2I and V2V Communications in Cellular Networks[2023]	LTE/5G and DSRC modules, Base Stations (BS), Wireless Antennas, Sensors (GPS, Cameras, Radar, Lidar). DBSCAN, MATLAB, NS-3, 5G Network Software Stack, Machine Learning Models.	Discusses wireless resource management for V2V and V2I communications, optimizing connectivity in Wi-Fi-based vehicular networks. Supports our decision to use Wi-Fi for V2V and V2I.

5	V-CAS: A Real-Time Vehicle Collision Avoidance System[2024]	Jetson Orin Nano, Three RGB Cameras, Vehicle Braking System Interface, Memory (64GB RAM, 8GB LPDDR5 RAM). PyTorch, CUDA, TensorRT, OpenCV, NumPy, RT-DETR, Nvidia DeepStream, Python Scripts.	Supports the use of sensor-based alerts and V2V communication for accident prevention.
6	Cooperative Collision Avoidance in a Connected [2016]	CarSim PC, dSpace SCALEXIO real-time HIL simulator, in-vehicle PC, DSRC modems, Kvaser CAN device.CarSim, Simulink, Simulink Coder, Stateflow, real-time Linux, SAE J2735 DSRC message set, CAN protocol.	Focuses on V2V communication for preventing accidents by sharing speed, direction, and emergency alerts among vehicles.
7	Event-Aided Time-to-Collision Estimation for Autonomous Driving[2024]	CarSim PC, dSpace SCALEXIO real-time simulator, in-vehicle PC, DSRC modems, Kvaser CAN device.CarSim, Simulink, Simulink Coder, Stateflow, real-time Linux, SAE J2735 DSRC message set, CAN protocol.	Introduces sensor-based tracking for predicting time-to-collision (TTC) and proactive accident prevention. This research supports our project's collision prediction system using ultrasonic and accelerometer sensors.
8	V2V and V2I Communication in a Heterogeneous Wireless Network – Performance Evaluation[2016]	Vehicles with DSRC & LTE communication modules, RSUs with Wi-Fi and LTE, onboard units (OBUs), sensors, mobile devices.NS-3 simulator, SAE J2735 DSRC message set, real-time data processing, application-layer handoff mechanisms.	Vehicles with DSRC & LTE communication modules, RSUs with Wi-Fi and LTE, onboard units (OBUs), sensors, mobile devices.NS-3 simulator, SAE J2735 DSRC message set, real-time data processing, application-layer handoff mechanisms.
9	Wireless Communication Between Vehicles: Exploring V2V and V2X Communication[2023]	Onboard sensors (GPS, radar, LiDAR, cameras), onboard computers, V2V communication modules (DSRC, C-V2X), antennas.DSRC, C-V2X, 5G NR, Wi-Fi (802.11p), ADAS, decision-making algorithms, traffic optimization models.	Wireless communication standards (DSRC, C-V2X, Wi-Fi) for V2V and V2I applications. Helps justify our decision to use Wi-Fi for communication.
10	Sensing Traffic Density Combining V2V and V2I Wireless Communications [2015]	ESP32 Microcontroller, Wi-Fi & Bluetooth Module, Amplifier Antenna, Battery, Solar Panel Onboard Unit (OBU), Ultrasonic Sensor. Arduino IDE, ESP32WiFi Library, C/C++ (Arduino-based).	V2V and V2I work together to reduce traffic congestion and optimize traffic flow. Supports our project's sensor-based traffic light system.

Chapter-3

Objectives:

In response to these concerns, the project suggests the establishment of a real-time, Wi-Fi- based vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication system employing microcontrollers (ESP32) and sensors. The major aims are as follows:

1. Research and Analyze Existing V2X Communication Systems

- Perform an extensive review of literature regarding V2V and V2I technologies such as DSRC, C-V2X, and Wi-Fi-based solutions.
- Determine their strengths, limitations, and usability in emergency traffic management.
- Prioritize low-latency, short-range communication protocols for cost-effective implementation in urban areas.[22]

2. Integrate Real-Time Collision and Obstacle Detection System

- Utilize gyroscope and proximity sensors on vehicles to identify sudden motion or obstacles.
- Upon detecting an obstacle, the vehicle must automatically stop and immediately send a warning signal to nearby vehicles (V2V).[11]
- This allows for following vehicles to respond in time and prevent chain-reaction crashes.

3. Facilitate Instantaneous Emergency Vehicle Communication

- Fit emergency vehicles with ESP32-based modules to send presence and direction data.
- Roadside units (RSUs) installed on intersections will be able to detect this signal and automatically change traffic lights to green for the oncoming emergency vehicle.
- At the same time, warn neighboring cars to yield and vacate the lane, enhancing safety and decreasing delays.[14]

4. Build a Smart Traffic Control System

- Employ ESP32 microcontrollers and Wi-Fi modules to implement a distributed traffic control system.

- Interact with traffic light hardware to dynamically override default signal patterns when high-priority vehicles are approaching.[18]
- Show important information on LCD displays, including:

Current vehicle speed, Obstacle alerts, Emergency vehicle warnings

Problem Statements:

Contemporary urban traffic systems are primarily based on fixed-timing traffic signals that are not dynamically adjusted to reflect actual road conditions. Such inflexibility is most troublesome in cases of emergency vehicles, where being held up by intersections can result in loss of life. Emergency vehicles like ambulances and fire trucks regularly experience considerable traffic congestion as a result of:

Shortage of Real-Time Traffic Signal Management: Old-fashioned traffic signals run on pre-set cycles and don't give priority to high-priority vehicles.[1] Consequently, emergency responders get held up time and again at intersections, wasting precious time.

Poor Vehicle Awareness: Vehicles nearby often remain oblivious to incoming emergency vehicles because of noise, distance, or lack of attention by drivers, enhancing response time and risk of accidents.[23]

Lack of Coordinated V2V and V2I Communication: In the absence of direct vehicle-to- vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, dynamic conditions such as obstacle detection, route clearance, or prioritization of emergency vehicles are hard to handle. **Lack of Access to Affordable, Scalable Technology:** Most current solutions rely on cellular connectivity (5G, LTE) or costly sensors (LiDAR, radar) and are not amenable to low-cost, extensive deployment.[6][7]

The system has the following goals:

- Decrease emergency response time by reducing intersection delay.
- Make drivers more aware through V2V warnings and visual indicators.
- Avoid collisions through sensor-based predictive response.
- Show a low-cost, scalable alternative to costly ITS infrastructure based on available microcontrollers and Wi-Fi.

Chapter-4

Block Diagram:

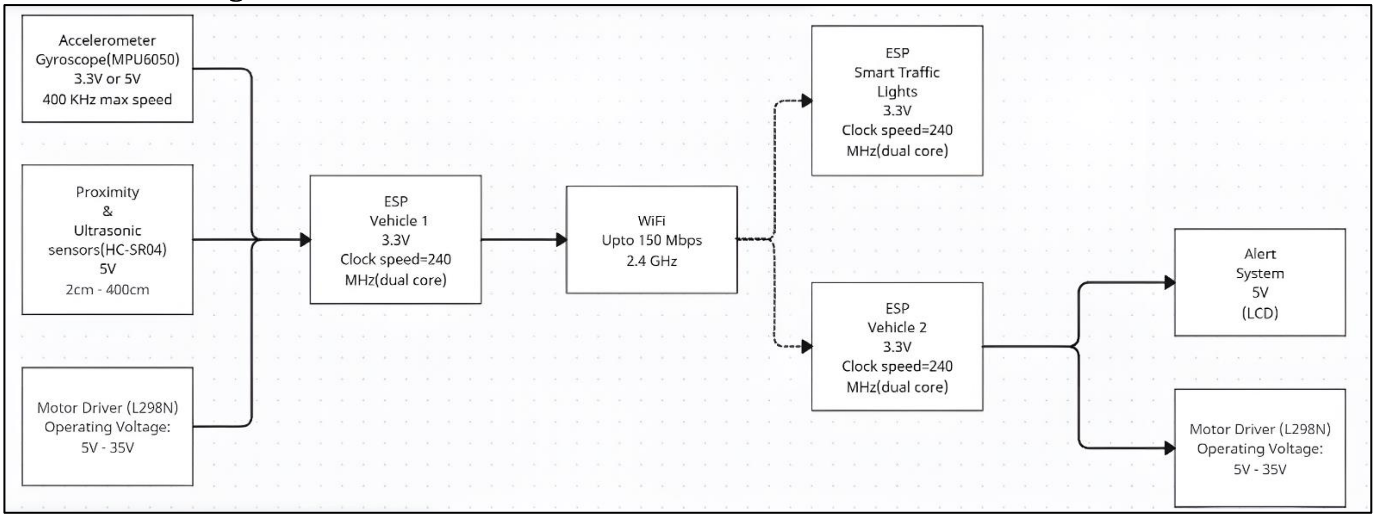

Fig. 4.1 : Block Diagram

Indeed! Here's a step-by-step description of the role each block plays within your system design, highlighting what they do and how they communicate without going into details:

LEFT SECTION – VEHICLE 1 (Sensing and Control Unit)

Accelerometer & Gyroscope (MPU6050)

Function: These sensors monitor the motion, tilt, and orientation of Vehicle 1. In case the vehicle starts decelerating suddenly, tilts irregularly (e.g., in a collision or skidding), or undergoes unprecedented movement, the information is transmitted to the ESP. It is an important piece of information that helps calculate possible collision risks and activate alerts to adjacent vehicles.

Proximity & Ultrasonic Sensors (HC-SR04)

Function: These sensors continuously monitor the environment in front of the vehicle to detect nearby objects or obstacles. When an object is detected within a dangerous range, the data is used to either stop the vehicle or alert other vehicles. It forms the basis for real-time obstacle detection and V2V communication.

Motor Driver (L298N)

Function: The motor driver takes instructions from the ESP controller (e.g., move forward, stop) depending on sensor information. If there is an obstacle or collision anticipated, the motor driver will instantly stop the motors to avoid an accident. It is the last actuator managing vehicle movement.

ESP Vehicle 1 (Microcontroller)

Function: It is the master control unit of Vehicle 1. It gathers data from sensors (ultrasonic and gyroscope), processes in real time, and determines if it should send alarms, stop the vehicle, or keep normal operation. It also sends emergency or hazard messages to other ESP modules over Wi-Fi.

MIDDLE SECTION – COMMUNICATION CHANNEL

Wi-Fi Communication

Function: Acts as the communication link between every ESP module in the system. It enables Vehicle 1 to wirelessly transmit information to intelligent traffic lights and other vehicles (such as Vehicle 2). This communication is necessary for both V2I (vehicle-to- infrastructure) and V2V (vehicle-to-vehicle) operations.

RIGHT SECTION – RECEIVING AND RESPONSE UNITS

ESP Smart Traffic Lights

Function: It picks up signals from Vehicle 1 (particularly if it's an emergency vehicle). When it senses such a signal, it overrides the regular traffic light cycle to turn green in the emergency vehicle's direction to allow it to pass faster and safely. It reverts to normal once the vehicle has passed.

ESP Vehicle 2

Function: This microcontroller serves as the receiver in the other car. It hears signals from Vehicle 1. In case an obstacle warning or collision warning is heard, it can act accordingly (e.g., decelerate, show warning on LCD, or shut down the motor). It facilitates cooperative vehicle behavior by way of V2V communication.

Alert System (LCD)

Function: The LCD shows crucial messages like "Obstacle Ahead," "Emergency Vehicle Approaching," or "Vehicle Stopped." This heightens driver alertness by showing safety information acquired through the ESP from other cars visually.

Motor Driver (Vehicle 2)

Function: Like Vehicle 1's driver, it performs motion control commands according to directions from the ESP. In case of receiving a warning signal from another vehicle, this driver will stop Vehicle 2 to avoid collision.

Summary of System Flow:

- Vehicle 1's sensors observe motion irregularities or obstacles.
- Vehicle 1's ESP processes the information and communicates over Wi-Fi.
- Traffic lights adjust in case there is an approaching emergency vehicle.
- Vehicle 2 takes precautions and gives warnings.
- The drivers are warned through alert messages, and the motors are managed to keep everything safe.

Working Principle and Methodology:

WORKING PRINCIPLE

The system to be developed functions on the concept of real-time vehicle-to-vehicle (Vehicle-to-Vehicle or V2V) and vehicle-to-infrastructure (Vehicle-to-Infrastructure or V2I) wireless communication with ESP32 microcontrollers via Wi-Fi.[9] The aim is to improve road safety and traffic flow by facilitating emergency vehicle prioritization at intersections and inter-vehicle awareness via sensor-based information sharing.

Key Concepts:

Vehicle 1 senses its surroundings with onboard sensors (gyroscope, accelerometer, and ultrasonic sensors).[10]

When Vehicle 1 recognizes an emergency situation (e.g., it is an ambulance) or senses an obstacle (e.g., oncoming vehicle or pedestrian), it sends information wirelessly to: ▪ Traffic lights (V2I communication) to alter light status. ▪ Surrounding vehicles (V2V communication) to show warnings or trigger safety measures.[13][17]

Receiving devices (Vehicle 2, Traffic Light Controller) act upon the data and perform actions like braking the vehicle, alerting, or giving a green signal to a traffic light.

METHODOLOGY

The deployment can be categorized into five major phases:

Sensing and Monitoring in Vehicle 1

1. Vehicle 1 is provided with an MPU6050 sensor (gyroscope and accelerometer) to detect tilt, orientation, and abrupt motion.

2. An ultrasonic proximity sensor (HC-SR04) senses objects close by and computes the distance to possible obstacles.

3. A microcontroller (ESP32) reads these sensor values continuously and monitors for any anomaly: ▪ An emergency vehicle status can be manually or automatically detected. ▪ Obstacles at unsafe distance cause a stop command.

4. A motor driver manages the vehicle motion according to commands from the ESP.

Processing and Decision-Making

1. If an obstacle is identified, or emergency vehicle status is verified, the ESP32 in Vehicle 1 decides: ▪ Stop the vehicle (if obstacle). ▪ Send emergency or hazard message (Wi-Fi).

2. The decision logic is embedded in the ESP's firmware, allowing autonomous response to dynamic road conditions.[18]

Wi-Fi Communication (ESP-Networked)

1. The ESP32 modules are set up to communicate over a 2.4 GHz Wi-Fi network.

2. Vehicle 1 transmits messages wirelessly: ▪ To an adjacent traffic signal system (ESP Smart Traffic Light) – V2I. ▪ To other adjacent vehicles (e.g., Vehicle 2) – V2V.

Response by Receiving Units

1. ESP Smart Traffic Light (V2I):

When it receives an indication from a coming emergency vehicle, the traffic light:

▪ Takes precedence over its standard timer or mode.

▪ Changes to green in the emergency vehicle's direction.

▪ Reverts back to normal mode when passage is detected.

2. ESP Vehicle 2 (V2V):

Vehicle 2 waits to hear from Vehicle 1.

When receiving an obstacle warning: ▪ Shows the warning on an LCD warning system. ▪ Instructs the motor driver to decelerate or halt.

In the absence of an alert, the vehicle runs in normal mode.

3. Alert and Display System

The alert device (LCD) in Vehicle 2 or any nearby vehicles: ▪ Alerts the driver of current events (e.g., "Obstacle Ahead," "Emergency Vehicle Close By," or speed). ▪ Increases driver situational awareness to avoid accidents.

Flow-Chart:

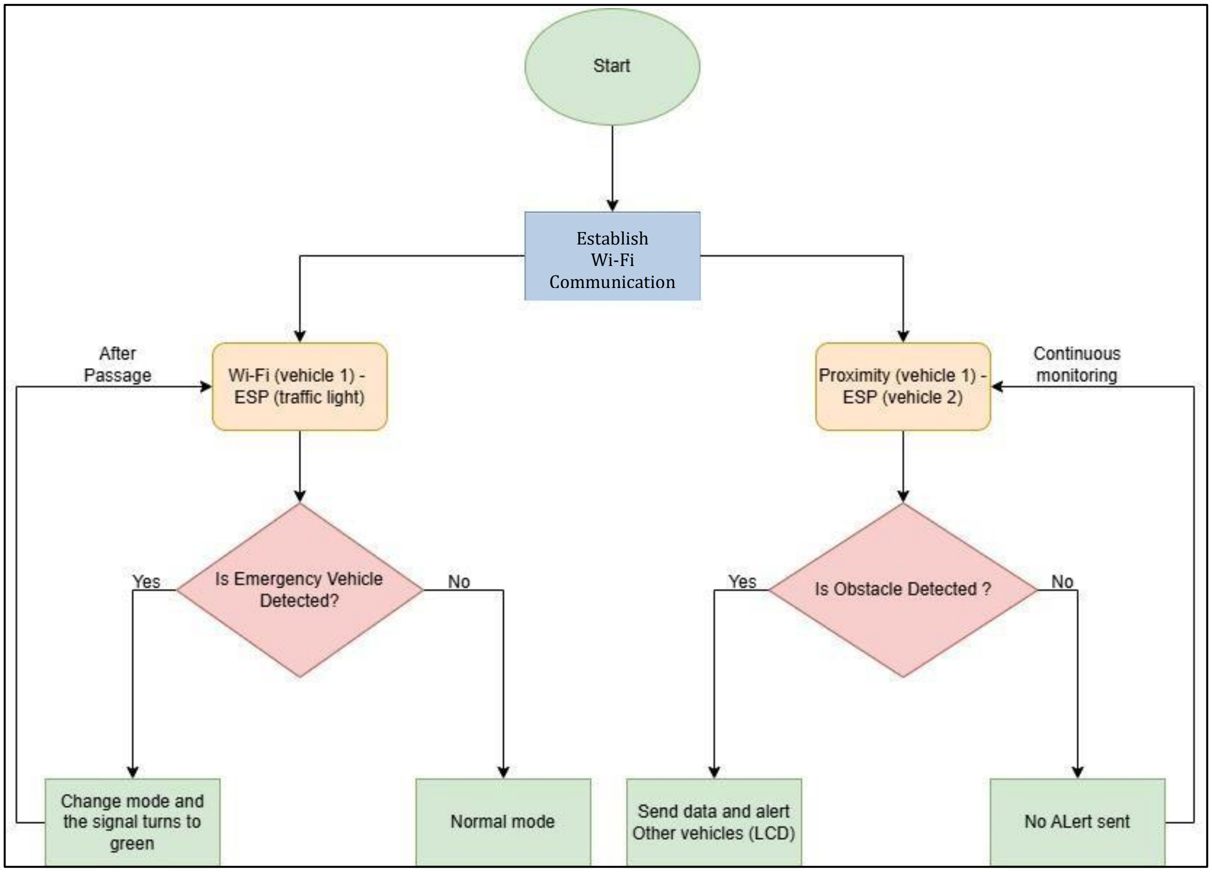

Fig. 4.2 : Flow – Chart

Start

- This is the startup of the system. It activates the microcontrollers (e.g., ESP32) and
- prepares the system for communication and sensor use.

Set Up Wi-Fi Telecommunications

- All ESP modules (in vehicles and at intersections) boot up and communicate via Wi-Fi.
- Guarantees a common communication channel exists for both V2V and V2I systems.
- This is an essential step in supporting real-time data exchange and message broadcasting.

Left Branch – V2I: Emergency Vehicle Detection

Wi-Fi (Vehicle 1) – ESP (Traffic Light)

- The ESP of the emergency vehicle transmits a signal through Wi-Fi to the ESP node of the traffic light.
- This module functions as a Roadside Unit (RSU) in the intersection.
- The RSU waits for permitted emergency signals.

Is Emergency Vehicle Detected?

- The RSU examines incoming packets to find out if an emergency vehicle (e.g., ambulance) is on its way.
- If "Yes," it sets to overrule the default traffic light pattern.
- If "No," normal operation resumes.

Change Mode and the Signal Turns Green

- The traffic light system goes into emergency mode.
- Signal turns green for the direction of the oncoming emergency vehicle.
- After the vehicle has passed, the system goes back to normal mode.

Normal Mode

- In the absence of an emergency vehicle, the system keeps running according to its default timing cycles.

Right Branch – V2V: Obstacle Detection & Alert

Proximity (Vehicle 1) – ESP (Vehicle 2)

- A car (Vehicle 1) employs sensors such as an ultrasonic sensor, gyroscope, or IR to detect surroundings.
- This car is in constant communication with another close-by car (Vehicle 2) via Wi-Fi.

Is Obstacle Detected?

- Vehicle 1 keeps checking for an obstacle using sensors.
- In case there's a possible collision or blockage, it creates a message event.

Send Data and Warn Other Vehicles (LCD)

- A warning is sent out to Vehicle 2 (or other vehicles within range).
- It is displayed on an LCD screen in the receiving vehicle.

- Can include messages such as "Obstacle Ahead," "Brake Engaged," or vehicle speed at present.

No Alert Sent

- If there is no obstacle, the system is in its default state.
- The vehicles remain in passive monitoring mode.

Ongoing Monitoring

- The system repeatedly cycles back to check sensor inputs and communication.
- Provides real-time reaction to dynamic road conditions.

Summary:

- This system promotes traffic efficiency and safety through:
- Prioritizing emergency vehicles via Wi-Fi-based V2I communication.
- Exchanging hazard and movement information among vehicles via V2V communication.
- Disabling real-time warning on LCDs, avoiding collision risk, and enhancing driver perception.

Chapter-5

Hardware & Software Tools Used

According to our mini-project here is a brief and organized overview of the hardware and software components of the project:

HARDWARE DESCRIPTION

ESP32 Microcontroller (Vehicle and Traffic Light Nodes)

- Serves as the brain of every subsystem (Vehicle 1, Vehicle 2, and Smart Traffic Light).
- Controls sensor data processing, Wi-Fi-based communication, and peripheral control like motors and LCDs.[1]

MPU6050 (Accelerometer + Gyroscope)

- Mounted on every vehicle to track vehicle orientation and movement.
- Senses sudden braking, tilting, or collision which could be a potential collision or danger.[2][3]

HC-SR04 (Ultrasonic Sensor)

- Tracks the distance between the vehicle and surrounding objects.
- Assists in real-time obstacle detection and sends alerts when any object is in close proximity.[5]

RC522 (RFID Module)

- Utilized in the emergency vehicle to recognize itself to the traffic signal system.
- When sensed by the roadside ESP32, it initiates priority signal control (turns green).

LCD Display (on Vehicle 2 or neighboring vehicles)

- Shows live messages like "Emergency Vehicle Approaching," "Obstacle Ahead,".
- Increases driver perception and enables instant response.

Motor Driver (L298N)

- Regulates the movement of each vehicle.
- Takes ON/OFF commands from the ESP depending on sensor input.

LEDs (on traffic light controller)

- Symbolize signal colors (Red, Yellow, Green).[1][2]

- Operated through ESP32 based on emergency vehicle communication or regular timer cycle

SOFTWARE DESCRIPTION

Arduino IDE

- Main development board used to compose, compile, and upload the code to ESP32.
- All ESP modules are coded in C/C++ with Wi-Fi libraries and sensor interfacing logic.
- Sensor Data Handling
- Code extracts real-time values from MPU6050 and HC-SR04.
- Depending on threshold values (e.g., sudden braking, proximity < safe distance), the ESP32
- performs actions such as sending alerts or stopping the motor.

Wi-Fi Communication Logic

- ESP32 devices are set in Access Point (AP) or Station (STA) mode.
- Emergency vehicles send signals to traffic lights (V2I) and surrounding vehicles (V2V) via
- Wi-Fi using HTTP or socket communication.

Signal Override Logic (Traffic Light)

- When an emergency vehicle is identified (using RFID or a predefined code sent via Wi-Fi), the ESP32 in the traffic light overrides the normal cycle and goes green in the direction of the vehicle.
- After a predetermined period or when the vehicle goes by, the light goes back to normal operation.

Display System (LCD)

- ESP32 gets warning information and provides text messages to the LCD.
- Provides human-readable, real-time safety feedback to drivers.
- Control Flow & Integration
- All the elements are connected using a well-structured flow: sensing → decision → communication → response.
- Testing was carried out in simulation for component-level operation and end-to-end communication.

Chapter-6

Photographs of the model/Simulation Results

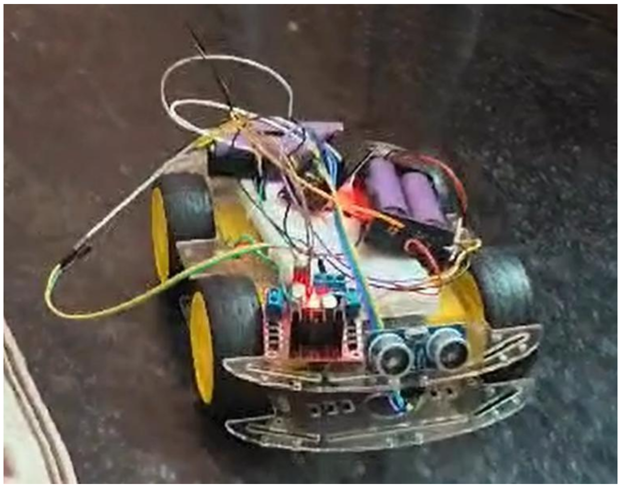

Fig. 6.1 : Sender Vehicle

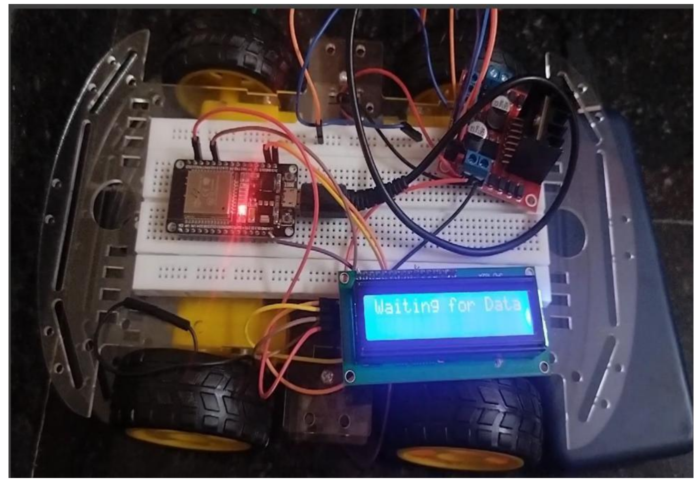

Fig. 6.2 : Receiver Vehicle

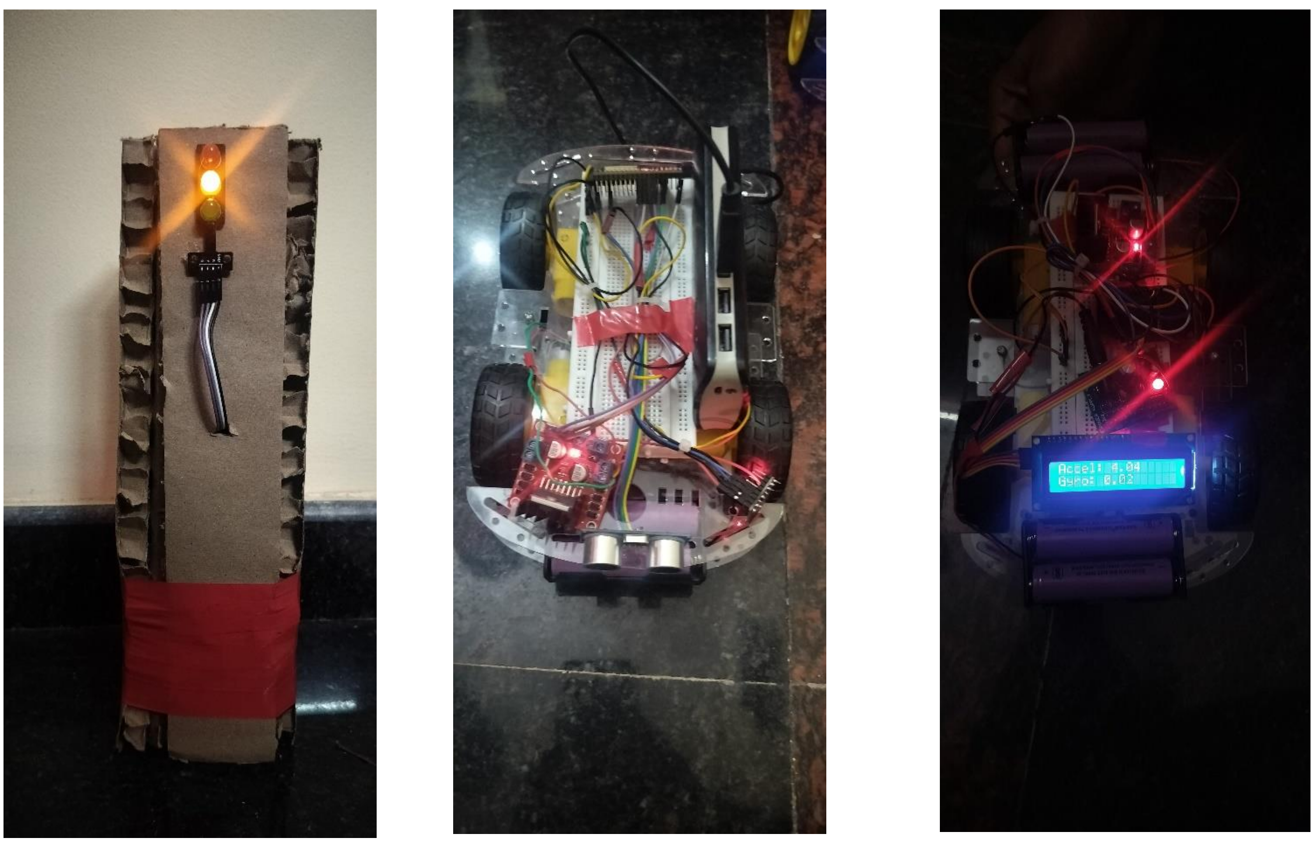

Fig. 6.3 : V2V and V2I

Chapter-7

Results and Discussions

Simulation results and experimental outcome

This chapter reports the experimental and simulation results from the deployment of a real- time V2V and V2I communication system based on ESP32 microcontrollers, sensors, and Wi- Fi. The system was experimentally tested in a controlled environment to ensure its functionality in both emergency vehicle prioritization and inter-vehicle hazard alert communication.

Experimental Setup

The following hardware modules were used in a prototype setup:

- Two vehicle units: Each with ESP32, MPU6050, HC-SR04, LCD, and motor driver.
- One intelligent traffic light system: ESP32-controlled LEDs with RFID-based emergency detection.

Wireless communication: All ESP32s on a common Wi-Fi network.

- The system was powered by USB or battery packs, and all the units were positioned at known distances to mimic real-world intersections and vehicle interactions.

Observed Results & Outcomes

The result of this mini-project work can be described as follows:

- Real-Time Obstacle Detection and Alert Transmission (V2V)
- When Vehicle 1 sensed an obstacle at a 20 cm range with the ultrasonic sensor, it effectively:
  - Shut down the vehicle motor.
  - Sent an alert message to Vehicle 2 over Wi-Fi.
  - Displayed "Brake Activated" and "Obstacle Ahead" on Vehicle 2's LCD.
- Emergency Vehicle Signal Recognition (V2I)
- When the emergency vehicle (Vehicle 1) reached the smart traffic signal:
  - The ESP32 traffic signal node received the RF-based or Wi-Fi signal.
  - The light changed to green upon immediate lanelight switching.
  - When a 10-second passage interval passed, the signal went back to normal mode.

LCD Alerts and Speed Display

- During this normal driving state, Vehicle 2's LCD showed ongoing speed information.
- Message reception during an emergency signal or obstacle alert was prompted with the display changing to display safety alerts.

Message Flow Verification

- With Arduino IDE serial monitor and Wi-Fi packet logging, the following behaviors were verified:
- Minimal latency (~100 ms) in obstacle-to-alert transmission via Wi-Fi.
- Uniform detection of emergency vehicle by traffic node.
- Glide override of LED traffic light cycle without skipping or lost signals.

Comparative Analysis with Other Works

Feature	**Other Solutions**	**Our Proposed System**
Communication Protocol	DSRC / 5G / Zigbee	Wi-Fi (ESP32) – Low cost, easily sourced
Emergency Vehicle Priority	Missing or delayed	Real-time override of traffic lights using ESP
Collision Prediction & Warning	Vision-based or GPS-based (high cost)	Sensor-based (gyroscope + proximity) warning
Display Interface	Usually missing or minimal	Real-time LCD warnings in receiving vehicles
Implementation Cost	High (owing to hardware/network)	Low – utilizes basic sensors and microcontrollers
Scalability	Difficult, not easily deployable	Easy deploy ability in smart city settings

Table 7.1 : Comparative Analysis

Summary of Results

- The system achieved all anticipated functional goals: real-time sensing, decision-making, and wireless transmission.
- Communication latency was low, allowing timely response in both V2V and V2I cases.
- Emergency vehicles were always given priority at intersections.
- Vehicle alerts were visually and functionally confirmed by LCD and motion control.

Chapter-8

Applications, Advantages, Outcome and Limitations

Advantages of the mini-project work

- Real-Time Communication:
  Facilitates real-time data exchange between vehicles and road infrastructure via Wi-Fi, providing timely alerting and response.
- Low-Cost Implementation:
  Employes readily accessible modules such as ESP32, ultrasonic sensors, and gyroscopes—thus rendering the system cost-effective for mass deployment.
- Smart Traffic Management:
  Provides priority green signal to emergency vehicles automatically, eliminating congestion and emergency response time enhancement.
- Improved Road Safety:
  V2V alerts prevent collisions by informing other vehicles of obstacles, sudden braking, or stops.
- Human-Centric Interface:
  LCD-based alert system enhances driver perception and decision-making through real-time messages.
- Scalable and Modular:
  System architecture can be scaled to additional vehicles and intersections, and integrated with IoT-based smart city infrastructure.

Applications of the mini-project work

- Emergency Vehicle Priority:
  In ambulances, fire trucks, or police cars, to alert traffic lights and nearby vehicles to clear the roadways quickly.
- Intelligent Traffic Systems:
  To develop adaptive traffic control systems that react to changing road conditions in urban areas.

- Smart City Deployments:

  Integration with city traffic infrastructure to control congestion and provide smoother flow at key intersections.
- School Buses and Public Transport:

  Priority can be allocated during rush hours or school areas for safety and timeliness.
- Collision Avoidance in High-Density Areas:

  Used in low-visibility or high-crash areas to reduce rear-end crashes.

Outcome of the mini-project work

- A working model of a real-time V2V and V2I communication system was successfully developed and tested.
- Emergency cars were able to notify traffic lights to switch signals, and surrounding vehicles were alerted using Wi-Fi.
- Cars could detect other obstacles, stop independently, and alert surrounding cars, featuring predictive safety.
- The technology is a move toward safer, smarter roads with the integration of IoT, automation, and communication.

Societal and Global Significance:

- For the Common Citizen: Minimizes accident threats and enhances road behavior by warning in advance through early warning systems and dynamic control of traffic signals.
- For Emergency Services: Supports ambulances, fire vehicles, and police cars in shaving precious minutes of time during crises.
- For Smarter Cities: Supports the general vision of smart transportation systems (ITS), environmentally friendly urbanization, and governance through digital methods.

Limitations / downfall of the mini-project project

- Limited Coverage Area:

  Wi-Fi limits reach to short ranges; not suitable for long-range or high-speed applications unless mesh networks or repeaters are employed.
- Prototype Scale Only:

  Implemented presently in a small-scale prototype with toy vehicles and simple infrastructure—not executed in real roads or complete traffic systems.

- Absence of Cloud Integration:

  No cloud logging or backend server is employed for long-term analysis of data or centralized monitoring.
- Security Issues:

  The system does not yet incorporate data encryption or authentication schemes—making it susceptible to spoofing or interference.
- Sensor Dependence:

  Weather conditions such as rain, fog, or vibrations can affect ultrasonic and gyroscope sensor performance.

How it helps the society?

- This mini-project provides a clever solution for enhancing road safety and emergency response by facilitating real-time communication among vehicles and traffic systems.
- It enables emergency vehicles (such as ambulances) to travel more quickly to their destination by automatically switching traffic lights green, saving lives during emergency situations.
- The system notifies surrounding vehicles about impending hazards (such as obstructions or unexpected stops), eliminating the likelihood of accidents.
- It is inexpensive and can be used in developing countries or smart cities to mitigate traffic congestion and enhance transport efficiency.
- Uses include intelligent traffic lights, school zones, hospital zones, and public transport priority control.
- The end result is an operating prototype that employs low-cost technology (ESP32, Wi-Fi, sensors) to visualize smart traffic control and car alert systems.
- For the average citizen, it translates to safer roads, reduced delays, and faster emergency response.
- For society, it adds to the growth of smart cities through providing a scalable and smart transportation solution.
- At an international level, this type of system decreases traffic casualties, enhances transport effectiveness, and works towards sustainable urban growth.

Chapter-9

Conclusions and Future Work

The mini-project effectively deployed a real-time Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication system utilizing ESP32 microcontrollers and Wi-Fi technology. The system allowed for intelligent traffic management and safety by enabling emergency vehicles to communicate wirelessly with traffic signals, taking precedence over normal operation to get a priority right-of-way at intersections. Further, cars with ultrasonic sensors could identify near-by obstacles and send warning signals to neighboring cars to avoid accidents and improve safety. Each car was equipped with an LCD-based warning interface to show important messages like "Obstacle Ahead" or "Emergency Vehicle Approaching" to the driver in real time. Experimental results were found to be low communication latency, validating the feasibility of Wi-Fi for short-range V2V communication in dynamic traffic environments.

Work which carried out further

- The deployment of inexpensive components such as ESP32, gyroscopes, and ultrasonic sensors makes this system cost-effective and scalable for smart cities.
- All major project requirements were satisfied, such as emergency detection, vehicle communication, warning display, and traffic light control.
- Wi-Fi range limits and environmental sensitivity of sensors are known issues in the existing configuration.
- Cloud-based platform integration may facilitate data analytics, remote monitoring, and unified traffic control.
- Machine learning algorithms may be investigated to forecast traffic density and further optimize signal behavior.
- Next-generation mini-project groups can expand upon this system through the addition of camera-based sensors or voice alarm systems for walkers.

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